Unto Häkkinen
Tuula Kurki
Antti Vento
Mikko Peltola

Risk Adjustment in Coronary Bypass Grafting

How EuroSCORE is related to cost, health-related quality of life, and cost-effectiveness

Unto Häkkinen[a,*]
Tuula Kurki[b]
Antti Vento[c]
Mikko Peltola[a]

[a] National Institute for Health and Welfare, Centre for Health and Social Economics (CHESS)
[b] Helsinki University Hospital, Department of Anaesthesia and Intensive Care Medicine
[c] Helsinki University Hospital, Department of Cardiothoracic Surgery
* Corresponding author: National Institute for Health and Welfare,
Centre for Health and Social Economics (CHESS)
P.O. Box 30, FI-00271 Helsinki, Finland
email:unto.hakkinen@thl.fi
tel + 358 20 610 7327
(GSM) +358 50 358 1141
fax + 358 02 06107485

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Abstract

The aim of this study was to evaluate how EuroSCORE predicts short- and long-term costs and outcomes of CABG patients. We analyzed the predictive power of EuroSCORE on various cost and outcome measures and evaluated which factors – in addition to the original EuroSCORE – affected the measures. We evaluated how patients' risk scores affected the QALYs gained and cost per QALY gained. We also assessed levels of bias in cost and QALY estimates due to the fact that HRQoL information is usually available for specific patients who are representative of the whole patient population.

We studied prospectively first-time consecutive coronary bypass patients operated on at the Helsinki University Central Hospital between 12/9/2000–21/12/2001. The patient-level risk score data was collected preoperatively from almost every patient. HRQoL was measured with the 15D. It is a generic, standardized, self-administrated instrument that can be used both as a profile and as a single index score measure. The patient-level cost data for the surgical hospital admission was based on the cost accounting system of Helsinki University Hospital, which is derived through a "bottom-up approach" and is as such very accurate. In addition, with the use of unique personal identification numbers it was possible to link various register data in the database, enabling a five-year follow up of patients.

We evaluated the performance of the risk system using various methods of multivariate analysis. Since our analysis is based on a before and after comparison, many important assumptions need to be made explicit in order to evaluate the incremental cost effectiveness (CE) ratio (= Δ cost/ Δ QALY). Thus we calculated the CE ratio by means of five cost- and two QALY specifications.

According to the results, EuroSCORE was quite strongly associated with costs, various mortality indicators and life expectancy but not with HRQoL. In addition to variables included in the EuroSCORE, previous-year costs and diabetes were significant additional "risk factors". We found that changes in HRQoL were heavily dependent on preoperative HRQoL status. CE ratio was crucially dependent on QALY measurements and especially on assumptions of the effects of treatment on life expectancy. If the operation affected the life expectancy of high risk patients more than low risk patients, the cost per QALY difference between the EuroSCORE groups will convergence. The cost-per-QALY figures derived from selected samples will overestimate the positive results.

Keywords: Bypass surgery, EuroSCORE, Cost, HRQoL, QALY

Contents

1   INTRODUCTION

Meaningful comparisons within health care require risk adjustment - accounting for patient-associated factors before comparing health care spending, resource utilization across different patient groups, treatments, providers, regions, countries or populations. In addition, risk-stratification models can be used to estimate the need for resources, proper informed consent and quality monitoring. During the last decades several models for calculating mortality risk before surgery have been developed. For heart surgery, several studies have indicated that EuroSCORE[1] (the European System for Cardiac Operative Risk Evaluation (Nashef *et al*., 1999; Roques *et al*., 1999) performs better than other commonly used preoperative risk scores (Geissler *et al.,* 2000). In recent years EuroSCORE has been routinely used in many countries. For example, since 2006 in Great Britain, cardiac surgical results (adjusted using EuroSCORE) for individual surgical units and in some cases for surgeons have been published on the web. In Finland, since 2005 the use of EuroSCORE for CABG patients has been included in the National Discharge Register.

EuroSCORE was originally developed using a multinational database of 19 030 patients compiled between 1995 and 1999. The 30-day mortality was as an outcome measure. Later, several studies analyzed the predictive power of EuroSCORE on cost and length of stay of surgery as well as on specific postoperative complications (Hekmat *et al.*, 2005; Tuompoulis *et al*., 2005). However, very seldom have the risk factors been evaluated with respect to health related quality of life (HRQoL) (Colak *et al.*, 2008; Jokinen *et al*., 2008;Loponen *et al.,* 2008).

It has been increasingly recognized that measures of health outcomes should take into account both reduced mortality (i.e. increased life expectancy) and quality aspects of life, which enables an evaluation of interventions in terms of QALYs (Quality-adjusted life years) gained. In order to calculate QALYs we need to know the effects in terms of HRQoLs. Although the feasibility of such data collection has been indicated, HRQoL data are not routinely available presently (Räsänen 2007), though this may change in the near future, as some countries have started to collect such data (Vallance-Owen *et al.,* 2004, Department of Health, 2007). In spite of the many practical challenges in this data collection, this kind of information is extremely important for productivity (Castelli *et al.,* 2007) and more generally for performance measurement in healthcare (Smith *et al.,* 2008).

The aim of this study is to evaluate how EuroSCORE predicts short- and long-term costs and outcomes of CABG patients. Firstly, we analyze the predictive power of EuroSCORE on various cost and outcome measures and evaluate which factors - in addition to the original EuroSCORE – affect the measures. Secondly, we evaluate how patients' risk-score affects QALYs gained and cost per QALY gained. We assess also the bias in cost and QALY estimates due to the fact that HRQoL information is usually available only for specific patients who are not representative of the whole patient population.

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1   The scoring system identifies three group of risk factors (patient-related, cardiac and operation related) with their weights (additive% predicted mortality) see (http://www.euroscore.org/).

2 DATA AND METHODS

2.1 Data

First-time consecutive coronary bypass patients operated on at Helsinki University Central Hospital (HUCH) between 12/9/2000–21/12/2001 were studied prospectively. The patient-level risk score data were collected preoperatively from almost every patient. In addition, other data (such as length of hospital stay and ICU length of stay) were collected postoperatively.

HRQoL was measured with the 15D. It is a generic, standardized, self-administered instrument that can be used both as a profile and single index score measure. It includes 15 dimensions: mobility, vision, hearing, breathing, sleeping, eating, speech, elimination, usual activities, mental function, discomfort and symptoms, depression, distress, vitality and sexual activity) (Sintonen, 1994, 1995, 2001). The valuation system of the 15D is based on an application of multi-attribute utility theory. A set of utility or preference weights, elicited from the general public through a valuation procedure, is used in an additive aggregation formula to generate the 15D score (single index number) over all the dimensions. The maximum score is 1 (no problems on any dimensions) and the minimum score is 0 (being dead). A change ≥ 0.03 in 15D was interpreted as being clinically significant.

A questionnaire for gathering demographic information (family background, education) and the 15D questionnaire were given to every patient before the operation. The 15D questionnaire was also mailed to the patients three months and one year following surgery. The later questionnaire included questions concerning the use and cost of health care services after surgery. In addition, various register data were linked in the database by means of unique identification numbers. This allowed us to follow up patients for five years. Register data included data from the Hospital Discharge Register, the Finnish Cause of Death statistics, the registers of the Social Insurance Institute and data from the Finnish Hospital Benchmarking Project. Using this data, the costs of hospital care (all inpatient care, outpatient visits of specialist hospital care) and costs of prescribed medicines in the year previous to and the five years following the operation were calculated.

Our data also included other risk score systems (Cleveland (Higgins *et al.,* 1992), Northern New England (Tu *et al.,* 1995), CABDEAL (Kurki and Kataja, 1996)), but against cost and outcome indicators, EuroSCORE performed either better or at least equivalent to the others.

The patient-level cost data for the surgical hospital admission was based on the cost-accounting system of HUCH, which is derived through a "bottom-up approach" and is as such very accurate. The utilization information for hospital inpatient care (other than surgery admission) was converted into costs using Finnish standard costs for different types of health care services (Hujanen, 2003). The somatic and other acute hospital inpatient admissions were first grouped according to the Finnish version of the NordDRG i.e. Nordic Diagnosis Related Groups. Each admission was then converted into costs using average costs per inpatient day, specific to each of the DRG groups. The outpatient visits in tertiary hospitals were converted using average cost per visit, specific to each specialty and type (emergency /elective) of visit (Peltola *et al.,* 2009). All costs were converted to 2001 prices using the municipal health care price index. The costs of prescribed medicines were based on information on actual reimbursement at prevailing prices. Since the questionnaire included information on costs and utilization up to one year following the operation, we were able to estimate those costs that were not included in registries.

We analyzed the cost of i) surgical admission; ii) surgical admission and further hospitalization together; iii) first year post-operative; and iv) five years post-operative. Outcomes were analyzed

by mortality indices and by survival at five years and changes in for pre- and post-operation HRQoL scores.

Figure 1 describes the total number of CABG patients in the study period and the data used in this study. The main analysis was performed using the whole sample (n = 925) which includes all patients for whom we had register data well as preoperative risk data. The HRQoL data include all 606 patients for whom we had preoperative 15D scores and scores after three months or patients who had died within three months. The HRQoL data indicated a clear selection bias (Table I). This was verified by estimating a logit regression for the "whole sample" to establish the probability of being included in the HRQoL sample. It indicated that in the HRQoL sample, costs, 5-year mortality, EuroSCORE status (EuroSCORE 7 or over) and the share of females were lower compared to the whole sample.
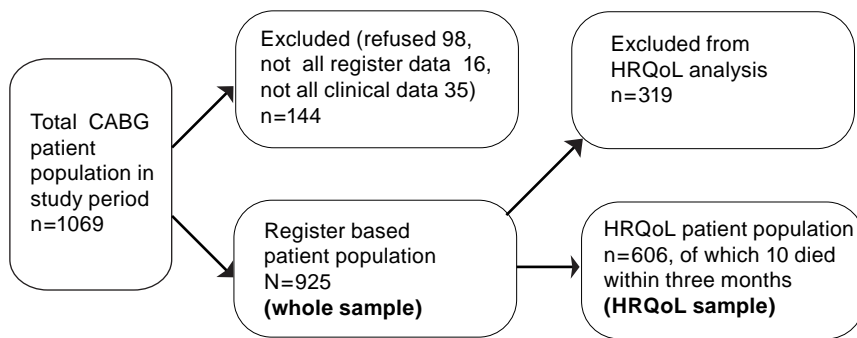
FIGURE 1. Description of samples

TABLE 1. Patient characteristics

Variable	Whole Sample (n = 925)		HRQol sample (n = 606)	
	Mean (%)	SD	Mean (%)	SD
Age	64,9	9,98	64,1	9,39
Share of females (%)	26,8	44,3	23,7	42,6
Average EuroSCORE	3,77	3,03	3,33	2,59
Cost of surgery admission	14 451	11 096	12 603	7 815
Cost of hospital stay	16 468	16 762	13 874	9 556
One year cost	20 101	16 762	17 172	10 963
Five year cost	30 285	26 442	26 960	20 494
Cost of previous year	3 229	2 315	3 160	2156
30 day mortality	0,035	0,186	0,014	0,12
One year mortality	0,06	0,24	0,026	0,16
Five year mortality	0,148	0,36	0,10	0,29
Diabetes with insulin (%)	0,0832	0,276	0,054	0,23

2.2 Performance of EuroSCORE

The performance of the risk system was evaluated using various multivariate analysis methods. The analysis was started by including risk scores into the model as bivariate dummy variables and as one continuous variable. Since in most cases the continuous specification performed better, the modeling was extended using this specification. In the modeling of cost, two extensions for the model were made. Firstly, two measures of mortality were included in the model to take into account the fact that a patient who died during a hospital stay or after will have been treated more intensively during the last days of life, though in the long-term, this would also reduce treatment costs. The first measure was a dummy variable for death in the follow-up period, which reflects the fact that the costs for those patients who died in surgery are higher than those who survived and more generally that the costs of health care are concentrated in proximity to death (Zweifel *et al.,* 1999, Häkkinen *et al.,* 2008). This was also found in an earlier Finnish study (Kurki *et al.,* 2001). The second variable described the survival time and takes into account the fact that costs are higher for those who lived longer. This variable is included in the estimation for five-year costs.

    In the second extension, other significant potential risk variables were included. As potential risk variables, two clinical factors were considered that are excluded from the EuroSCORE model but included in other risk score systems used in heart surgery (Geissler *et al.,* 2000): diabetes with insulin and body mass index (BMI). BMI was specified in two alternative ways: 28–30 and > 30. However, BMI did not become significant in any models and thus it is not reported in the tables. In addition, total health care costs (hospital care and prescribed medicines) for the previous year were treated as a potential risk variable, since the variable has in many studies been found to be a good predictor of current costs (Ellis, 2007). This may take into account all the costs related to co-morbidity more widely than the specific clinical factors included in the EuroSCORE measure.

    There is no uniformly agreed upon regression model with which to analyze cost data (Austin *et al.,* 2003). Here we modeled the cost variation using a generalized linear model (GLM, gamma distribution with log link). GLM was compared with a traditional OLS by calculating the mean square error (MSE) for comparing the predictive power of the alternative specifications. The comparison was made using EuroSCORE as a continuous variable. In all cases the MSE criterion favored GLM over OLS. The better performance of GLM was most clear in one- and five-year costs. In the tables, marginal effects are reported since they are more informative than the coefficients of a GLM model. The predictive accuracy was measured in terms of R^2 and mean absolute error (MAD) (Cumming et al. 2002)[2] . Althought R^2 is not a good measure of the predictive accuracy of a GLM model we nevertheless report it since it allows us to compare our result with previous studies that have usually applied the OLS model. MAD is a single summary measure of predictive accuracy that does not square the prediction errors and so, is not sensitive to large costs. The smaller the prediction error, the better the model is performing. However, it is not expressed as a standardized scale, so a comparison across studies is not possible. The evaluation of the risk-score system for survival was done in a similar way to costs. Survival was analyzed using Cox-regression. The predictive power was measured by the area under the receiver operator characteristics (ROC) curve after logit regression on 30-day, 90-day, one-year and 5-year mortality. The discriminative power of the ROC curve is excellent if the area is >0.80, very good if >0.75 and good if > 0.70. In addition the calibration of the logit models was assessed by Hosmer-Lemeshow goodness-of-fit statistics. For the test, the predicted risk of an individual patient was rank-ordered into 9 groups[3] of equal size, based on their predicted probability. A p value>0.05 indicates an acceptable calibration of the model.

    The analysis of the changes in 15D was made applying traditional OLS.

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2   MAD =(Σ| c_i-^c_i|)/n, where c_i is actual cost for patient i, ^c predicted cost for patient i and n is sample size. The "deviation" in MAD denotes the same quantity as "error " in phrase "mean squared error " (MSE) and the measures are related: MAD ~ = 0.8*MSE (Iezzoni,2003)

3   It is recommended that 10 groups are the best possible number of groups. However, in this case only 9 equal size risk groups could be formed.

2.3 Cost of QALY gained

The cost-effectiveness analysis (CE) aims to evaluate the incremental ratio:

CE = Δ cost/ Δ QALY

Since our analysis is based on before and after comparisons, many important assumptions should be made. In measuring costs we need to define how to measure the change in cost due to the operation. Usually only the cost of operation is used as a measure. However, a significant number of patients transfer to another department in the hospital or even to another hospital for further rehabilitation (at the end of surgery admission), and it can be justified that this should also be included in the analysis. In addition, one can argue, that at least a considerable part of other costs during the first year following surgery must be included in the costs due to the operation. But the inclusion of health care costs for later years is not so straightforward. There is no consensus among economic analysts about whether survivors' medical costs should be included in the analysis (Drummond *et al.,* 1997; Gold *et al.,* 1996; Nyman *et al.,* 2004). The question is more problematic in a non-randomized study in which there are no ways to separate what part of costs and QALY development is due to the operation. Metzler (1997) has made a strong case for including future cost in the economic evaluation, particularly if an intervention increases length of life. It is customary to subtract any medical savings that are due to effectiveness in treating the original disease. Nyman (2004) argues that inclusion of unrelated medical care (i.e. care to treat another disease) should be included in the numerator only when the utility from the survival medical care is included in the nominator.

In this study the medical costs for the four years following on from the first year post-operation (i.e. the costs of the second, third, fourth and fifth year after the operation) were treated by two alternative methods. Firstly, they were included in total. This can be seen as a maximum cost and is based on the assumption that all patients would have died if the operation had not been performed. The second alternative tries to take into account the fact that the operation may reduce future treatment costs. This calculation is based on the difference in the annual average cost of the last four years post-operatively against the previous year costs before the operation. Thus it is assumed that without treatment, the costs would have been the same as they would have been for the year before the operation. This calculation is based on the assumption that the operation has not affected survival.

The measurement of QALY gains requires several assumptions, illustrated by Figure 2, adapted from Williams (1985) and Castelli et al.*(* 2007). It plots an individual's health status—measured on the vertical axis, using a scale where 1 indicates full health and 0 indicates death—against time. The health stream without the operation is the lowest curve h(ng), with a patient dying at time t^0. At time t the operation is performed. Treatment initially reduces health but health soon improves and health and life is extended to t^g as described in the highest curve H(g). There is a risk that treatment will kill the patient before he is able to enjoy the improvement associated with treatment. Hence the expected health stream, conditional on surviving treatment, is shown by the dotted line ah(g). Typically, in before and after comparisons, it is assumed that the difference in HRQoL before and after the treatment will prevail for the rest of the life. It is thus assumed that the treatment does not affect life expectancy (life expectancy will be t^0 in Figure 2). If the treatment increases life expectancy, the assumption underestimates the QALY gains (the area under the H(g) curve from t^0 to t^g). The value of this area depends on the difference in the life expectancies between patients operated on and those not operated on. If treatment is lifesaving (i.e. all patients would have died very soon after if they had not been operated on) the health effects will be the whole area under the H(g) curve from t to t^g.
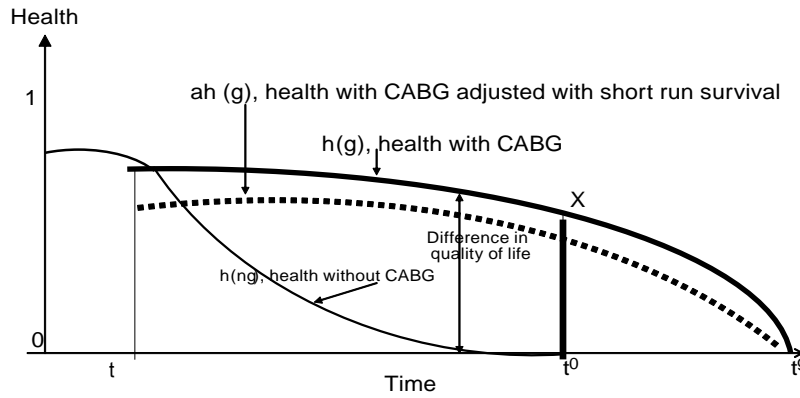
FIGURE 2. Health profile with and without treatment (CABG)

Δ QALY was calculated by two alternative assumptions of life expectancy differences. The first (QALY1) is based on a traditional way of assuming that the life expectancy difference is minimal. This is based on the difference in the area under ah(g) and h(ng). The difference in HRQoL after the operation (q^*) and before the operation (q^0) is assumed to prevail for the whole life. The expected increase in QALYs from operation at time t is:

$$a\ q^*-q^0$$

where a is the probability of surviving after treatment. The preoperative 15D score is used as measure of q^0 and the 15D score after three months as a measure of q^*. Survival probabilities (a) were estimated using a logit model for three months mortality, where the independent variable is patients' EuroSCORE status. The QALY gain is based on changes in HRQoL and patients' five-year survival. For those who survived after five years, we estimated the gains for rest of life using patients' age- and gender-specific expected life years from life tables for the whole population (Statistics Finland). Thus we assumed that health gains by operation lasted until the end of life. We present also the figures for the first five years which are based on observed actual survival. Since we do not have HRQoL data for the whole sample we use means for the HRQoL sample by risk score groups for those patient with missing data. The expected discounted health gains from treatment for patient i were calculated using the formula:

$$(a_k\ q^*_i-q^0_i)\ ((1-e^{-rLi})/r)$$

where r is the discount rate, a_k the expected survival in each EuroSCORE category of patients (k), Li the expected life-expectancy of the patient. A 3% discount rate was used for QALY changes in future years.

The second measurement (QALY2) is based on the assumption that without the operation all patients would have died. In this case health gains are the area under the ah(g) curve in Figure 2. It is based on a discounted value for $a_k * q^*_i$ and patients five-year survival. Since health status (stock) is deteriorating with age, we include a year factor (-0.002). It is based on the cross-sectional effect of age on preoperative 15D status. In addition, we take into account the days that the patient has been in hospital receiving inpatient care during the five-year follow-up. It is assumed that in those days, a patient's 15D status has been 0.5.

CE figures were calculated by dividing the cost of surgical admission (COST1), surgical admission and further hospitalization together (COST2), first year post-operative (COST3), and first-year cost and the difference in the annual average cost of the last four years post-operatively

against the previous year costs before the operation (COST4) by QALY1 and the total discounted five-year post-operative cost (COST5) by QALY2. Sensitivity analysis was performed using varying discount rates and using upper and lower 95% confidence intervals for the mean differences in costs and QALYs. In addition, figures derived from the whole sample were compared to figures calculated for the HRQoL sample.

3   RESULTS

3.1 Cost

The effects of EuroSCORE on time spent in the intensive care unit seem to be stronger than on the cost of surgical admission. The risk score is less related to length of stay for the operative admission (Figure 3). The risk system explains about 18% of the cost variation in surgery admission and the explanatory power increases to 21% when death and diabetes with insulin were included in the model (Table 2). The effect of the risk score on costs decreases somewhat when additional variables were included in the model. Death during the hospital stay increases the cost by over €7000 and patients with diabetes (insulin) were about €4000 more costly than other patients. When costs are analyzed for the whole hospitalization (COST2), the effects of risk scores and diabetes increases compared to the model of the cost of surgical admission alone. The increase is most clear in mortality, which may indicate that severe patients who are going to die are moved to another department or hospital.
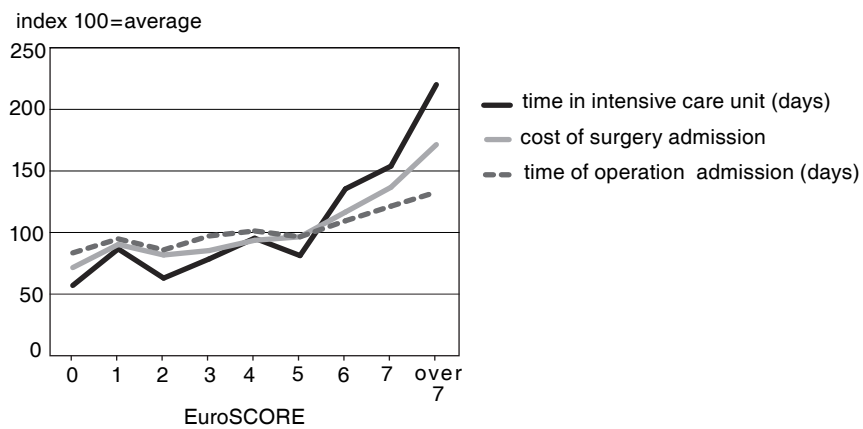

Figure 3. The relative cost of surgery admission and length of stay in operation admission and in intensive care unit according to EuroSCORE level (indices, 100 = average in whole sample)

TABLE 2. GLM estimation on cost of operation admission and whole hospitalisation, marginal effects of coefficients (constant not reported), loglikelyhood and measures of predictive accuracy of models

	Cost of surgical admission								Cost of surgical admission and further hospitalization together							
	Dummy specification of risk score		Continuous specification of risk score						Dummy specification of risk score		Continuous specification of risk score					
	Restricted specification		Restricted specification		Restricted specification +death		Extended specification		Restricted specification		Restricted specification		Restricted specification +death		Extended specification	
	marginal effects	z-value	marginal effects	z-value	marginal effects	z-value	marginal effects	z-value	marginal effects	z-value	marginal effects	z-value	marginal effects	z-value	marginal effects	z-value
EuroSCORE			1 122	11,2	1 048	10,4	1 028	10			1 549	12,02	1 393	11,15	1 356	11,19
EuroSCORE , O reference value																
1	3 555	2,9							4 510	2,6						
2	1 954	1,8							2 661	1,7						
3	2 625	2,4							4 435	2,8						
4	4 187	3,3							6 521	3,6						
5	4 720	3,6							7 491	4,0						
6	8 481	4,8							12 375	5,3						
7	12 228	5,5							18 438	6,6						
over 7	17 825	8,3							27 663	10,5						
Death during the follow up (1 if death)					7 891	2,35	7 313	2,3					19 019	4,4	17 701	4,3
Diabetes insulin (1 if user)							4 239	3,5							6 015	3,92
Previous years cost/€1000																
log likelyhood	-13 929		-9 752		-9 747		-9 748		-9 857		-9 858		14 047		-14 047	
R2	0,14		0,18		0,20		0,21		0,16		0,17		0,20		0,23	
MAD	5 762		5 655		5 558		5 531		7 373		7 265		7 101		7 040	

The cost of surgery admission accounts for 70–80% of the total one-year health care cost of those patients who were alive after one year and completed the questionnaire (Figure 4). The share was highest among low-score patients and lowest among those whose risk score was 7 or higher. Patients with a risk score higher than 4 had much greater costs related to the additional use of hospital care either by additional hospital days immediately after operating admission, or later in the year in the form of new hospitalizations or use of hospital outpatient services. Prescribed medicines as well as other use of outpatient services were divided rather evenly according to risk score groups. The health care costs (outpatient visits in primary care as well as OTC medicines) for which no information was available in the registers accounted for only 2–4% of total one-year costs.

Risk score was associated with one-year total cost of health care to about the same degree ($R^2 = 0.17$) as in shorter-term cost estimates (Table 3). The inclusion of other significant variables in the model increased further the explanatory power by 3 percentage points. Severe diabetes increased first-year costs by €7600. Contrary to shorter-time cost estimates, the previous-year costs now also became significant: an increase of €1000 in the previous-year costs increased the one-year post-operative cost by €700.
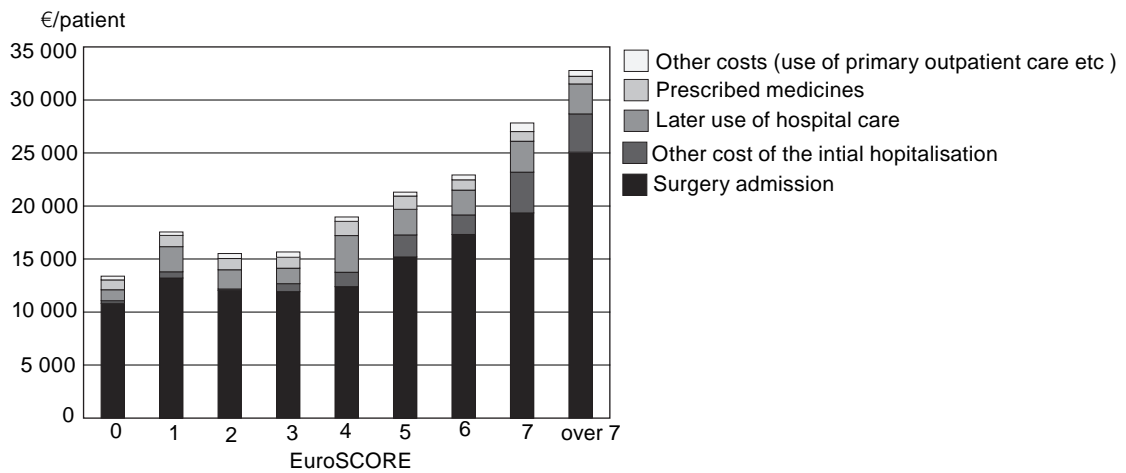

FIGURE 4. The composition of the first year cost according to EuroSCORE status of patients. Based on those alive patients who filled the follow-up questionnaire (n = 533)

TABLE 3. GLM estimation on first and five years post-operative costs (marginal effects of coefficients (constant not reported), loglikelyhood and measures of predictive accuracy of models)

	First year cost								Five year cost							
	Dummy specification of risk score		Continuous specification of risk score						Dummy specification of risk score		Continuous specification of risk score					
	Restricted specification		Restricted specification		Restricted specification +death		Extended specification		Restricted specification		Restricted specification		Restricted specification +death		Extended specification	
	marginal effects	z-value	marginal effects	z-value	marginal effects	z-value	marginal effects	z-value	marginal effects	z-value	marginal effects	z-value	marginal effects	z-value	marginal effects	z-value
EuroSCORE			1 776	12	1 594	10,74	1 540	11,4			2 543	9,46	2 137	8,07	2 118	9,14
EuroSCORE , O reference value																
1	5 963	3 ,02							7 519	2,30						
2	4 773	2,54							10 183	3,12						
3	5 721	3,12							9 895	3,18						
4	9 166	4,39							17 483	4,81						
5	10 590	4,9							25 837	6,49						
6	14 497	5,48							23 423	5,20						
7	21 653	6,9							36 604	6,73						
over 7	31 512	10,8							38 878	8,47						
Death during the follow up (1 if death)					9 322	4,11	7 290	3,59					25 780	4,83	18 120	4,11
Days lived in follow-up													8,5	2,63	7,7	2,72
Diabetes insulin (1 if user)							7 646	4,49							13 068	4,6
Previous years cost/€1000							696	4,01							1 909	5,94
log likelyhood	-14 339		-14 339		-9 731		-9 691		-10 434		-10 438		-10 427		-10 405	
R2	0,15		0,17		0,17		0,21		0,10		0,10		0,13		0,26	
MAD	8 945		8 798		8 648		8 460		14 913		14 929		14 306		13 379	

About 80% of the five-year cost was devoted to hospital care (Figure 5). The share of hospital care was highest (87%) among patients with a risk score >7 and lowest (25%) among patients with a risk score of 0. The cost of surgery admission alone accounted for about 48% of the five-year costs. However, after the first year, some 50% of costs derive from the use of prescribed medicines. The five-year costs are related to mortality and survival time in two ways as expected. The mortality increased costs by €26 000. On the other hand, an increase of life expectancy by 1 day increased costs by €8 i.e. increased survival by one year will increase costs by €3100. The EuroSCORE status together with mortality and survival explained 13% of the variation in five-year costs. The explanatory power increased to 26% when diabetes status (effect €13 000) and previous year's health care were included in the model (Table III). Their inclusion decreases the effects of mortality and survival time.
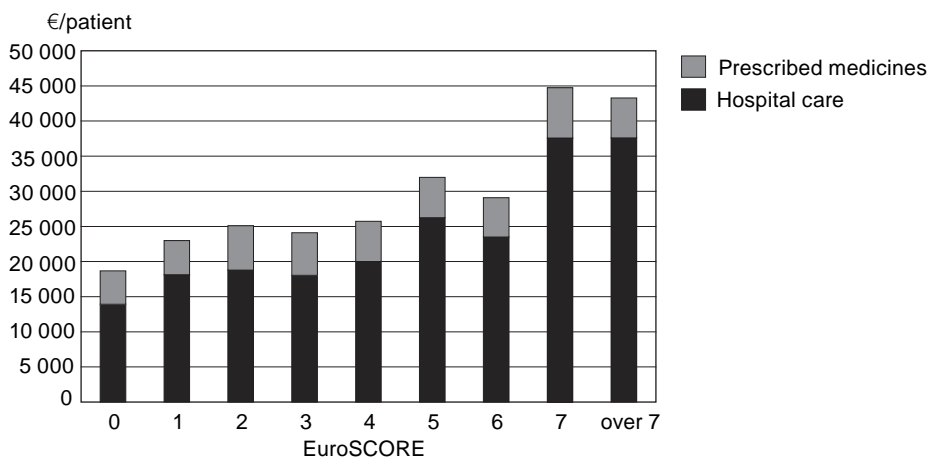

FIGURE 5. Five years cost of hospital care (including outpatient visits in specialist care) and prescribed medicines according to EuroSCORE status of patients. Based on alive patients after five years (n = 788)

3.2 Outcomes

The average change between the three-month 15D and postoperative 15D score was 0.041 (+/- 0.008) among those who survived the follow-up. Most of the improvement occurred during the first three months and by the one-year follow-up the 15D score somewhat decreased. After three months, 35% (32% after one year) of patients had a clinically significant (> 0.003) increase in 15D. Clinical improvement was evident in 46.0% (40.3% after one year) of patients with a risk score of 0, 41.3% (39.4%) with a risk score of 1, 38.0% (38.0%) with a risk score of 2, 39.1% (37. 6%) with a risk score of 3, 37.0% (36.1%) with a risk score of 4, 21.2% (19.3%) with a risk score of 5, 33.8% (29.4%) with a risk score of 6, 32.1% (23.2%) with a risk score of 7 and 11.7% (16.0%) with a risk score >7.

The most important positive changes in 15D occurred in moving, breathing and vitality (Figure 6). Risk score was not very clearly associated with changes in HRQoL. The change was highest among those with a risk score of 0 and also clearly positive among patients with a score > 4 (Figure 7). The EuroSCORE's explanatory power was very low (Table 4) and increased considerably when the initial 15D score was included in the model. The effect of the initial 15D score was negative, indicating that the operation benefited most of those patients whose initial health status was worse. The change in HRQoL was smaller among patients who had a higher health care cost than in the previous year.
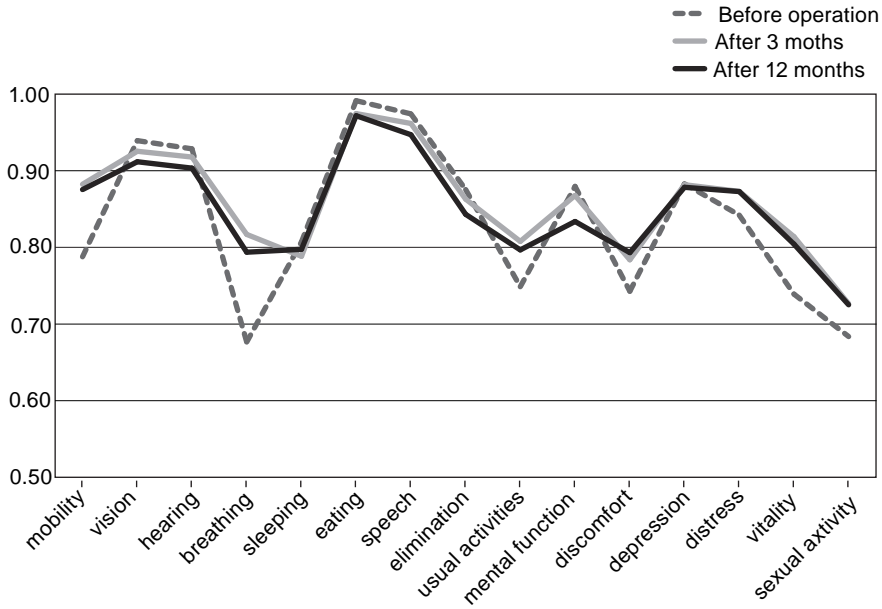
FIGURE 6. The 15 dimensions and mean 15D score of health before, 3 and 12 months after by CABG (HRQoL sample deaths included)
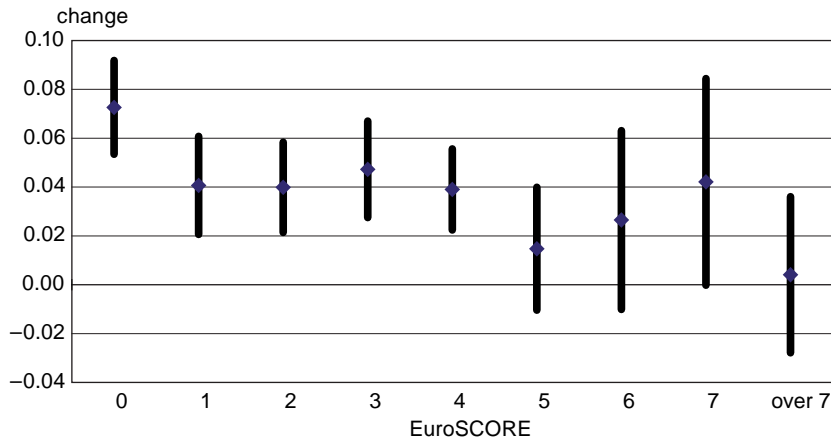

FIGURE 7. The average change (and its confidence intervals) of 15D score between three months after and before CABG operation according to EuroSCORE status of patients, HRQoL sample death excluded

TABLE 4. OLS estimation on change in 15D score (after 90 days year and before operation) and logit model for 90 day mortality

	OLS for 15D change (HRQoL sample), deaths excluded						logit for 90 day mortality (whole sample)					
	Dummy specification of riskscore		Continous spefification of riskscore				Dummy specification of riskscore		Continous spefification of riskscore			
	Restricted specification		Restricted specification		Extended specification		Restricted specification		Restricted specification		Extended specification	
	coeff.	t-value	coeff.	t-value	coeff.	t-value	marginal effects	z-value	marginal effects	z-value	marginal effects	z-value
Constant	0,073	7,15	0,058	8,27	0,428	14,03	0,062	5,93				
EUROscore			-0,005	9,18	-0,007	-4,91			0,008	7,87	0,008	-4,82
EUROscore , O reference value												
1	-0,032	-2,16										
2	-0,033	-2,26					0,015	0,46				
3	-0,025	-1,86					0,011	0,36				
4	-0,034	-2,24					0,076	1,63				
5	-0,058	-3,53					0,105	1,98				
6	-0,046	-2,56					0,297	3,21				
7	-0,030	-1,47					0,205	2,55				
over 7	-0,069	-3,6					0,410	3,94				
Preoperative 15 D score					-0,425	-12,53						
Previous years cost/€1000					-0,004	-2,49					0,002	2,63
R2 /pseudo R2	0,03		0,02		0,22		0,19		0,20		0,21	

The EuroSCORE model had very good discriminatory ability against most of the mortality indicators (Table 5). Only for five-year mortality was the area under the ROC curve under 80. In all except one-year mortality the Hosmer-Lemeshow test also showed good calibration. In most cases the extended model performed somewhat better than the restricted model. Previous-year costs and diabetes with insulin (five-year mortality) seemed, in addition to the risk score, to be an important factor for explaining mortality. Both variables were also significant predictors for 5-year survival (Table 5) in the whole sample but not in the HRQoL sample.

In the whole sample, the patients with a EuroSCORE ≥ 7 had the highest hazard rate and they were clearly distinct from other patients (Table 6). The five-year mortality in this group was 40%. Patients with a risk score of 6 or 7 had rather a high hazard rate, which was also higher than patients with lower risk scores. Only one person who had a EuroSCORE of 0 died within five years. A comparison of hazard rates between the whole sample and the HRQoL sample indicates again the selection of less severe patients to the HRQoL group.

TABLE 5. Validity of EuroSCORE on different measures of mortality

Mortality indicator	Model	Pseudo-R2	Hosmer-Lemeshow after logit model		Area under ROC
			chi²	p	
30 day mortality	Restricted model	0,1638	8,29	0,3081	0,8178
90 day mortality	Restricted model	0,1976	8,21	0,3144	0,8384
	Extended (previous year cost)	0,2124	9,29	0,2328	0,8483
one year mortality	Restricted model	0,1764	13,9	0,053	0,83
	Extended (previous year cost)	0,1888	14,39	0,0446	0,8388
five year mortality	Restricted model	0,1275	12,74	0,0787	0,7698
	Extended (preivious year expenditure,diabets with insulin)	0,1515	9,58	0,2136	0,7844

TABLE 6. Estimation results of a cox regression model (five years follow-up)

EuroSCORE	Whole sample						HRQoL sample			
	Dummy specification of risk score		Continous spefication of risk score				Dummy specification of risk score		Continous spefication of risk score	
	Restricted specification		Restricted specification		Extended specification		Restricted specification		Restricted specification	
	hazard ratio	z-value	hazard ratio	z-value	hazard ratio	z-value	hazard ratio	z-value	hazard ratio	z-value
EuroSCORE			1,27	11,03	1,28	10,82			1,206	4,72
EuroSCORE, O and 1 (reference values)										
2	3,9	2,22					5,3	2,43		
3	6,4	3,30					4,5	2,23		
4	9,9	4,13					8,6	3,33		
5	10,3	4,20					6,4	2,62		
6	20,0	5,47					12,5	3,79		
7	22,3	5,62					14,5	3,78		
over 7	31,6	6,57					11,6	3,55		
Diabetes insulin (1 if user)					1,77	2,41				
Previous years cost/€1000					1,08	3,87				
log likelyhood	-866		-874		-865		-351		-357	

3.3 Cost per QALY gained

All incremental cost measures increased with risk scores (Table 7). In the lowest risk score groups, annual costs even decreased when they were compared with the cost before the operation. The estimated QALY gains were positive in the five lowest EuroSCORE groups, when calculation was based on an assumption of no effects on life expectancy (QALY1). However, if an extreme effect of life expectancy is assumed (i.e. without an operation all patients would have died) the QALY gains were rather high even in the highest risk score groups (Table 8). The cost per QALY gained were dependent on both the cost and the QALY measures. The average incremental cost per QALY varied between €60 000–€85 000 when only a change in the quality components of life is assumed and was reduced by about one tenth when an extreme effect of life expectancy is assumed. The CE increases greatly with risk score level. In the extreme assumption of life expectancy, the cost per QALY gained has been rather low even among patients with high risk scores (Table 9). Sensitivity analyses indicated that the measurement of QALY was the most critical (Table 10). In addition, the CE figures derived from the HRQoL sample were 40% lower compared to respective figures derived from the whole sample (Figure 8). The difference was due to two reasons: HRQoL sample underestimated the cost and overestimated the QALY gains. Only in COST5/QALY2 was the difference between the two samples small.

TABLE 7. Estimates of incremental cost of CABG patients according to EuroSCORE status

	Cost of surgery admission (COST1)	Cost of surgical admission and further hospitalization together (COST2)	Cost of first year (COST3)	Annual cost diffrence (aveage) of following four years against one year before operation (3% discount rate)	First year cost (COST3) and cost diffrence in following four years	Cost of following four years (3 % discount rate)	Total five year cost (3% discount rate) COST5
	COST 1	COST2	COST3	ACC	COST4 (=COST3+ACC)	C4Y	COST5 (=COST3+C4Y)
EuroSCORE							
0	10 342	10 642	12 914	-4 694	8 220	5 379	18 293
1	13 047	13 812	17 054	-4 166	12 888	6 177	23 230
2	11 814	12 495	16 218	-2 623	13 595	8 594	24 812
3	12 338	13 787	16 919	-625	16 294	7 811	24 730
4	13 541	15 278	19 370	415	19 785	10 352	29 723
5	13 955	15 987	20 404	7 238	27 642	14 914	35 318
6	16 850	19 460	23 078	310	23 388	10 477	33 555
7	19 756	23 839	28 164	5 426	33 590	14 060	42 224
over 7	24 762	31 711	36 437	4 245	40 682	9 067	45 504
Averege	14 451	16 468	20 101	86	20 188	9 192	29 293

TABLE 8. Post and preoperative HRQoL, short run survival, life extepectancy and QALYs according to EuroSCORE status

| EuroSCORE | HRQoL (15D) | | | | Short run (3 months) survival | Averege life expectancy of the survived | QALY1 | | | | QALY2 | |
| | preopertive (N = 596) | 3 months after opeation (n = 596) | differnce between 3 months follow-up and preoprative (N = 596) | 1 year after operation (n = 570) | | | HRQoL sample | | whole sample | | HRQoL sample | Whole sample |
							five years	whole life	five years	whole life		
0	0,828	0,901	0,073	0,897	0,994	26,483	0,310	1,211	0,265	1,039	4,084	4,070
1	0,831	0,872	0,041	0,871	0,991	24,846	0,151	0,544	0,150	0,564	3,924	3,959
2	0,844	0,884	0,040	0,889	0,987	20,856	0,127	0,394	0,128	0,413	3,950	3,944
3	0,838	0,886	0,047	0,886	0,981	17,436	0,148	0,494	0,138	0,444	3,895	3,827
4	0,852	0,891	0,039	0,873	0,974	14,920	0,081	0,246	0,092	0,272	3,727	3,569
5	0,831	0,846	0,015	0,842	0,963	14,397	-0,068	-0,086	-0,033	-0,030	3,546	3,494
6	0,820	0,846	0,027	0,846	0,948	13,106	-0,039	0,009	-0,062	-0,064	3,453	3,423
7	0,745	0,787	0,042	0,779	0,928	12,064	-0,012	0,002	-0,058	-0,109	3,039	2,932
over 7	0,811	0,815	0,004	0,812	0,780	11,126	-0,662	-1,555	-0,621	-1,418	2,776	2,521
Average	0,830	0,871	0,041	0,868	0,956	18,287	0,073	0,331	0,042	0,239	3,745	3,634

TABLE 9. Cost per QALY gained according to EuroSCORE status

EuroSCORE	Cost of Surgery admission (COST 1)/ QALY1	Cost of surgical admission and further hospitalization together (COST2)/ QALY1	Cost of first year (COST 3)/ QALY1	Cost of first year and cost differnce in four following years (COST4)/ QALY1	Cost of five years (COST 5)/ QALY
0	9 954	10 243	12 430	7 912	4 494
1	23 144	24 502	30 252	22 862	5 868
2	28 601	30 249	39 263	32 913	6 290
3	27 780	31 042	38 093	36 687	6 462
4	49 696	56 073	71 092	72 615	8 329
5	a	a	a	a	10 109
6	a	a	a	a	9 804
7	a	a	a	a	14 403
over 7	a	a	a	a	18 052
totally	60 496	68 938	84 149	84 511	8 061

TABLE 10. Sensitivity of cost of first year (COST3) per QALY1 estimates

| EuroSCORE	Discount rate for QALY1		Cost estimate (QALY1 fixed)		QALY1 estimate (COST 3 fixed)	
	not discounted	5% discount rate	upper 95%l	lower 95%	upper 95%l	lower 95%
0	8 537	15 488	13 373	11 488	9 759	17 114
1	20 797	37 521	35 075	25 428	20 288	59 445
2	28 812	47 170	43 254	35 272	26 293	77 490
3	27 718	45 868	42 484	33 703	24 336	87 625
4	53 585	83 971	82 541	59 643	42 992	205 225
5	á	a	a	a	139 518	a
6	a	a	a	a	103 794	a
7	a	a	a	a	264 899	a
over 7	a	a	a	a		
totally	55 011	108 453	88 677	79 621	60 406	138 642

a = Can not be established
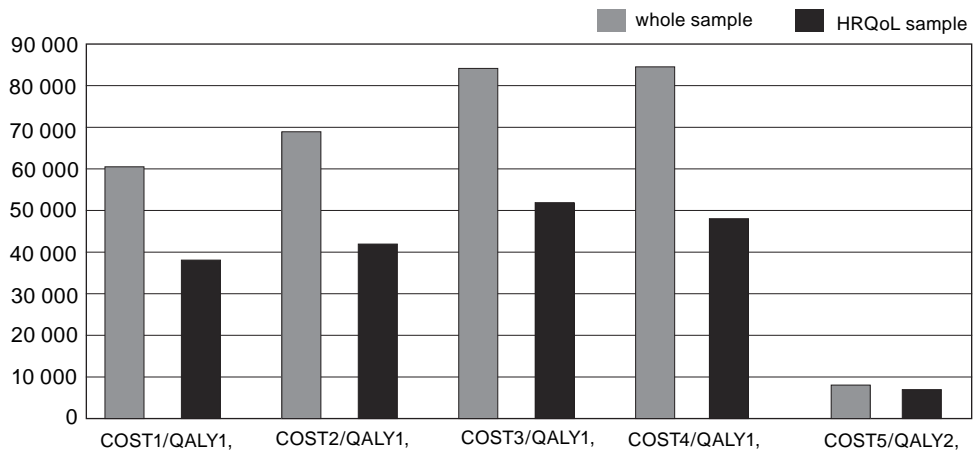
FIGURE 8. A comparison of C/E estimates calculated from whole and HRQoL sample

4 CONCLUSIONS

Of the earlier studies on EuroSCORE and the hospital cost of cardiac surgery, our result (R^2 = 0.19) were similar to Pintor et al. (2003) (R^2 = 0.22), Sokolovic et al. (2002) (R^2 = 0.19) and Nielson et al. (2004) (0.22), though we found a stronger relationship than Hekmat et al. (2005) (R^2 = 0.05). In addition, in our study EuroSCORE predicts to some extent also the one-year and even five-year costs. The prediction of cost can be somewhat improved by including two additional postoperative variables (previous year cost and diabetes with insulin).

The EuroSCORE model, initially designed to predict 30-day mortality, also satisfactory predicted one-year mortality and even five-year survival. Again the two variables improved the predictions. However, the risk stratification model does not greatly predict the changes in HRQoL. As in a previous Finnish study (Loponen *et al.,* 2008) a significant difference in changes in HRQoL between low-risk and high-risk patients was found. A recent Croatian study (Colak *et al.,* 2008) using a small sample (111) indicated the opposite: patients with a high operative risk (EuroSCORE $\geq$ 6) were likely to experience significant improvement in a greater number of health domains (using SF 36 scores) compared to patients with low and medium risks (EuroSCORE < 6). However, the results are not comparable because they used a different HRQoL measure, which were used only as a profile measure. The Finnish experience indicates that EuroSCORE does separate patients into 2–3 groups according to changes in HRQoL but does not perform well as a predictive model for the changes. For example, initial HRQol status predicts HRQoL changes much better than EuroSCORE.

According to our calculation the average cost per QALY was among patients with a risk score of less than 2, at usually less than €30 000–40 000, which has sometimes been used as a maximum that society is willing to pay for an extra QALY. However the CE ratio is crucially dependent on measuring QALYs and specially the assumptions on the effects of treatment on life expectancy. If the operation affects the life expectancy of high risk patients more than low risk patients, the CE difference between risk score groups will convergence.

Nowadays it is widely accepted that measures of outcome and even the outputs of health should be based on QALYs. Usually the effects of treatment have been estimated using the difference in HRQoL before and after treatment. It is suggested that this kind of data enables a comparison between providers, regions, countries or years. However, our study indicates clear challenges in the routine collection of outcome data. Although we managed to get HRQoL data for about 65% of patients, the sample was clearly selective, affecting crucially the CE ratios. For example, an average CE ratio (COST1/QALY1) will decrease from € 60 000 to € 38 000 (40%) when it is estimated from the HRQoL sample rather than the whole sample. This indicates that many previous studies based on patient-reported changes in HRQol have seriously overestimated the real health benefits of treatments and thus also the COST per QALY gained.

Our study indicates that a routine collection of risk scores together with register-based measurement of costs and outcomes give much more information for operational planning. Specific attention should be paid to high risk groups because the HRQoL changes are rather modest among patients with a EuroSCORE higher than seven, or who have extended ICU stays, high mortality and costs.

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