Impact of frailty scores on outcome of octogenarian patients undergoing transcatheter aortic valve implantation

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Background For selected patients with symptomatic aortic stenosis, transcatheter aortic valve implantation (TAVI) is an alternative to surgical aortic valve replacement (AVR). In addition to co-morbidities, frailty has to be taken into account in the decision-making process. Criteria for patient selection, according to current guidelines, include EuroSCORE and STS score but frailty is not easy to quantify. ISAR (Identification of Seniors At Risk) detects seniors at risk for adverse health outcome after an emergency visit and SHERPA (Score Hospitalier d'Evaluation du Risque de Perte d'Autonomie) assesses the risk of functional decline after hospitalization.

Objectives The aim of the present study was to evaluate the impact of ISAR and SHERPA scores in the prediction of patient outcome after TAVI.

Methods and results A prospective cohort of 30 consecutive octogenarian patients (16 males, 86 ± 3 y, EuroSCORE 34 ± 12%) underwent a transfemoral TAVI and a complete geriatric assessment in our institution. Survival at one year was 73%. The ISAR score was similar between both groups (3.1 ± 1 vs. 3.6 ± 1; $P = 0.10$) but the SHERPA score was significantly higher in non-survivors (7.8 ± 1.6) than among survivors (4.9 ± 2.4; $P = 0.001$). With multivariate analysis, SHERPA score and BMI were independent predictors of 1-year mortality. Kaplan-Meier analysis showed that 1-year survival was significantly lower in patients with than in those without a SHERPA score > 7 (40 vs. 89%; $P = 0.004$).

Conclusions The result of this study showed that SHERPA score predicts 1-year survival after transfemoral TAVI and could be considered as a useful frailty score in patient selection.

Keywords *Aortic valve stenosis – transfemoral aortic valve implantation – frailty – survival.*

INTRODUCTION

Degenerative aortic valve stenosis (AS) is the most frequent type of valvular heart disease in Europe and North America. The prevalence of the disease increases with age, and affects 2 to 7% of the population >65 years[1]. Surgical aortic valve replacement (SAVR) is the recommended treatment of symptomatic AS[2] providing relief of symptoms and life prolongation[3]. Recently, transcatheter aortic valve implantation (TAVI) has offered an alternative for patients with symptomatic AS who are not candidates for SAVR[4], showing a superiority versus medical treatment[5] and a non-inferiority as compared with surgery[6]. Patients denied surgery are often elderly, with comorbidities leading to a high surgical risk quantified by the Society of Thoracic Surgeons (STS) score and/or logistic EuroSCORE[7-8]. These scores are not designed to evaluate the risk of TAVI[9] and whether this mini-invasive approach is appropriate to improve the outcome of older patients. Frailty is a parameter of paramount importance in a geriatric population, which is usually evaluated by clinical judgement[10] or specific assessment, including Comprehensive Geriatric Assessment, and is not well quantified yet in the specific setting of TAVI screening. The ISAR (Identification of Seniors At Risk) tool detects seniors at risk for adverse health outcome after an emergency visit[11]. The SHERPA (Score Hospitalier d'Evaluation du Risque de Perte d'Autonomie) score assesses

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the risk of functional decline following hospitalization for older patients admitted through the emergency room[12]. The aim of the present study was to evaluate the impact of the frailty, detected by those scales, on the outcome of a population of patients undergoing TAVI.

METHODS

Study population

Octogenarian patients undergoing a transfemoral TAVI and a complete geriatric assessment in our institution between January 2009 and December 2011 were prospectively enrolled in the study. Patients were suffering severe calcific aortic stenosis (aortic valve area < 1 cm² and/or peak transvalvular velocity > 4 m/sec) and were eligible for transfemoral TAVI after team consensus. Anatomic exclusion criteria were ilio-femoral artery diameter < 6 mm, congenital or non-calcified aortic stenosis, unprotected left main lesion, coagulation disorder, endocarditis, recent myocardial infarction or stroke (within 1 month), aortic annulus diameter < 18 or > 25 mm, left ventricular ejection fraction < 20%, and severe tortuosity and/or calcification of the aorta.

Study protocol

Baseline demographics, previous medical history and comorbidities were prospectively collected, allowing calculation of the Charlson index[13] and the logistic EuroSCORE I. Physical examination was performed by a cardiologist; weight and height were noted to calculate the body mass index (BMI), patients were considered as underweight if BMI was < 23 kg/m². A blood test, including albumin, brain natriuretic peptide (BNP), troponin-I (ULN = 0.08 ng/ml) and creatinine serum levels, was performed. Glomerular filtration rate (GFR) was estimated using the MDRD-4 formula[14] and renal failure was defined as a GFR < 60 ml/ min/1.73m². The aortic valve orifice area (AVA), the left ventricular ejection fraction (LVEF) and the transvalvular gradient were measured by transthoracic and/or transoesophageal echocardiography.

Geriatric features were collected by the hospital geriatric liaison team including the two frailty scores, ISAR and SHERPA. Geriatric assessment included evaluation of impairments in both basic and instrumental Activities of Daily Living (ADL). Basic ADL (BADL) consists of self-care tasks including dressing, eating, walking, toileting, hygiene, while Instrumental ADL (IADL: shopping, housekeeping, accounting, food preparation/medications, telephone/transportation) are not necessary for fundamental functioning, but they allow an individual to live independently in a community. The cognitive evaluation through an abbreviated Mini Mental State Evaluation (MMSE)[15] and the prevalence of delirium was assessed at least once during hospitalization by the Confusion Assessment Method[16]: delirium was noted whether the score was ≥ 4. The ISAR score aimed at assessing the post-hospital risks of functional decline, institutionalization in a nursing home or death at 6 months (table 1), and is based on 6 self-rated questions with dichotomous answers (baseline functional dependence, recent increase in functional dependence, hospitalization in the last 6 months, impaired memory, impaired vision, daily use of 3 or more medications). Patients were considered at low risk if the score was 0-1/6, intermediate risk if the score was 2-3/6 and high risk if the score was > 3/6. The SHERPA score developed five risk factors easily available upon hospital admission: age category, IADL evaluated by the Lawton scale, cognitive decline (assessed by an abbreviated MMSE), history of fall in the previous year, and self-perceived health (table 2). Each factor has a weight proportional to its odds ratio. The resulting score ranges from 0 to 11.5, and stratifies elderly patients into high (> 6), moderate (5-6), mild (3.5-4.5) and low (0-3) risk groups for functional decline in the 3 months following emergency hospitalization.

The TAVI procedure was performed using a transfemoral Sapien valve (Edwards Lifesciences, Irvine, California, USA) implantation. After the procedure, major cardiac and cerebral adverse events (MACCE) were noted according to the VARC-2 consensus criteria[17].

Patients were scheduled for a clinical follow-up 30 days and 1 year after TAVI. Patient survival and occurrence of clinical events were determined from reviews of the medical records or direct patient and/or referring physician contact.

Statistics

Data are presented as mean ± 1 standard deviation unless otherwise stated. Differences between patient groups were analysed with a Student t test for continuous variables or χ^2 test for categorical variables. Multivariate analysis of the predictive factors of death and MACCE was performed using the Cox proportional-hazards method. The receiver operating characteristic (ROC) curve was determined to evaluate the performance of the SHERPA score to predict survival. Optimal cut-off points for the SHERPA score were chosen with maximum sensitivity and specificity. Survival curves according to the SHERPA score were established by the Kaplan-Meier estimation method. A p value < 0.05 was considered statistically significant. Analyses were performed using the SPSS version 15.0 (SPSS Inc., Chicago, Illinois).

RESULTS

Study population

Cardiovascular characteristics of patients are listed in table 3. The population of this study consists of octogenarian patients (mean age 86 years, range 81-95 years) with severe AS at very high risk for surgery (mean logistic EuroSCORE I = 34%). The most frequent comorbidity was hypertension followed by renal failure, coronary artery and peripheral vascular disease.

Admission troponin-I level was higher than ULN in 7 patients (23%). Nine patients (30%) had undergone balloon aortic valvuloplasty in the last 12 months.

The Charlson index showed a large variation among the patients, with a mean and a median index of 16 and 20, respectively. The logistic EuroSCORE I was normally distributed with similar mean, median and mode values (34, 32 and 32%, respectively).

Table 4 provides the geriatric characteristics of the study population. Half of the 30 patients were dependent in some BADL. Malnutrition was not frequent as reflected by the prevalence of underweight (26%). Cognitive deficits were frequent while acute delirium was rare (6%). A large majority of these octogenarian patients were living at home (83%).

Frailty scores: ISAR and SHERPA

The ISAR score was low in 5 patients (17%), moderate in 16 (53%) and high in 9 (30%). ISAR scores were normally distributed (mean 3.5 ± 1; mode 4; median 3). The prevalence of the six ISAR items by decreasing order of frequency was: daily use of ≥ 3 medications, hospitalization in the last six months, recent increase in functional dependence, baseline functional dependence, impaired vision, and severe memory impairment.

Using the SHERPA score, 8 patients were at low risk, 11 patients at moderate, and 11 patients were assessed at high risk of functional decline. The SHERPA distribution was skewed to lower values (mode 9; mean 5.7 ± 1; median 6.3). The prevalence of the five SHERPA items was as follows: dependency in ≥ 4 IADL, age ≥ 85 years, fall in the previous year, short MMSE < 15/21, and self-perceived lower health status as compared with other persons of the same age.

Table 1 The ISAR score

	Items
Prior to admission to the emergency room, did you need help at home?	1
Since the beginning of the symptoms that led you to the emergency room, do you need more help at home?	1
Have you been hospitalized during the last six months?	1
In everyday life, do you have vision problems?	1
In everyday life, do you suffer of memory problems?	1
Do you take more than 3 drugs per day?	1

Table 2 The SHERPA score

		Items
MMSE < 15/21	YES	2
	NO	0
Year	< 75	0
	75-84	1.5
	> 84	3
Perceived poor health	YES	1.5
	NO	0
Fall in the last year	YES	2
	NO	0
Number of IADL realized in autonomous way before admission	6-7	0
	5	1
	3-4	2
	0-1-2	3

MMSE: minimal mental state examination, IADL: instrumental activities of daily living.

Procedural outcome

Procedural success was observed in all patients without any procedural death. There were 5 in-hospital MACCE including 1 ischaemic minor stroke, 2 renal failures (one stage 3 and one stage 2 according to the AKIN criteria) treated conservatively and 3 minor vascular complications. Frailty parameters were not predictors of these procedural adverse events and were similar between patients with and those without MACCE (ISAR: 3.5 ± 1 vs. 3.1 ± 1, respectively, p=NS; SHERPA: 7.1 ± 2 vs. 5.3 ± 2, respectively, p = NS). Patients were discharged at 7 ± 5 days; time to discharge was not influenced by the frailty profile of the patients.

Predictors of one-year survival after TAVI

Overall survival at 1 year was 73%. Causes of death were heart failure in 2 patients, pulmonary sepsis in 2 other cases, one sudden death, one cancer and 2 unknown reasons. Non-survivors were more frequently males, with diabetes and low BMI (tables 3 and 4); they have a higher tendency of pulmonary hypertension, atrial fibrillation, renal failure and high baseline

Table 3 Cardiovascular characteristics of patients

		All n = 30	Survivors n = 22	Non-survivors n = 8	*P*-value
Age	years	86 ± 3	85 ± 3	86 ± 2	0.2
Male gender	n(%)	16 (53)	9 (41)	7 (87)	0.024
Aortic valve area	cm^2	0.58 ± 0.1	0.6 ± 0.1	0.5 ± 0.1	0.1
Peak gradient	mmHg	65 ± 25	65 ± 26	64 ± 27	0.92
Mean gradient	mmHg	42 ± 17	42 ± 17	42 ± 18	0.97
Left ventricular ejection fraction	%	52 ± 14	54 ± 13	48 ± 15	0.34
B-type natriuretic peptide	pg/ml	691 ± 643	583 ± 488	975 ± 921	0.1
Troponin I	ng/ml	0.07	0.04	0.08	0.03
Glomerular filtration rate	ml/min/1.73 m2	52 ± 17	55 ± 21	46 ± 14	0.2
Creatinine	mg/dl	1.25 ± 0.44	1.18 ± 0.46	1.42 ± 0.45	0.20
Co-morbidities					
Hypertension	n(%)	26 (87)	19 (86)	7 (88)	0.9
Atrial fibrillation	n(%)	11 (40)	6 (27)	5 (63)	0.07
Stroke/transient ischaemic attack	n(%)	5 (17)	3 (14)	2 (25)	0.4
Previous myocardial infarction	n(%)	11 (33)	8 (32)	3 (38)	0.7
Previous coronary angioplasty	n(%)	13 (43)	9 (41)	4 (50)	0.6
Coronary arterial by-pass graft	n(%)	4 (14)	3 (14)	1 (13)	0.9
Previous balloon valvuloplasty	n(%)	9 (30%)	5 (23)	4 (50)	0.16
Carotid stenosis	n(%)	5 (17)	4 (18)	1 (13)	0.5
Peripheral arterial disease	n(%)	12 (40)	7 (32)	5 (63)	0.1
Renal failure	n(%)	18 (60)	11 (50)	7 (88)	0.06
Chronic obstructive pulmonary disease	n(%)	6 (20)	4 (18)	2 (25)	0.6
Mediastinal radiation	n(%)	1 (3)	1 (4)	0	1
Pulmonary hypertension	n(%)	10 (33)	5 (22)	5 (62)	0.07
Pacemaker	n(%)	4 (13)	3 (13)	1 (12)	1
Diabetes mellitus	n(%)	6 (20)	2 (9)	4 (50)	0.02
Charlson index	%	16 ± 20	16 ± 20	16 ± 24	0.9
EuroSCORE I	%	34 ± 12	33 ± 11	40 ± 17	0.2

troponin-I level. The ISAR score was similar between both groups (3.1 ± 1 vs. 3.6 ± 1; $P = 0.10$) but the SHERPA score was significantly higher in non-survivors (7.8 ± 1.6) than among survivors (4.9 ± 2.4; $P = 0.001$). Interestingly, the items of the SHERPA largely differing between survivors and non-survivors, were: cognitive dysfunction (MMSE), fall (in the previous year) and poor self-perceived health (table 4).

With multivariate analysis, SHERPA score and BMI were independent predictors of 1-year mortality (table 5). ROC analysis (figure 1) showed that the optimal cut-off value of the SHERPA score to predict 1-year survival was 7 with a sensitivity of 80% and a specificity of 87%. Area under the curve (AUC) was 0.85. Kaplan-Meier analysis showed that 1-year survival was significantly lower in patients with than without a SHERPA score > 7 (40 vs. 89%; $P = 0.004$; figure 2).

DISCUSSION

In this prospective analysis (focused on a geriatric population ≥ 80 years old), we found that the SHERPA score predicts 1-year mortality but not procedural outcome, in patients who received transfemoral TAVI, while the ISAR score was not a predictor.

Table 4 Geriatric characteristics of patients

		All n = 30	Survivors n = 22	Non-survivors n = 8	*P*-value
Age ≥ 85	n (%)	17 (56)	12 (59)	5 (75)	0.42
Nursing home	n (%)	13 (43)	5 (23)	8 (100)	0.15
Function dependency BADL		8.1 ± 2.1	8.2 ± 2.4	8.1 ± 1.5	0.97
Nutritional status					
Weight	kg	69 ± 11	69 ± 11	67 ± 10	0.49
Height	m	1.63 ± 0.9	1.61 ± 0.9	1.69 ± 0.7	0.07
BMI	kg/m^2	25.1 ± 4	25.3 ± 4	24 ± 2	0.05
BMI < 23	n (%)	8 (26)	4 (18)	4 (50)	0.06
Albumin	g/dl	3.5 ± 0.6	3.6 ± 0.6	3.4 ± 0.4	0.43
Cognitive function					
Delirium	n (%)	2 (6)	1 (5)	1 (13)	0.49
Short MMSE		17.5 ± 3	18 ± 3	17 ± 3	0.33
Geriatric syndromes, others					
Multiple falls	n (%)	10 (33)	5 (22)	5 (63)	0.04
Daily medications ≥ 7	n (%)	21 (70)	15 (68)	6 (75)	0.7
ISAR score		3.5 ± 1	3.1 ± 1	3.6 ± 1	0.1
Need for help in ADL	n (%)	12 (40)	9 (41)	3 (38)	0.87
Increased need for help	n (%)	19 (63)	12 (55)	7 (88)	0.09
Memory problems, serious	n (%)	7 (23)	6 (27)	1 (13)	0.4
Vision problems	n (%)	8 (27)	5 (23)	3 (38)	0.42
Hospital stay < 6 months	n (%)	21 (70)	14 (64)	7 (88)	0.21
Drugs ≥ 3 daily	n (%)	29 (97)	21 (95)	8 (100)	0.54
SHERPA score		5.7 ± 2.5	4.9 ± 2.4	7.8 ± 1.6	0.01
Age category		2.6 ± 0.7	2.5 ± 0.7	2.8 ± 0.5	0.31
Fall in last year	n (%)	13 (43)	7 (31)	6 (75)	0.04
Health perception	n (%)	4 (13)	1 (4)	3 (37)	0.02
IADL		1.8 ± 1.3	1.7 ± 1.3	2 ± 1.3	0.56
Short MMSE < 15/21	n (%)	7 (23)	3 (13)	4 (50)	0.04

BADL: basic activities of daily living, BMI: body mass index, CAM: confusion assessment method, MMSE: minimal mental state examination, IADL: instrumental activities of daily living.

The ISAR and SHERPA scores were developed to evaluate the risk of functional decline after hospitalization in older patients. This negative outcome is the consequence of frailty. Our population shared some geriatric characteristics: older age, falls, dependence in BADL, cognitive impairment, which are all linked to frailty. Although pevious publications showed the impact of frailty in older adults with cardiac disease and after TAVI, this is the first time that the SHERPA score (not designed for mortality prediction, but easy to apply in daily practice) demonstrated a predictive value after TAVI. Philip Green et al.[18] defined frailty score based on grip strength, gait speed, ADL and serum albumin and showed that it provides independent prognostic information of older adults undergoing TAVI. The MGA (Multidimensional Geriatric Assessment) of Stephan Stortecky et al.[19] grouping MMSE, MNA (Mini Nutritional Assessment), TUG (Timed Get Up and Go test), BADL, mobility and preclinical disability predict all-cause mortality and MACCE in elderly patients undergoing TAVI. Contrary to these complex assessments requiring a performance test (e.g. grip strength) or a blood sample (albumin) or the expertise

Table 5 Univariate and multivariate analysis for predictors of 1-year survival according to Cox models

		Univariate analysis	
Variable	HR	95% CI	*P* value
SHERPA (1 point increase)	2.01	1.29-3.12	0.002
BMI (1 unit increase)	0.81	0.66-1.01	0.051
Pulmonary hypertension	4.29	1.02-17.99	0.047
Male gender	7.53	0.92-61.27	0.059
Diabetes	5.71	1.41-23.21	0.015
		Multivariate analysis	
	HR	95% CI	*P* value
SHERPA (1 point increase)	2.74	1.39-5.39	0.004
BMI (1 unit increase)	0.54	0.35-0.85	0.007

SHERPA: Score Hospitalier d'Evaluation du Risque de Perte d'Autonomie, BMI: body mass index, HR: hazard ratio, CI: confidence interval.

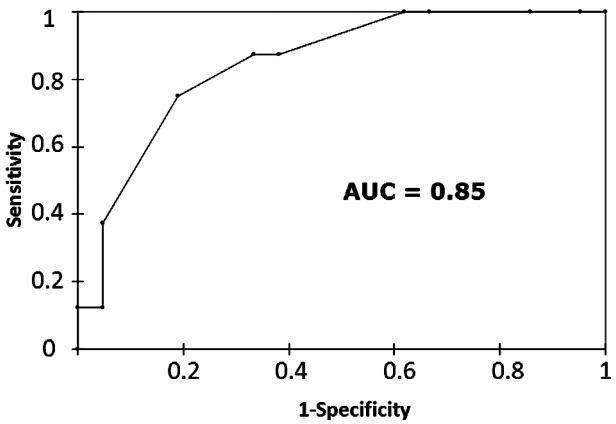

Fig. 1 ROC curve analysis showing the relation between the SHERPA score and 1-year survival.
AUC: area under the curve.

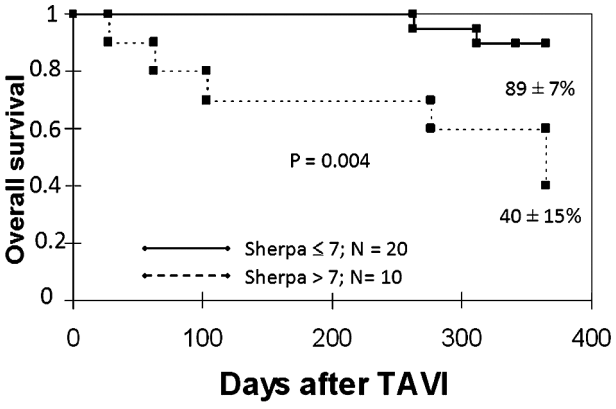

Fig. 2 Kaplan-Meier analysis shows the effect of the SHERPA score on 1-year survival. Patients with a SHERPA >7 had reduced survival.

of a geriatric team for comprehensive geriatric assessment, the SHERPA score is a quick and simple test that can be done by a non-geriatric expert. Moreover, these scores target dimensions of the geriatric standardized assessment predictive of functional decline and mortality. SHERPA-ADL refers to the ability of living independently at home and thus detects earlier manifestations of dependence. IADL are also associated with the probability of recovery after severe medical events such as pneumonia[20] and can be a strong and independent predictor of heart failure[21].

The ISAR score does not predict mortality. The SHERPA score included a cognitive evaluation (MMSE) more objectively than the single question used in the ISAR score "subjective memory complaints". Moreover, falls are also an important geriatric syndrome probably associated with further medical complications and are not evaluated in the ISAR score. SHERPA is a composite index which captures a broader range of functional abilities. It helps to better discriminate the risk across the spectrum of frailty.

Malnourishment is a poor prognostic factor. The obesity paradox has been observed in the general and cardio-surgical population[22], partly explained by the lack of protective peripheral body fat or modified inflammatory response. In our population, low BMI predicts 1-year mortality after TAVI; this is consistent with other published series showing that underweight patients display a worse outcome after surgery. Due to the fact that the weight of decompensated patients could be influenced by significant oedema, ideally, BMI should be evaluated after diuretics and optimal medical therapy in stable conditions.

The Logistic EuroSCORE does not predict mortality at one year in our population. This is not surprising because this score is designed and validated for the prediction of peri-operative mortality of open heart surgery, including a logarithmic exponential risk calculation if several factors are presents. It is not explicitly designed for the prediction of long-term prognosis in TAVI patients with a risk of major overestimation. In addition to this, it does not include frailty, an important parameter.

The SHERPA and ISAR scores do not predict procedural outcome, which is probably more dependent on technical aspects, anatomic features of the patient and on the experience of the centre[23] than on the frailty of the patient.

Study limitations

The main limitation of this study is the small number of participants. A larger cohort will more accurately identify which component of SHERPA is associated with various complications after TAVI, MACCE at 30 days and even admission to a nursing home. Our study did not include a functional evaluation after the procedure.

Indeed, as demonstrated by Schoenenberger et al.[24], functional limitations prior to TAVI are predictors of functional decline after TAVI. A post-procedure functional evaluation could have indicated which SHERPA items improved or regressed, allowing the development of preventive tools.

CONCLUSIONS

This study shows that the SHERPA score predicts mortality at one year after transfemoral TAVI. Our data suggest that the SHERPA score could become a screening tool for TAVI like EuroSCORE for open heart surgery. As a quick and easy score, the SHERPA could be considered as one of the key points on which to base clinical decision to perform TAVI, providing cardiologists with clues about the relevancy of therapeutic choices in a population of elderly patients. Larger studies are needed to optimize the SHERPA score for use in clinical routine.

CONFLICT OF INTEREST: none.

REFERENCES

1. Iung B, Baron G, Butchart E, Delahaye F, Gohlke-Barwolf C, Levang OW, Tornos P, Vanoverschelde JL, Vermeer F, Boersma E, Ravaud P, Vahanian A. A prospective survey of patients with valvular disease in Europe: The Euro Heart Survey on Valvular Heart Disease. *Eur Heart J* 2003; **24**: 1231-43.
2. Joint Task Force on the Management of Valvular Heart Disease of the European Society of Cardiology (ESC); European Association for Cardio-Thoracic Surgery (EACTS), Vahanian A, Alfieri O, Andreotti F, Antunes MJ, Barón-Esquivias G, Baumgartner H, Borger MA, Carrel TP, De Bonis M, Evangelista A, Falk V, Lung B, Lancellotti P, Pierard L, Price S, Schäfers HJ, Schuler G, Stepinska J, Swedberg K, Takkenberg J, Von Oppell UO, Windecker S, Zamorano JL, Zembala M. Guidelines on the management of valvular heart disease (version 2012). *Eur Heart J* 2012; **33**: 2451-96.
3. The European Association for Cardio-Thoracic Surgery. Fourth EACTS adult cardiac surgical database report 2010. Henley-on-Thames, UK Dendrite Clinical Systems; 244 pages.
4. Cribier A, Eltchaninoff H, Tron C, Bauer F, Agatiello C, Nercolini D, Tapiero S, Litzler PY, Bessou JP, Babaliaros V. Treatment of calcific aortic stenosis with the percutaneous heart valve. *J Am Coll Cardiol* 2006; **47**: 1214-23.
5. Leon MB, Smith CR, Mack M, Miller DC, Moses JW, Svensson LG, Tuzcu EM, Webb JG, Fontana GP, Makkar RR, Brown DL, Block PC, Guyton RA, Pichard AD, Bavaria JE, Herrmann HC, Douglas PS, Petersen JL, Akin JJ, Anderson WN, Wang D, Pocock S; PARTNER Trial Investigators. Transcatheter aortic-valve implantation for aortic stenosis in patients who cannot undergo surgery. *N Engl J Med* 2010; **363**: 1597-607.
6. Smith CR, Leon MB, Mack MJ, Miller DC, Moses JW, Svensson LG, Tuzcu EM, Webb JG, Fontana GP, Makkar RR, Williams M, Dewey T, Kapadia S, Babaliaros V, Thourani VH, Corso P, Pichard AD, Bavaria JE, Herrmann HC, Akin JJ, Anderson WN,Wang D, Pocock SJ; PARTNER Trial Investigators. Transcatheter versus surgical aortic-valve replacement in high-risk patients. *N Engl J Med* 2011; **364**: 2187-98.
7. Edwards F, Peterson E, Coombs L, DeLong ER, Jamieson WR, Shroyer ALW, Grover FL. Prediction of operative mortality after valve replacement surgery. *J Am Coll Cardiol* 2001; **37**: 885-92.
8. Nashef S, 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.
9. Watanabe Y, Hayashida K, Lefèvre T, Chevalier B, Hovasse T, Romano M, Garot P, Farge A, Donzeau-Gouge P, Bouvier E, Cormier B, Morice MC. Is EuroSCORE II better than EuroSCORE in predicting mortality after transcatheter aortic valve implantation? *Catheter Cardiovasc Interv* 2013; **81**: 1053-60.
10. Vahanian A, Alfieri O, Al-Attar N, Antunes M, Bax J, Cormier B, Cribier A, De Jaegere P, Fournial G, Kappetein A, Kovac J, Ludgate S, Maisano F, Moat N, Mohr F, Nataf P, Pierard L, Pomar J, Schofer J, Tornos P, Tuzcu M, van Hout B, Von Segesser L, Walther T. Transcatheter valve implantation for patients with aortic stenosis: a position statement from the European Association of Cardio-Thoracic Surgery (EACTS) and the European Society of Cardiology (ESC), in collaboration with the European Association of Percutaneous Cardiovascular Interventions (EAPCI). *Eur Heart J* 2008; **29**: 1463-70.
11. McCusker J, Bellavance F, Cardin S, Belzile E, Verdon J. Prediction of hospital utilization among elderly patients during the 6 months after an emergency department visit. *Ann Emerg Med* 2000; **36**: 438-445.
12. Cornette P, Swine, Malhomme B, Gillet JB, Meert P, D'Hoore W. Early evaluation of the risk of functional decline following hospitalization in older patients: development of a predictive tool. *Eur J Public Health* 2006; **16**: 203-8.
13. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chron Dis* 1987; **40**: 373-83.
14. Verhave JC, Fesler P, Ribstein J, du Cailar G, Mimran A. Estimation of renal function in subjects with normal serum creatinine levels: influence of age and body mass index. *Am J Kidney Dis* 2005; **46**: 233-41.
15. Folstein MF, Folstein SE. "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician. *J Psychiat Res* 1975; **12**: 189-98.
16. Wei LA, Fearing MA, Sternberg EJ, Inouye SK. The Confusion Assessment Method: a systematic review of current usage. *J Am Geriatr Soc* 2008; **56**: 823-30.
17. Kappetein AP, Head SJ, Généreux P, Piazza N, van Mieghem NM, Blackstone EH, Brott TG, Cohen DJ, Cutlip DE, van Es GA, Hahn RT, Kirtane AJ, Krucoff MW, Kodali S, Mack MJ, Mehran R, Rodés-Cabau J, Vranckx P, Webb JG, Windecker S, Serruys PW, Leon MB; Valve Academic Research Consortium-2. Updated standardized endpoint definitions for transcatheter aortic valve implantation: the Valve Academic Research Consortium-2 consensus document. *Eurointervention* 2012; **8**: 782-95.
18. Green P, Woglom AE, Genereux P, Daneault B, Paradis JM, Schnell S, Hawkey M, Maurer MS, Kirtane AJ, Kodali S, Moses JW, Leon MB, Smith CR, Williams M. The impact of frailty status on survival after transcatheter aortic valve replacement in older adults with severe aortic stenosis. *JACC Cardiovasc Interv* 2012; **5**: 974-81.
19. Stortecky S, Schoenenberger AW, Moser A, Kalesan B, Jüni P, Carrel T, Bischoff S, Schoenenberger CM, Stuck AE, Windecker S, Wenaweser P. Evaluation of multidimensional geriatric assessment as a predictor of mortality and cardiovascular events after transcatheter aortic valve implantation. *JACC Cardiovasc Interv* 2012; **5**: 489-96.
20. Torres OH, Munoz J, Ruiz D, Ris J, Gich I, Coma E, Gurgui M, Vazquez G. Outcomes predictors of pneumonia in elderly patients: importance of functional assessment. *J Am Geriatr Soc* 2004; **52**: 1603-9.

21. Bowling CB, Fonarow GC, Patel K, Zhang Y, Feller MA, Sui X, Blair SN, Alagiakrishnan K, Aban IB, Love TE, Allman RM, Ahmed A. Impairment of activities of daily living and incident heart failure in community-dwelling older adults. *Eur J Heart Fail* 2012; **14**: 581-7.
22. ValentijnT, Gala W, Tjeertes E, Hoeks S, Verhagen H, Stolker R. The obesity paradox in the surgical population. *Surgeon* 2013; **11**: 169-76.
23. Bosmans JM, Kefer J, De Bruyne B, Herijgers P, Dubois C, Legrand V, Verheye S, Rodrigus I; Belgian TAVI Registry Participants. Procedural, 30-day and one year outcome following CoreValve or Edwards transcatheter aortic valve implantation: results of the Belgian national registry. *Interact Cardiovasc Thorac Surg* 2011; **12**: 762-7.
24. Schoenenberger AW, Stortecky S, Neumann S, Moser A, Jüni P, Carrel T, Huber C, Gandon M, Bischoff S, Schoenenberger CM, Stuck AE, Windecker S, Wenaweser P. Predictors of functional decline in elderly patients undergoing transcatheter aortic valve implantation (TAVI). *Eur Heart J* 2013; **34**: 684-92.