Risk Stratification in Cardiac Surgery

J R Sadaba



"Accurate hospital statistics are much more rare than is generally imagined"

(Florence Nightingale, 1863)

Risk stratification is defined as the ability to predict outcomes from a given intervention by arranging patients according to the severity of their illness

Uses of risk stratification and outcome assessment

The ultimate goal of risk stratification and outcome assessment is to account for differences in patient risk factors so that patient outcomes can be used as an indicator of quality of care

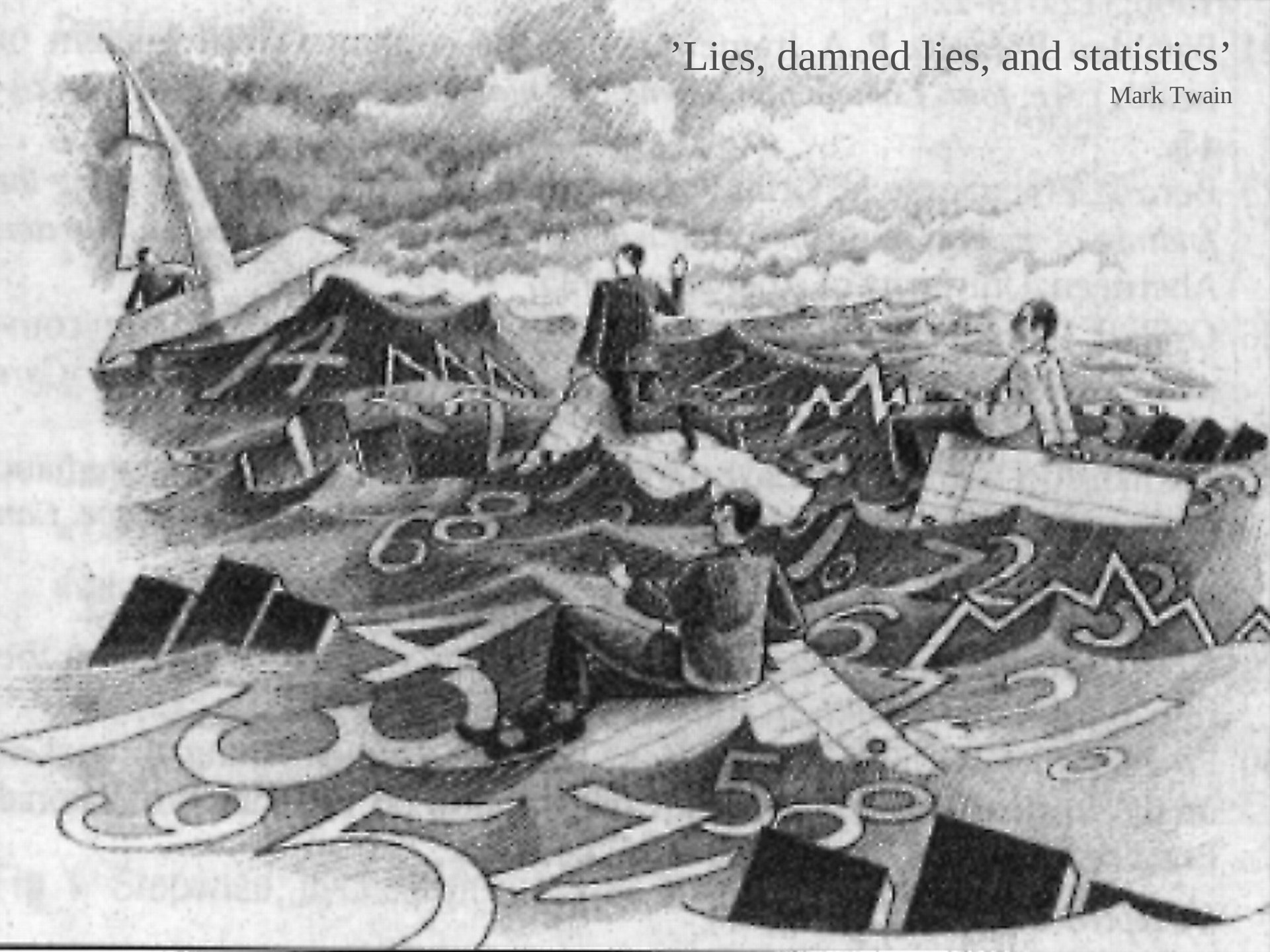
Uses of risk stratification and outcome assessment

- A vivid example of failure to adjust for severity of illness occurred when the leaders of the Health Care Financing Administration (HCFA) released hospital mortality figures in March of 1986
- At the facility with the most aberrant death rate, 87.6% of Medicare patients died compared to a Medicare average of 22.5%.
- What was not taken into account was that this particular facility was a hospice caring for terminally ill patients. The HCFA model had not adequately accounted for patient risks and co-morbidities.

TABLE 6-1 Examples of risk stratification systems used for patients undergoing cardiac surgical procedures

Severity system	Data source	Classification approach	Outcomes measured
APACHE III[8]	Values of 17 physiologic parameters and other clinical information	Integer scores from 0 to 299 measured within 24 hours of ICU admission	In-hospital death
Pennsylvania[6]	Clinical findings collected at time of admission	Probability of in-hospital death ranging from 0 to 1 based on logistic regression model and MediQual's Atlas admission severity score	In-hospital death and cost of procedure
NY[175,189,266]	Condition-specific clinical variables from discharge record	Probability of in-hospital death ranging from 0 to 1 based on logistic regression model	In-hospital death
STS[103,105,267]	Condition-specific clinical variables from discharge record	Bayesian algorithm used to assign patient to risk interval (percent mortality interval); more recently converted to logistic regression model	In-hospital death and morbidity
VA[181,268,269]	Condition-specific clinical	variables measured 30 days after operation	Logistic regression model used to assign patient to risk interval (percent mortality interval) In-hospital death and morbidity
Parsonne[270–273]	Condition-specific clinical variables from discharge record	Additive multiple regression model with scores between 0 and 158 based on 14 weighted risk factors	Death within 30 days of operation
Canadian[7,274]	Condition-specific clinical variables entered at time of referral for cardiac surgery	Range of scores from 0 to 16 based on logistic regression odds ratio for 6 key risk factors	In-hospital mortality, ICU stay, and postoperative length of stay
New England[138,193,275]	Condition-specific clinical variables and comorbidity index entered from discharge record	Scoring system based on logistic regression coefficients used to calculate probability of operative mortality from 7 clinical variables and 1 comorbidity index	In-hospital mortality
Cleveland[276]	Condition-specific clinical variables from discharge record	Range of scores from 0 to 33 based on univariate odds ratio for each of 13 risk factors	In-hospital death or death within 30 days of operation

Penn = Pennsylvania Cost Containment Committee for Cardiac Surgery; NY = New York State Department of Health Cardiac Surgery Reporting System; STS = Society of Thoracic Surgeons Risk Stratification System; VA = Veteran's Administration Cardiac Surgery Ris



’Lies, damned lies, and statistics’

Mark Twain

Statistics

- Some people use statistics like a drunk uses a lamp post - for support rather than for illumination.

- Statistics are like a bikini.
  What they reveal is suggestive, but what they conceal is vital.

Tools for Risk Stratification and Outcomes Analysis

- Databases
- Analytic Tools of Risk Stratification:
  - **Regression Analysis**: statistical technique that is commonly used to describe how one variable (the dependent or *outcome variable*) depends on or varies with a set of independent (or *predictor*) variables. Regression analysis means determining the relationship that describes how an outcome variable depends on (or is associated with) a set of independent predictor variables.
  - Dependent or outcome variables can be:
    - continuous (e.g., hospital cost or length of stay)
    - discrete (e.g., mortality)
      - dichotomous (two discrete values, such as alive or dead)
      - nominal (multiple discrete values, such as improved, unimproved, or worse).

Tools for Risk Stratification and Outcomes Analysis

- When the outcome variable of interest is a continuous variable , **linear multivariate regression** is often used to construct a model to predict outcome.
- It contains a set of independent variables that are linearly related to, and can be used to predict, an outcome variable
- These significant independent variables are termed risk factors, and knowledge of these risk factors allows separation of patients according to their degree of risk—i.e., **risk stratification**

Tools for Risk Stratification and Outcomes Analysis

- When the outcome variable of interest is a discrete variable (e.g., mortality), then **non-linear regression analysis** is used
- **Logistic regression** is the non-linear method most widely used to model dichotomous outcomes in the health sciences
- The significant independent variables identified by the logistic regression model are risk factors that allow risk stratification of patients according to their risk of experiencing the dichotomous outcome (e.g., survival versus death).

Outcome and Follow-up of Aortic Valve Replacement With the Freestyle Stentless Bioprosthesis

(Ann Thorac Surg 2001;71:601–8)

Table 3. Logistic Regression Analysis For Hospital Mortality (N = 27)

Risk Factor	OR	±95% CL
Crossclamp time (continuous)[a]	1.02	1.01, 1.04
Age (continuous)[a]	1.07	1.02, 1.13
Myocardial infarction[a]	6.11	1.66, 22.44
Diabetes mellitus[a]	5.33	1.49, 19.04
Left ventricular hypertrophy	5.14	1.51, 17.53
Coronary artery disease	3.50	1.55, 7.90
Concomitant cardiac procedure	3.17	1.40, 7.18
NYHA class III or IV	2.50	1.02, 6.11
Female gender[a]	2.39	1.05, 5.40
Urgent operation	1.37	0.29, 6.36
Left ventricular dilatation	1.29	0.52, 3.21
Past cardiac operation	1.00	0.28, 3.55
Operative technique		
Subcoronary	1.00	
Root inclusion	1.07	0.40, 2.91
Root	1.60	0.58, 4.39
Valve size (mm)		
21	1.00	
23	1.18	0.35, 3.96
25	0.32	0.07, 1.40
27	0.32	0.08, 1.29

[a] Significant in multivariate analysis.

CL = confidence limits; NYHA = New York Heart Association; OR = odds ratio.

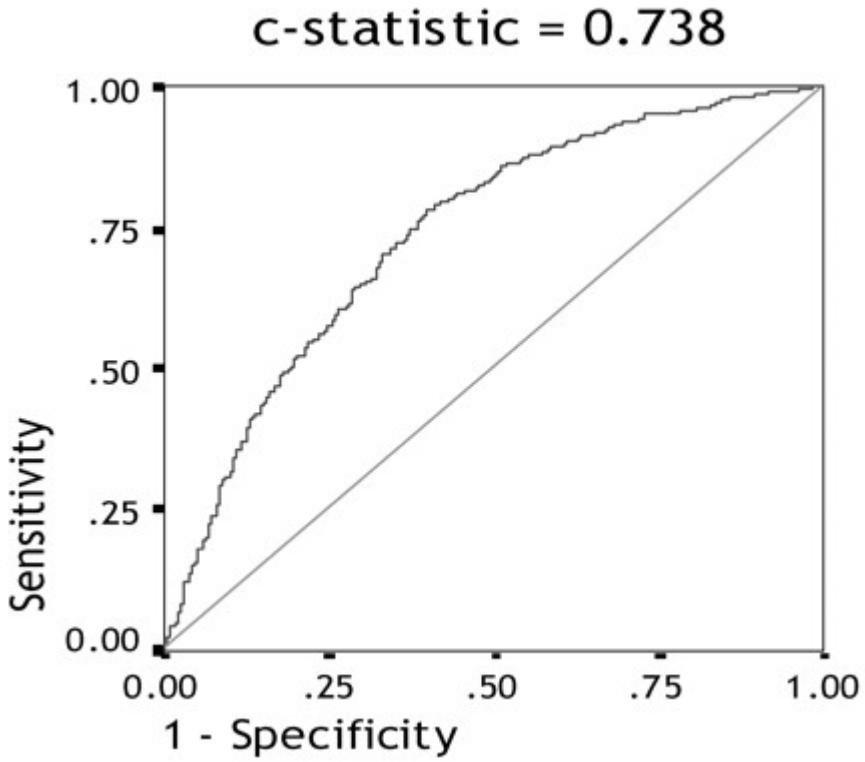
Receiver Operator Characteristic

- One commonly used parameter to evaluate the **performance** of logistic regression models is the **c-statistic.**
- The c-statistic is equal to the **area under the receiver operator characteristic** (ROC) curve and can be generated from the sensitivity and specificity of measurements of any dichotomous outcomes

Sensitivity measures the number of people who truly have the disease who test positive.

Specificity measures the number of people who do not have the disease who test negative.

Receiver Operator Characteristic



Receiver operating characteristic (ROC) curve demonstrating association of preoperative aspirin use in 2606 patients before CABG with postoperative blood transfusion. For this analysis, postoperative transfusion was considered a dichotomous variable (patients either received a transfusion or they did not). The area between the diagonal line and the upper curve represents the c-statistic.

Cox Proportional Hazards Regression Model

- When the outcome of interest is a time-dependent variable (e.g., hospital length of stay or survival after valve implantation), then regression modelling may be a more complex but still manageable process.
- With time-dependent outcome variables, the possibility exists that only a portion of the survival time is observed for some patients
- Thus the data available for analysis will consist of some outcomes that are incomplete or "censored"
- **Cox's model** overcomes these technical problems by assuming that the independent variables are related to survival time by a multiplicative effect on the hazard function—thus it is a "proportional hazards" model.

Effect of Blood Transfusion on Long-Term Survival After Cardiac Operation

(Ann Thorac Surg 2002;74:1180–6)

Table 3. Predictors of Total 5-Year Mortality

Variable Transfusion	Risk Ratio	95% Confidence Interval	*p* Value
None	1.0 (reference)		
Intraoperative	1.2	0.6–1.7	0.534
Postoperative	1.6	1.2–2.0	0.029
Both	2.4	2.0–2.8	< 0.001
Peripheral vascular disease	1.9	1.5–2.2	< 0.001
Chronic obstructive pulmonary disease	2.2	1.9–2.6	< 0.001
New York Heart Association functional class IV	1.5	1.2–1.8	0.013
Age	1.045	1.027–1.063	< 0.001

Risk Ratio = the risk of death for a patient with that factor compared with a patient without that factor, or for continuous variables it is the increased risk for each year's increase in age. The risk ratio of the No Transfusion group is defined as 1.0 and called the reference.

Outcome and Follow-up of Aortic Valve Replacement With the Freestyle Stentless Bioprosthesis

(Ann Thorac Surg 2001;71:601–8)

Table 5. Risk Factors For Late Mortality Analyzed With Cox Proportional Hazards Analysis

Risk Factor	RR	±95% CL
Valve-related event	3.86	1.28, 11.67
Coronary artery disease[a]	3.40	1.41, 8.21
Concomitant cardiac procedure	3.19	1.32, 7.75
History of myocardial infarction	1.87	0.25, 14.03
Age (continuous)	1.04	0.99, 1.09
Female gender	0.65	0.26, 1.63
Operative technique		
Subcoronary	1.00	
Root inclusion	0.62	0.18, 2.19
Root	0.68	0.15, 3.03
Preoperative congestive heart failure	1.35	0.48, 3.80
Left ventricular hypertrophy	3.13	0.92, 10.71
Left ventricular dilatation	0.89	0.30, 2.70
Left ventricular dysfunction	2.17	0.50, 9.35
Valve size (mm)		
21	1.00	
23	1.12	0.22, 5.79
25	1.34	0.25, 7.17
27	1.46	0.30, 7.06
NYHA class III or IV preoperatively	2.49	0.90, 6.86
Cancer preoperatively	2.18	0.29, 16.35

[a] Significant in multivariate analysis.

Abbreviations as in Table 3.

Bayesian Analysis

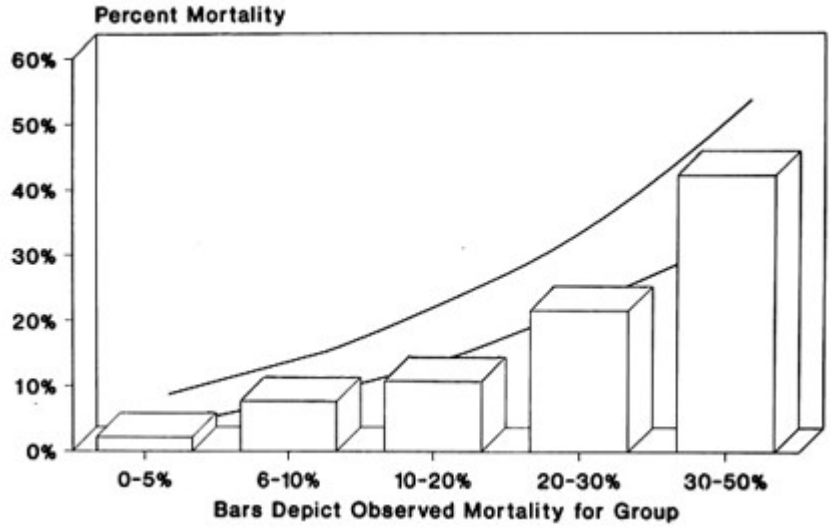
The probability of H conditional on E is defined as
$\mathbf{P}_E(H) = \mathbf{P}(H \,\&\, E)/\mathbf{P}(E)$,
provided that both terms of this ratio exist and $\mathbf{P}(E) > 0$

- Using the Bayesian approach, three sets of probabilities are defined:
  - (1) the probability of an event before the presence of a new finding is revealed (prior probability);
  - (2) the probability that an event is observed given that an independent variable is positive (conditional probability); and
  - (3) the probability of an event occurring after the presence of a new finding is revealed (posterior probability).
- The mathematical relationship between the three probabilities is Bayes' theorem
- Bayesian multivariate regression models are generated using computer-based iterative techniques

Use of a Bayesian Statistical Model for Risk Assessment in Coronary Artery Surgery

As Originally Published in 1988:

Updated in 1995 by Fred H. Edwards, MD, Richard J. Peterson, MD, Charles Bridges, MD, and Eric L. Ceithaml, MD



Predicted operative mortality compared with observed mortality, 1984 to 1990. The curved lines in the background show predicted mortality, whereas the bars reflect observed mortality in each subgroup

PARSONNET'S RISK STRATIFICATION SYSTEM

"Following univariate regression analysis of 3500 consecutive operations, 14 risk factors were chosen that met these conditions. A few factors were excluded because they were insufficiently objective or not always available. An additive model was constructed, using the factors chosen, to calculate the probability of mortality within 30 days"

Parsonnet V., Dean D. and Bernstein A.D.

Sup. 1 Circ. Vol 79 No 6 - 1989,

In 1995 Parsonnet developed a new "Cardiac Risk Stratification Project".

> *"Use of the modified system shows good correlation between expected and observed outcomes at our institution and in other cases reported to the New Jersey Department of Health. It has improved the results especially in high risk cases: in total, a group of 5.336 patients have been assessed by the modified system: the expected mortality overall was 7.2% and the observed mortality was 5.4%. In 1280 high-risk patients i.e. those with an expected mortality of greater than 11%, the expected mortality was 16.2% and observed mortality was 12.3%."*

Risk factor	*Score*
Female	1
Obesity, > 1.5 times ideal weight	3
Diabetes	3
Hypertension	3
Ejection fraction (%)	
> 50	0
30–49	2
< 30	4
Age (years)	
71–74	7
75–79	12
⩾ 80	20
First reoperation	5
Second reoperation	10
Preoperative IABP	2
Emergency from procedures laboratory	10
Dialysis dependent	10
Catastrophic states	10
Valve surgery	
Mitral	5
PAP > 60 mm Hg	3
Aortic	5
Gradient > 120 mm Hg	2
CABG with valve	2

Heart 2000;84:71–78

Limitations of the Parsonnet score for measuring risk stratified mortality in the north west of England

K Wynne-Jones, M Jackson, G Grotte, B Bridgewater, on behalf of the North West Regional Cardiac Surgery Audit Steering Group

Abstract

Objective—To study the use of the Parsonnet score to predict mortality following adult cardiac surgery.

Design—Prospective study.

Setting—All centres performing adult cardiac surgery in the north west of England.

Subjects—8210 patients undergoing surgery between April 1997 and March 1999.

Main outcome measures—Risk factors and in-hospital mortality were recorded according to agreed definitions. Ten per cent of cases from each centre were selected at random for validation. A Parsonnet score was derived for each patient and its predictive ability was studied.

Results—Data collection was complete. The operative mortality was 3.5% (95% confidence interval 3.1% to 3.9%), ranging from 2.7% to 3.8% across the centres. On validation, the incidence of discrepancies ranged from 0% to 13% for the different risk factors. The predictive ability of the Parsonnet score measured by area under the receiver operating characteristic curve was 0.74. The mean Parsonnet score for the region was 7.0, giving an observed to expected mortality ratio of 0.51 (range 0.4 to 0.64 across the centres). A new predictive model was derived from the data by multivariate analysis which includes nine objective risk factors, all with a significant association with mortality, which highlights some of the deficits of the Parsonnet score.

Conclusions—Risk stratified mortality data were collected on 100% of patients undergoing adult cardiac surgery in two years within a defined geographical region and were used to set an audit standard. Problems with the Parsonnet score of subjectivity, inclusion of many items not associated with mortality, and the overprediction of mortality have been highlighted.

(*Heart* 2000;84:71–78)

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EUROPEAN JOURNAL OF
CARDIO-THORACIC
SURGERY

Risk factors and outcome in European cardiac surgery: analysis of the EuroSCORE multinational database of 19030 patients ☆

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Table 1
National patient and centre distribution[a]

Country	Number of centres	Number of patients
Germany	23	4799
France	41	4701
UK	15	3593
Italy	20	2846
Spain	25	2444
Finland	6	1275
Sweden	1	245
Switzerland	1	111
Total	132	20014

[a] Data collection was organized separately for England (11 centres, 2774 patients) and Scotland (four centres, 819 patients).

68 preoperative and 29 operative risk factors were selected and defined on the basis of credibility, objectivity, reliability and prevalence. The statistical model was multiple logistic regression.

All variables significant at the $P < 0.2$ level were entered into the model provided they were present in at least 2% of the sample.

Determinants of operative mortality for adult patients undergoing open heart surgery

Variable	Odds ratio	Standard error	*P* value
Age (continuous)	1.1	0.007	0.001
Female	1.4	0.128	0.001
Serum creatinine > 200	1.9	0.256	0.001
Extracardiac arteriopathy	1.9	0.376	0.001
Pulmonary disease	1.6	0.284	0.006
Neurological dysfunction	2.3	0.584	0.001
Previous cardiac surgery	2.6	0.324	0.001
Recent myocardial infarct	1.6	0.208	0.001
LVEF 30–50%	1.5	0.138	0.001
LVEF < 30%	2.5	0.340	0.001
Chronic congestive heart failure	1.5	0.179	0.001
Systolic pulmonary pressure > 60	2	0.423	0.001
Active endocarditis	2.5	0.678	0.001
Unstable angina	1.5	0.202	0.001
Urgent operation	1.6	0.173	0.001
Emergency operation	2.8	0.440	0.001
Critical preoperative state	2.2	0.319	0.001
Ventricular septal rupture	3.8	1.735	0.002
Non-coronary surgery	1.6	0.170	0.001
Thoracic aortic surgery	3.2	0.650	0.001

Area under ROC curve 0.79

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EUROPEAN JOURNAL OF
CARDIO-THORACIC
SURGERY

European system for cardiac operative risk evaluation (*Euro*SCORE)☆

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Risk factors, definitions and weights (score)

	Definition	Score
Patient-related factors		
Age	Per 5 years or part thereof over 60 years)	1
Sex	Female	1
Chronic pulmonary disease	Longterm use of bronchodilators or steroids for lung disease	1
Extracardiac arteriopathy	Any one or more of the following: claudication, carotid occlusion or >50% stenosis, previous or planned intervention on the abdominal aorta, limb arteries or carotids	2
Neurological dysfunction	Disease severely affecting ambulation or day-to-day functioning	2
Previous cardiac surgery	Requiring opening of the pericardium	3
Serum creatinine	>200 μmol/l preoperatively	2
Active endocarditis	Patient still under antibiotic treatment for endocarditis at the time of surgery	3
Critical preoperative state	Any one or more of the following: ventricular tachycardia or fibrillation or aborted sudden death, preoperative cardiac massage, preoperative ventilation before arrival in the anaesthetic room, preoperative inotropic support, intraaortic balloon counterpulsation or preoperative acute renal failure (anuria or oliguria < 10 ml/h)	3
Cardiac-related factors		
Unstable angina	Rest angina requiring i.v. nitrates until arrival in the anaesthetic room	2
LV dysfunction	Moderate or LVEF 30–50%	1
	Poor or LVEF < 30	3
Recent myocardial infarct	(<90 days)	2
Pulmonary hypertension	Systolic PA pressure >60 mmHg	2
Operation-related factors		
Emergency	Carried out on referral before the beginning of the next working day	2
Other than isolated CABG	Major cardiac procedure other than or in addition to CABG	2
Surgery on thoracic aorta	For disorder of ascending, arch or descending aorta	3
Postinfarct septal rupture		4

Application of scoring system

EuroSCORE	Patients	Died	95% confidence limits for mortality	
			Observed	Expected
0–2 (low risk)	4529	36 (0.8%)	(0.56–1.10)	(1.27–1.29)
3–5 (medium risk)	5977	182 (3.0%)	(2.62–3.51)	(2.90–2.94)
6 plus (high risk)	4293	480 (11.2%)	(10.25–12.16)	(10.93–11.54)
Total	14799	698 (4.7%)	(4.37–5.06)	(4.72–4.95)

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EUROPEAN JOURNAL OF CARDIO-THORACIC SURGERY

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Logistic or additive EuroSCORE for high-risk patients?☆

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Abstract

Objectives: To assess whether the use of the full logistic European System for Cardiac Operative Risk Evaluation (EuroSCORE) is superior to the standard additive EuroSCORE in predicting mortality in high-risk cardiac surgical patients. **Methods**: Both the simple additive EuroSCORE and the full logistic EuroSCORE were applied to 14,799 cardiac surgical patients from across Europe, of whom there were 4293 high-risk patients (additive EuroSCORE of 6 or more). The systems were compared for absolute prediction and discrimination (area under the receiver operating characteristic (ROC) curve). **Results**: Actual mortality was 4.72%. The logistic model was closer to this than the additive model (4.84% (4.72–4.94) versus 4.21 (4.21–4.26)). Most of this difference was due to high-risk patients where actual mortality was 11.18% and predicted was 7.83% (additive) and 11.23% (logistic). Discrimination was similar in both systems as measured by the area under the ROC curve (additive 0.783, logistic 0.785). **Conclusions**: The additive EuroSCORE model remains a simple "gold standard" for risk assessment in European cardiac surgery, usable at the bedside without complex calculations or information technology. The logistic model is a better risk predictor especially in high-risk patients and may be of interest to institutions engaged in the study and development of risk stratification.
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Keywords: EuroSCORE; Risk stratification; Cardiac surgery

Surgeon specific mortality in adult cardiac surgery: comparison between crude and risk stratified data

Ben Bridgewater, Antony D Grayson, Mark Jackson, Nicholas Brooks, Geir J Grotte, Daniel J M Keenan, Russell Millner, Brian M Fabri, Mark Jones on behalf of the North West Quality Improvement Programme in Cardiac Interventions

BMJ VOLUME 327 5 JULY 2003 bmj.com

Results 8572 patients were operated on by 23 surgeons. Overall mortality was 1.7%. Observed mortality between surgeons ranged from 0% to 3.7%; predicted mortality ranged from 2% to 3.7%. Eighty five per cent (7286) of the patients had a EuroSCORE of 5 or less; 49% of the deaths were in this lower risk group. A large proportion of the variability in predicted mortality between surgeons was due to a small but differing number of high risk patients.

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Validation of European System for Cardiac Operative Risk Evaluation (EuroSCORE) in North American cardiac surgery ☆

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Abstract

Objective: To assess the performance of the European System for Cardiac Operative Risk Evaluation (EuroSCORE) when applied in a North American cardiac surgical population. **Methods**: The simple additive EuroSCORE model was applied to predict operative mortality (in-hospital or 30-day) in 401 684 patients undergoing coronary or valve surgery in 1998 and 1999 as well as in 188 913 patients undergoing surgery in 1995 in the Society of Thoracic Surgeons (STS) database. **Results**: The proportion of isolated coronary artery bypass grafting (CABG) was greater in STS patients (84%) than in Europe (65%). STS patients were also older (mean age 65.3 versus 62.5), and had more diabetes (30 versus 17%) and prior cardiac surgery (11 versus 7%). Other comorbidity was also significantly more prevalent in STS patients. EuroSCORE predicted overall mortality was virtually identical to the observed mortality (1998/1999: predicted 3.994%, observed 3.992%; 1995: observed and predicted 4.156%). Predicted mortality also closely matched observed mortality across the risk groups. Discrimination was good to very good for the population overall and for isolated CABG in both time periods, with the area under the receiver operating characteristic curve between 0.75 and 0.78. **Conclusion**: Despite substantial demographic differences between Europe and North America, EuroSCORE performs very well in the STS database, and can be recommended as a simple, additive risk stratification system on both sides of the Atlantic. © 2002 Elsevier Science B.V. All rights reserved.



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EUROPEAN JOURNAL OF CARDIO-THORACIC SURGERY

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Risk stratification in heart surgery: comparison of six score systems☆

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Validity of scores (areas under ROC)

	Area under ROC (%)	
	Mortality	Morbidity
Initial Parsonnet score	75.5	64.4
Cleveland Clinic score	73.1	68.6
French score	71.9	63.6
Euro score	78.6	63.8
Pons score	74.5	67.6
Ontario Province Risk score	70.1	62.1

Coming next...

Variable Life Adjusted Display (VLAD)

CUSUM (Cumulative Sum Techniques)

Outcomes and Risk Stratification

- There are at least 4 outcomes of interest to surgeons dealing with cardiac surgical patients: mortality, serious non-fatal morbidity, resource utilisation, and patient satisfaction. Which patient characteristics constitute important risk factors may depend largely on the outcome of interest
- Operative mortality is an easily defined, readily measured outcome

Correlation and regression

Correlation and regression help us to understand the relation between variables and to predict patients' status in regard to a particular variable of interest.

Correlation examines the strength of the relation between two variables, neither of which is considered the variable one is trying to predict (the target variable).

Regression analysis examines the ability of one or more factors, called independent variables, to predict a patient's status in regard to the target or dependent variable.

Independent and **dependent** variables may be continuous (taking a wide range of values) or binary (dichotomous, yielding yes-or-no results).

Regression models can be used to construct clinical prediction rules that help to guide clinical decisions. In considering regression and correlation, clinicians should pay more attention to the magnitude of the correlation or the predictive power of the regression

than to whether the relation is statistically significant.

http://homepages.pathfinder.gr/nikgabi/stat04.htm

Regression

- Clinicians may be interested in making predictions or causal inferences than in understanding the relation between phenomena.
- Which clinical features of patients with chest pain presenting to the emergency department predict whether they have a myocardial infarction?
- Can we predict which critically ill patients will tolerate weaning from a ventilator and which will not?
- We call the statistical techniques for exploring this issue — making a prediction or causal inference — "regression."

Regression

- As surgeons, we are often interested in prediction: we wish to know which patient will fare well (survive a procedure) and which will fare poorly. Regression analysis is useful in addressing these sorts of issues.
- We will use the walk test to illustrate the concepts involved in statistical regression.

Regression

- The term "regression" refers to a mathematical equation that allows one variable (the target variable) to be predicted from another (the independent variable).

Regression

Summary points

- An association between two variables is likely to be causal if it is strong, consistent, specific, plausible, follows a logical time sequence, and shows a dose-response gradient
- A P value of <0.05 means that this result would have arisen by chance on less than one occasion in 20
- The confidence interval around a result in a clinical trial indicates the limits within which the "real" difference between the treatments is likely to lie, and hence the strength of the inference that can be drawn from the result
- A statistically significant result may not be clinically significant. The results of intervention trials should be expressed in terms of the likely benefit an individual could expect (for example, the absolute risk reduction)

Look at!!!

http://bmj.bmjjournals.com/cgi/content/full/315/7105/422

J Thorac Cardiovasc Surg 2001;122:1063-1076

Regression

- The term "regression" refers to a mathematical equation that allows one variable (the target variable) to be predicted from another (the independent variable)
- Regression, then, implies a direction of influence, although it does not prove causality
- In the case of multiple regression, a far more complex mathematical equation (which, thankfully, usually remains the secret of the computer that calculated it) allows the target variable to be predicted from two or more independent variables (often known as covariables).

Measures of Comorbidity

- Co-morbidities are coexisting diagnoses that are indirectly related to the principal surgical diagnosis but may alter the outcome of an operation
- In one series of patients with myocardial infarction, 26% also had diabetes, 30% had arthritis, 6% had chronic lung problems, and 12% had gastrointestinal disorders (Functional status and well-being of patients with chronic conditions: results from the Medical Outcomes Study. *JAMA* 1989; 262:907)

- BMJ 2003;327:13-17 (5 July), doi:10.1136/bmj.327.7405.13
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Risk stratification in heart surgery: comparison of six score systems

Eur J Cardiothorac Surg 2000;17:400-406

Risk assessment serves many masters:

the payer to justify expenditure and provide a tool for health policy

the hospital to defend itself in league tables

the surgeon to watch his back

the patient who has to decide whether or not to entrust his or her life into the hands of strangers.

Intuitively, we might expect that the routine feedback of risk adjusted data on local performance in a cardiac surgical unit would heighten awareness and lead to self examination, which in turn would improve quality and outcome