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Comprehensive assessment of frailty for elderly high-risk patients undergoing cardiac surgery☆

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Abstract

Objective: Cardiosurgical operative risk can be assessed using the logistic European system for cardiac operative risk evaluation (EuroSCORE) and the Society of Thoracic Surgeons (STS) score. Factors other than medical diagnoses and laboratory values such as the 'biological age' are not included in these scores. The aim of the study was to evaluate an additional assessment of frailty in routine cardiac surgical practice. **Methods:** 'The comprehensive assessment of frailty' test was applied to 400 patients ≥74 years who were admitted to our centre between September 2008 and January 2010. For comparison, the STS score and the EuroSCORE were calculated. The primary end point was the correlation of Frailty score to 30-day mortality. A total of 206 female and 194 male patients were included. **Results:** Median Frailty score was 11 [7,15]. Median of logistic EuroSCORE was 8.5% [5.8%; 13.9%]. Median of STS score was 3.3% [2.1%; 5.1%]. There were low-to-moderate albeit significant correlations of Frailty score with STS score and EuroSCORE ($p < 0.05$). There was also a significant correlation between Frailty score and observed 30-day mortality ($p < 0.05$). Patients received isolated coronary artery bypass grafting (CABG) ($n = 90$), isolated valve surgery ($n = 128$), trans-catheter valve implantation ($n = 59$) or combined procedures ($n = 123$). **Conclusions:** The comprehensive assessment of frailty is an additional tool to evaluate elderly patients adequately before cardiac surgical interventions. The Frailty score combines characteristics of the Fried criteria [1], of patient phenotype, of his physical performance and laboratory results. Further analysis on a larger patient population is warranted. A combination of the new Frailty score and the traditional scoring systems may facilitate a more accurate risk scoring in elderly high-risk patients scheduled for conventional cardiac surgery or trans-catheter aortic valve replacement.

Keywords: Risk scores; Elderly patients; Frailty; Trans-catheter valves

1. Introduction

Several scores to assess perioperative risk in cardiac surgery are available. Two scores are widely used in clinical routine and for scientific work: the European system for cardiac operative risk evaluation (EuroSCORE) and the Society of Thoracic Surgeons (STS) score. A disadvantage of both scores is that medical diagnoses and co-morbidities are the main variables included for scoring the perioperative risk. A factor that is not represented besides these medical features is the 'biological status' of the patient. Today's population is rapidly ageing and, as a result, a growing number of frail patients presents with coronary heart disease and degenerative valve disease. Just 20 years ago, cardiac surgery was restricted to patients younger than 65 years of age. By contrast, today the number of patients older than 75 years undergoing cardiac surgery is increasing rapidly [2]. Those patients usually have several co-morbidities [3,4] and additional factors resulting from age that lead to a higher operative risk and higher mortality compared with younger patients [4]. The EuroSCORE seems to overestimate mortality at lower score levels (EuroSCORE ≤ 6) and underestimate mortality at higher score levels (EuroSCORE > 13) [5,6]. Other authors describe a strong overestimation of the perioperative risk in high-risk patients by the EuroSCORE [7]. By contrast, the STS score seems to slightly underestimate perioperative risk [8].

To improve risk assessment, it is important to integrate factors that describe the biological status of the patient. In geriatric medicine, many efforts have been made to describe the condition of elderly patients. Patients show different vulnerability to external factors, a condition referred to as the geriatric syndrome of frailty [9,10]. Several factors contribute to the frailty of a patient and there is a variety of

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scores measuring this state [1,11,12]. It seems to be reasonable to use these well-established methods for our aims.

Here, we present a scoring system that was designed to include age-related factors in addition to clinical and laboratory data to assess the perioperative risk for mortality.

2. Methods

2.1. The Comprehensive Assessment of Frailty (CAF)

The background of the study was a frailty test initially developed by our colleagues in Medical City Dallas. For the study presented here, the original test was slightly modified. The detailed test design, including its individual items and scoring templates, can be accessed online. The first part is deduced from the Fried criteria [1]: unintentional weight loss, weakness, self-reported exhaustion, slowness of gait speed and low activity. In the CAF, all factors except the unintentional weight loss are assessed. Weakness is measured by assessing grip strength with a dynamometer that measures grip strength in kilograms (kg). Self-reported exhaustion is assessed through a questionnaire. Slowness of gait speed is measured in metres per second by assessing the time to walk 4 m in usual gait speed. Activity level is assessed by asking for the instrumental activity of daily living (IADL). The result is calculated as 'Physical activity score'. IADL that are assessed are: going for a walk, working in the household (using the vacuum cleaner, etc.), and regular sports such as swimming, gymnastics and other activities. Kilocalories per week are calculated by the following formula: ($w \times$ frequency of activity $\times$ duration of activity)/2. The variable 'w' is dependent on the activity.

The second part of the CAF test is designed to test physical performance. First, the standing balance is tested. The patient has to stand still with both feet together, then in the so-called 'semi-tandem' position with one feet halfway in front of the other and finally in the 'tandem' position with one foot completely in front of the other. The time the patients are able to maintain each position is measured and frailty points referring to a table are added to the Frailty score. In the last item of the balance test, the patient is asked to spin around 360° as fast as possible. Again, the time is measured and, according to a grading table, the corresponding points are added to the CAF. This is followed by tests to assess body control. The patient has to get up and down from a chair three times, has to pick up a pen from the floor and has to put on and remove a jacket.

Selected laboratory tests are included in the CAF score. Serum albumin as a marker for nutritional state and liver function, creatinine as a marker for kidney function and brain natriuretic peptide (BNP) as a marker for heart failure were measured. To assess respiratory function, the forced expiratory volume in 1 s (FEV1) was measured. All laboratory values were included into the overall CAF, according to a grading table (see online table: 'How to score the CAF').

In addition, two physicians (one cardiac surgeon and one experienced clinician) different from the person observing the CAF testing itself were asked to estimate frailty of the patient according to the Clinical Frailty Scale from the Canadian Study of Health and Aging [12].

The complete CAF test is available in the online supplementary 'CAF Test Sheet' and 'How to score the CAF'. A video clip is added to the online supplementary where the assessment is shown.

2.2. Patients

From September 2008 to January 2010, 400 patients (206 female and 194 male) $\geq$74 years undergoing elective cardiac surgery were included in the study. All tests were carried out in a standardised environment. The assessment of the test battery took 10–20 min. Results of the CAF scores were stratified arbitrary into three groups labelled 'not frail' (1–10 points), 'moderately frail' (11–25 points) and 'severely frail' (26–35 points).

In addition to the CAF, the STS score and the logistic EuroSCORE were calculated as described in the literature [8,13].

2.3. Statistical analysis

The primary end point was the 30-day mortality. To measure the accuracy of the different scores regarding the 30-day mortality, receiver operating characteristics (ROC) curves were plotted and the area under the ROC curve (AUC) was calculated. A logistic regression was used to show that each variable used to create the CAF score is a dependent variable according to 30-day mortality. To analyse the three categories of frailty to mortality, a contingency table and the Armitage's Trend Test for proportions was used. Furthermore, Spearman's rank correlation was used to compare the CAF to the STS score and EuroSCORE. A p-value of less than 0.05 was considered significant.

3. Results

For the study lasting over 16 months, the only exclusion criterion was age younger than 74 years. The mean age was 80.3 ± 4 years. Sample size calculations showed that the number of patients included in the study was sufficient. The baseline characteristics of the patient population are shown in Table 1. Out of the study population, 22.5% underwent isolated coronary revascularisation, 32% isolated valve procedures (aortic valve replacement or mitral valve repair or replacement or tricuspidal valve repair or replacement) and 30.5% underwent combined procedures. Trans-catheter transfemoral aortic valve implantation and trans-catheter trans-apical aortic valve implantation was performed in 14.8%. Median of logistic EuroSCORE for all patients was 8.5% [5.8%; 13.9%]. Median of STS score was 3.3% [2.1%; 5.1%] and the overall 30-day mortality was 5.5%. The median of CAF score was calculated with a value of 11 [7,15]. Patients who were assessed for trans-catheter aortic valve implantation had a significantly higher Frailty score ($p < 0.05$). CAF for those patients was 12 [7,19].

A total of 199 patients were assessed as 'not frail', 170 as 'moderately frail' and 31 patients as 'severely frail'.

Table 1
Baseline characteristics of patients included for assessment of the CAF.

n	400
Age (years)	80.1 ± 4.0
Weight (kg)	75.1 ± 13.3
Height (cm)	166 ± 0.09
BMI (kg/m^2)	27.4 ± 4.2
BNP (pg/ml)	2081 ± 3079
CAF	11 [7; 15]
Logistic EuroSCORE (%)	8.5 [5.8; 13.9]
STS score (%)	3.3 [2.1; 5.1]
CABG (%)	22.5
Single valve (except trans-catheter) (%)	32
Trans-apical valve (%)	11.3
Transfemoral valve	3.5
Combined procedures (%)	30.7
30-day mortality (%)	5.5

BMI: body mass index; BNP: brain natriuretic peptide; CAF: comprehensive assessment of frailty; and CABG: coronary artery bypass grafting.

All score variables were tested with respect to their dependence or independence to 30-day mortality by logistic regression. Each variable of the test had a *p*-value higher than 0.5. However, the CAF score resulting from the addition of the single parameters was an independent factor ($p < 0.05$).

The distribution of frailty points given for single parameters of the Frailty score divided to the three risk groups is shown in Table 2.

Calculation of the Spearman's correlation of the CAF score to the EuroSCORE ($p = 0.35$) and to the STS score ($p = 0.42$) is suggestive of a relation of CAF with conventionally used risk stratification systems. The low-to-moderate values demonstrate that the Frailty score overlaps only partly with traditional scores and has the potential to complement them.

Table 2
Distribution of frailty points in percent (%) in the three risk groups concerning to the parameters of the CAF.

Frailty test	Frailty points	Not frail	Moderately frail	Severely frail
Grip strength	0	75	46	19
	1	25	54	81
Walking speed	0	97	68	0
	1	3	32	100
Balance	0	64	26	0
	1	29	29	4
	2	7	26	4
	3	0	16	33
	4	0	3	59
Rise up from chair	0	26	1	0
	1	44	8	0
	2	20	18	4
	3	10	58	0
	4	0	15	96
Pick up a pen	0	41	5	0
	1	52	54	7
	2	7	24	8
	3	0	9	15
	4	0	8	70
Put on and remove a jacket	0	73	23	11
	1	20	41	4
	2	7	20	15
	3	0	16	40
	4	0	0	30

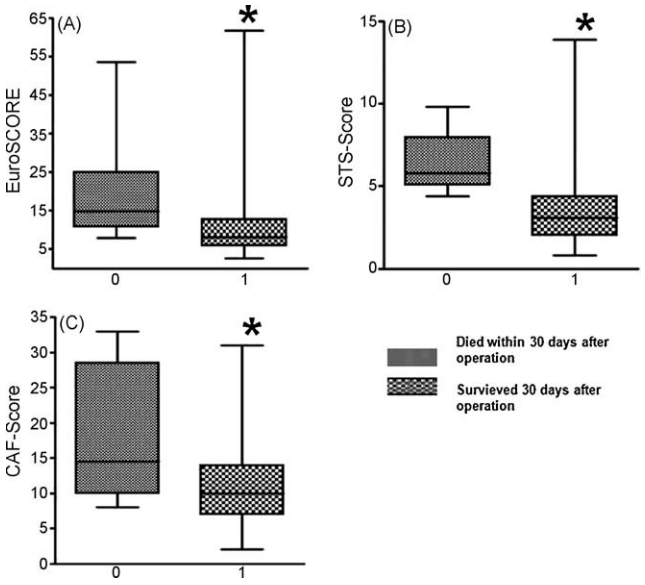

Fig. 1. Differences of risk-score values between patients who died within 30 days and patients who survived 30 days; (A) EuroSCORE, (B) STS score, (C) CAF score; 0 = died within 30 days, 1 = survived 30 days after operation. *Means a significant difference between the means with a $p < 0.05$

The risk-score values of those patients who died within 30 days and those patients who survived were analysed. A highly significant difference between the two groups was observed for the logistic EuroSCORE ($p < 0.05$) (Fig. 1(A)), the STS score ($p < 0.05$; Fig. 1(B)) and the CAF score (Fig. 1(C)) ($p < 0.05$). In addition, the 30-day mortality within each CAF subgroup (not frail, moderately frail and severely frail) shows a significantly higher mortality rate among the patients in the CAF category 'severely frail' compared with the patients of the less frail groups (Table 3).

The CAF score demonstrated a good accuracy regarding the prediction of 30-day mortality. ROC curves were plotted and the AUC for all scores was calculated. For the logistic EuroSCORE, an AUC of 0.79, for the STS score an AUC of 0.76 and for the CAF score an AUC of 0.71 was observed (Fig. 2).

4. Discussion

The study used a new scoring system ('Comprehensive Assessment of Frailty') as a predictive tool to quantify the perioperative risk in elderly people undergoing elective

Table 3
Mortality rate among each CAF category.

	CAF category		
	Not frail (1–10 points)	Moderately frail (11–25 points)	Severely frail (26–35 points)
Survival			
Alive % within CAF category	96.4	92.2	78.3
Dead % within CAF category	3.6	7.8	21.7

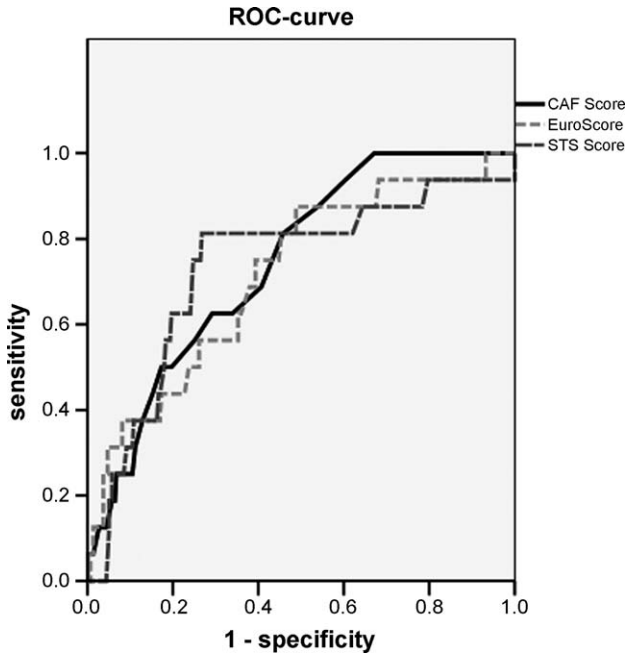

Fig. 2. ROC curves for risk scores; continuous line: ROC curve CAF; bright grey spotted line: ROC curve EuroSCORE; dark grey spotted line: ROC curve STS score.

cardiac surgery in addition to conventional risk scores. The new score is a combination of clinical features and laboratory values and the measurement of frailty.

The key finding of this study is that there is a correlation between a high CAF score and an increased 30-day mortality. The values for the AUC of ROC proved the validity of the CAF score to assess the risk profile of the individual elderly patient regarding 30-day mortality.

Furthermore, a low-to-moderate correlation between CAF score, EuroSCORE and STS score demonstrated the potential of the Frailty score as a valuable risk assessment in addition to the commonly used scoring systems.

The key feature of the new CAF score is the ability to include the 'biological' status in addition to conventional scoring items of elderly patients to assess the operative risk prior to elective cardiac surgery. The results show that it is necessary and possible to use a score containing mainly factors concerning the biological age and frailty of a patient to calculate the perioperative risk. Nevertheless, the values describing the accuracy of the test regarding the 30-day mortality have been as good as those of EuroSCORE and STS score, but not better. A reason for that could be that the test is not yet well established. It might be possible to shorten the test and thereby achieve a better accuracy by excluding confounding factors. A disadvantage of the test is that it is not accomplished as easily as the traditional scores. It takes around 10—20 min to perform the test. It is also necessary to have special equipment, for example, to measure the grip strength. Therefore, it might be difficult to integrate the test in the daily clinical routine. A next possible step is to evaluate whether a combination of the Frailty score and the STS score might be a better-suited prediction for perioperative mortality. The ROC curve shows a difference between Frailty score and STS score but not with the EuroSCORE. It might be feasible to create a cut-off point between STS and CAF from where a clinician can choose the test with the best predictive value according to risk assessment.

It was not the main goal of the study to create an independent score that is separately used to assess risk for elderly patients but to show that also additional factors should be used to make a prediction regarding the outcome of a procedure. With altered age structures in developed countries, it is very important to create new tools to pay attention to those circumstances; hence, it is useful to use the test as an additional tool for elderly patients to calculate their risk profile before cardiac surgery.

With the evolution of new trans-catheter procedures to treat elderly high-risk patients with severe aortic stenosis, such scoring tools may be needed. The general justification to treat these patients with the new trans-catheter approaches is derived from the assessment of their potential 'high' risk nature for conventional aortic valve replacement. On the other hand, conventional surgical valve replacement has been shown to be associated with excellent short- and long-term outcome even in octogenarians [14].

Although there is strong evidence available demonstrating that the logistic EuroSCORE badly overestimates the true operative risk in case of conventional surgery [7], the 'calculated' predicted 30-day mortality is often used to 'prove' superiority of the new trans-catheter approaches [15]. The STS score seems to be a better tool to assess the 'true' risk in this special subgroup of patients, but it is certainly lacking an option to take into account factors that are at present only assessable by the so-called 'eyeball-test'.

In summary, there is a strong need for the development of a more accurate risk scoring system in elderly patients scheduled for cardiac surgical procedure. A combination of traditional scoring systems with the new Frailty score presented here is a potential option to finally design a highly sophisticated scoring system.

References

[1] Fried LP, Tangen CM, Walston J, Newman AB, Hirsch C, Gottdiender J, Seeman T, Tracy R, Kop WJ, Burke G, McBurnie A. Frailty in older adults: evidence for a phenotype. J Gerontol A Biol Sci Med Sci 2001;56:M146—56.

[2] Alexander KP, Newby LK, Cannon CP, Armstrong PW, Gibbler WB, Rich MW, Van de Werf F, White HD, Weaver WD, Naylor MD, Gore JM, Krumholz HM, Ohman M. Acute coronary care in the elderly. Part I: Non-ST-segment-elevation acute coronary syndromes: a scientific statement for health-care professionals from the American Heart Association Council on Clinical Cardiology: in collaboration with the Society of Geriatric Cardiology. Circulation 2007;115:2549—69.

[3] Alexander KP, Anstrom KJ, Muhlbaier LH. Outcomes of cardiac surgery in patients age ≥80 years: results from the national cardiovascular network. J Am Coll Cardiol 2000;35:731—8.

[4] Friedrich I, Simm A, Kötting J, Thölen F, Fischer B, Silber RE. Cardiac surgery in the elderly patient. Dtsch Arztebl Int 2009;109:416—22.

[5] Gogbashian A, Sedrakyan A, Treasure T. EuroSCORE: a systematic review of international performance. Eur J Cardiothorac Surg 2004;25:695—700.

[6] Nashef SAM, Roques F, Hammill BG, Peterson ED, Michel P, Grover FL, Wys RKH, Ferguson TB. Validation of European System for Cardiac Operative Risk Evaluation (EuroSCORE) in North American cardiac surgery. Eur J Cardiothorac Surg 2002;22:101—5.

[7] Dewey TM, Brown D, Ryan WH, Herbert MA, Prince SL, Mack MJ. Reliability of risk algorithms in predicting early and late operative outcomes in high-risk patients undergoing aortic valve replacement. J Thorac Cardiovasc Surg 2008;135:180—7.

[8] Wendt D, Osswald BR, Kayser K, Thielmann M, Tossios P, Massoudy P, Kamler M, Jakob H. Society of Thoracic Surgeons Score is superior to the EuroSCORE determining mortality in high risk patients undergoing isolated aortic valve replacement. Ann Thorac Surg 2009;88:468—74.
[9] Rockwood K, Abeysundera MJ, Mitnitski A. How should we grade frailty in nursing home patients. J Am Med Dir Assoc 2007;8:595—603.
[10] Topinkova E. Aging, disability and frailty. Ann Nutr Metab 2008;52:6—11.
[11] Chin A, Paw MJM, Dekker JM, Feskens EJM, Schouten EG, Kromhout D. How to select a frail elderly population? A comparison of three working definitions. J Clin Epidemiol 1999;52:1015—21.
[12] Rockwood K, Song X, MacKnight C, Bergman H, Hogan DB, McDowell I, Mitnitski A. A global clinical measure of fitness and frailty in elderly people. CMAJ 2005;173:489—95.
[13] Nashef SA, Roques F, Michel P, Gauducheau E, Lemeshow S, Salamon R. European system for cardiac operative risk evaluation (EuroSCORE). Eur J Cardiothorac Surg 1999;16:9—13.
[14] Leontyev S, Walther T, Borger MA, Lehmann S, Funkat AK, Rastan A, Kempfert J, Falk V, Mohr FW. Aortic valve replacement in octogenarians: utility of risk stratification with EuroSCORE. Ann Thorac Surg 2009;87:1440—5.
[15] Kallenbach K, Karck M. Percutaneous aortic valve implantation — contra. Herz 2009;342:130—9.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.ejcts.2010.04.013.