JACC: CARDIOVASCULAR INTERVENTIONS
VOL. 5, NO. 5, 2012

ISSN 1936-8798/$36.00
PUBLISHED BY ELSEVIER INC.
DOI: 10.1016/j.jcin.2012.02.012

Evaluation of Multidimensional Geriatric Assessment as a Predictor of Mortality and Cardiovascular Events After Transcatheter Aortic Valve Implantation

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Objectives This study evaluated Multidimensional Geriatric Assessment (MGA) as predictor of mortality and major adverse cardiovascular and cerebral events (MACCE) after transcatheter aortic valve implantation (TAVI).

Background Currently used global risk scores do not reliably estimate mortality and MACCE in these patients.

Methods This prospective cohort comprised 100 consecutive patients ≥70 years undergoing TAVI. Global risk scores (Society of Thoracic Surgeons [STS] score, EuroSCORE) and MGA-based scores (cognition, nutrition, mobility, activities of daily living [ADL], and frailty index) were evaluated as predictors of all-cause mortality and MACCE 30 days and 1 year after TAVI in regression models.

Results In univariable analyses, all predictors were significantly associated with mortality and MACCE at 30 days and 1 year, except for the EuroSCORE at 30 days and instrumental ADL at 30 days and 1 year. Associations of cognitive impairment (odds ratio [OR]: 2.98, 95% confidence interval [CI]: 1.07 to 8.31), malnutrition (OR: 6.72, 95% CI: 2.04 to 22.17), mobility impairment (OR: 6.65, 95% CI: 2.15 to 20.52), limitations in basic ADL (OR: 3.63, 95% CI: 1.29 to 10.23), and frailty index (OR: 3.68, 95% CI: 1.21 to 11.19) with 1-year mortality were similar compared with STS score (OR: 5.47, 95% CI: 1.48 to 20.22) and EuroSCORE (OR: 4.02, 95% CI: 0.86 to 18.70). Similar results were found for 30-day mortality and MACCE. Bivariable analyses, including STS score or EuroSCORE suggested independent associations of MGA-based scores (e.g., OR of frailty index: 3.29, 95% CI: 1.06 to 10.15, for 1-year mortality in a model including EuroSCORE).

Conclusions This study provides evidence that risk prediction can be improved by adding MGA-based information to global risk scores. Larger studies are needed for the development and validation of improved risk prediction models. (J Am Coll Cardiol Intv 2012;5:489–96) © 2012 by the American College of Cardiology Foundation

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Manuscript received September 9, 2011; revised manuscript received January 27, 2012, accepted February 1, 2012.

JACC: CARDIOVASCULAR INTERVENTIONS, VOL. 5, NO. 5, 2012
MAY 2012:489–96

Until recently, 2 treatment options for patients with symptomatic severe aortic stenosis were available: surgical aortic valve replacement (SAVR) and medical treatment, the latter option with less favorable outcomes as compared with SAVR (1). However, SAVR is frequently not performed in patients with high operative risk, mainly elderly patients with comorbid conditions (2,3). Recently, transcatheter aortic valve implantation (TAVI) has been introduced as an alternative, less invasive treatment option and has been shown to reduce mortality compared with medical treatment in patients deemed inoperable (4). Therefore, TAVI offers a promising alternative to conservative treatment for severe aortic stenosis of elderly, inoperable patients.

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Abbreviations and Acronyms

BADL = Basic Activities of Daily Living
CI = confidence interval
IADL = Instrumental Activities of Daily Living
MACCE = major adverse cardiovascular and cerebral events
MGA = Multidimensional Geriatric Assessment
MMSE = Mini Mental State Examination
MNA = Mini Nutritional Assessment
OR = odds ratio
SAVR = surgical aortic valve replacement
STS = Society of Thoracic Surgeons
TAVI = transcatheter aortic valve implantation
TUG = Timed Get Up and Go test

Currently, the risk for cardiosurgical procedures is usually estimated using Society of Thoracic Surgeons (STS) score and/or logistic EuroSCORE (5). Recently, these global risk scores have been deemed suboptimal for the risk assessment of elderly patients with aortic stenosis (6–9). There are 3 main reasons: first, these scores were mainly derived in adults undergoing cardiovascular surgery; second, organ-specific (e.g., cardiac-related) risk predictors are probably under-represented in these scores; third, specific geriatric conditions that are not measured by these scores may have a major impact on prognosis in elderly patients. Multidimensional Geriatric Assessment (MGA) is a diagnostic process intended to determine an older person's medical and functional resources and problems (10). MGA consists of several components, some of which assess cognitive and functional capacity. Components of MGA have proven their usefulness for risk prediction in elderly patients with acute medical illness (11–14). Only a few studies have hitherto evaluated measures from MGA for the prediction of surgical outcomes and found a significant predictive ability (15–20). So far, there is no study having assessed MGA-based scores to estimate risk related to TAVI. The present study, therefore, evaluated MGA-based scores as predictors of mortality and major adverse cardiovascular and cerebral events (MACCE) in patients undergoing TAVI.

Methods

Study population. Consecutive patients ≥70 years with severe symptomatic aortic stenosis and referred for an in-hospital evaluation for TAVI to Bern University Hospital, Switzerland, between September 1, 2009 and December 31, 2010, were eligible for this study. Aortic stenosis was considered severe if the effective orifice area was <1 cm^2 and/or <0.6 cm^2/m^2 body surface area. An interdisciplinary team of interventional cardiologists and cardiac surgeons reviewed the individual cases and formed a consensus on treatment selection (TAVI, SAVR, or medical treatment). The consensus was based on several parameters, including anatomic characteristics of the aortic root, vascular access site specifications, perioperative risk as calculated with the logistic EuroSCORE and the STS score, underlying comorbidities (previous cardiac surgery, pulmonary insufficiency, liver cirrhosis, severe connective tissue disease, history of mediastinal radiotherapy, porcelain aorta), and general impression. Patients with a logistic EuroSCORE $<5\%$ were advised to undergo SAVR or medical treatment. The treatment was either selected during the in-hospital evaluation phase or in the following 1 to 2 weeks after evaluation. The following patients were excluded: 1) patients with a treatment other than TAVI (i.e., SAVR or medical treatment); 2) patients who lived abroad and were not able to participate in the follow-up; and 3) patients in whom TAVI was performed as an emergency procedure (Fig. 1). All other patients were asked for study participation. If they gave informed consent, MGA was performed. Of the patients who received MGA during the study period, the following were also excluded: 1) patients who still waited for TAVI after December 31, 2010; 2) patients who died before TAVI; 3) patients who crossed over to SAVR or medical treatment after initial allocation to TAVI; and 4) patients in whom the time between MGA and TAVI was >3 months. The final study population consisted of all patients in whom TAVI and MGA was performed during the study period. The cohort study complies with the Declaration of Helsinki, was approved by the local ethics committee, and all patients provided informed written consent.

Baseline examinations. All participating patients received an extensive cardiologic and geriatric baseline examination during the in-hospital evaluation. Patient history was recorded, including symptoms, cardiovascular risk factors, medication, prior cardiovascular events, and further comorbidities. Physical examination included the measurement of weight, height, and blood pressure. Left ventricular ejection fraction, aortic valve orifice area, and transvalvular mean gradient were measured with transthoracic or transesophageal echocardiography. All patients underwent cardiac catheterization providing information about the presence of coronary artery disease and hemodynamic evaluation of

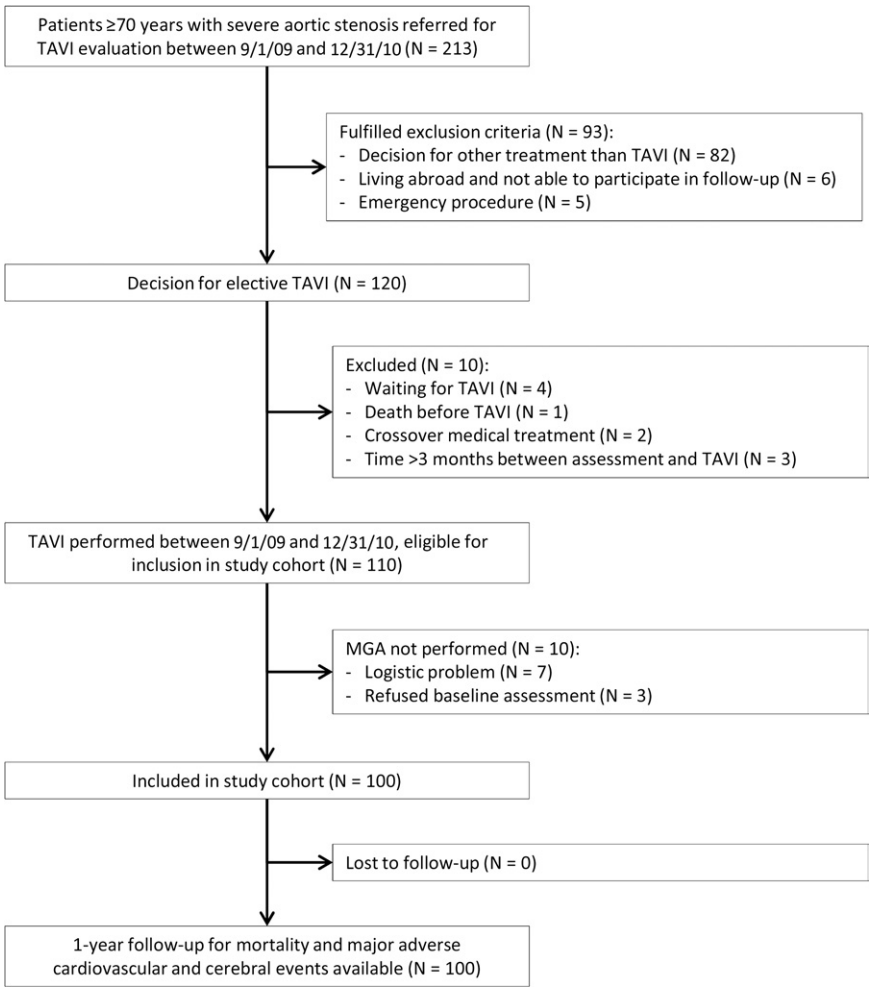

Figure 1. Flow Chart: Patient Flow During Study

The flow chart displays the patient flow during the study. The study population finally consisted of 100 patients who underwent transcatheter aortic valve implantation (TAVI). MGA = multidimensional geriatric assessment.

transvalvular gradient, cardiac output, aortic valve area, and right-sided filling pressures. Based on the gathered information, STS score and logistic EuroSCORE were calculated. For the purpose of this analysis, both scores were dichotomized at standard cut-points: STS score at ≥5% (higher risk) versus <5% (lower risk) and logistic EuroSCORE at ≥15% (higher risk) versus <15% (lower risk).

The baseline examination during the in-hospital evaluation included an MGA consisting of validated instruments. For this study, instruments assessing physiological functioning were selected; instruments for psychosocial functioning were not considered. The following instruments were used in this study: Mini Mental State Exam (MMSE) (21); Mini Nutritional Assessment (MNA) (22); Timed Get Up and Go test (TUG) (23); Basic Activities of Daily Living (BADL), and Instrumental Activities of Daily Living (IADL) (24); and questions about pre-clinical mobility disability (25). For the purpose of this analysis, the instruments were dichotomized at standard cut-points: MMSE at ≥27 points (cognitive impairment improbable) versus <27 points (cognitive impairment probable), MNA at ≥12 points (malnutrition improbable) versus <12 points (malnutrition probable), and TUG at ≥20 s (moderate or severe limitation of mobility) versus <20 s (no or only slight limitation of mobility). BADL and IADL were considered abnormal if there was at least 1 activity with a limitation. Pre-clinical mobility disability was considered present if in response to the questions about mobility, the patient reported that the frequency of walking 200 m and/or of climbing stairs had decreased during the preceding 6 months.

Based on theoretical considerations from existing literature, a frailty index was constructed by the geriatrician

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authors (A.W.S. and A.E.S.) before statistical analysis (17,25). The intention of constructing a frailty index was to have a quantitative measure of the patient's general condition. The frailty index was defined as a summary score calculated from instruments of the MGA: 2 points were assigned if MMSE was <21 points; 1 point was assigned for each of the following: MMSE ≥21 and <27 points, MNA <12 points, TUG ≥20 s, BADL with at least 1 limited activity, IADL with at least 1 limited activity, and a pre-clinical mobility disability. Thus, the frailty index had a range from 0 to 7 points. For the purpose of this analysis, the frailty index was dichotomized at ≥3 points (frailty probable) versus <3 points (frailty improbable).

TAVI procedure and follow-up. TAVI was performed after the cardiologic and geriatric baseline examination, usually within 2 weeks. The transcatheter aortic valve bioprosthesis was introduced transfemorally whenever feasible. The transapical approach was reserved for patients with severe peripheral vascular disease that precluded a transfemoral approach. The procedure was performed under local anesthesia and mild conscious sedation using the Medtronic CoreValve (Medtronic, Minneapolis, Minnesota) in 63 patients and the Edwards Sapien XT bioprosthesis (Edwards Lifesciences, Irvine, California) in 37 patients (26).

Patients were scheduled for a clinical follow-up 30 days and 1 year after TAVI. Endpoint adjudication was performed by a team of interventional cardiologists and cardiovascular surgeons. All-cause mortality as well as MACCE constituted the endpoints of this study (27,28).

Statistical methods. Baseline characteristics were described by counts, percentages, and mean ± SD. Univariable associations between the clinical endpoints and the dichotomized risk scores were assessed by sample odds ratios and 2-sided p values from a Fisher exact test or a chi-square test. Additionally, the same risk measures were evaluated as continuous linear variables in a logistic regression. For interpretational purposes, the measures were divided in subintervals. The MMSE was divided in subintervals of 3 points to obtain odds ratios for a change of 3 points, and it was analyzed reciprocally, as in contrast to all other scores in the logistic regression, a lower MMSE score indicates a more severe limitation. The TUG was divided in subintervals of 5 s, and values >30 s were set to 30 s. We used a logistic regression for assessing bivariable associations of the clinical endpoints at 1 year with the STS score or logistic EuroSCORE and selected MGA-based risk scores as independent variables. Bivariable analyses only included MGA-based risk scores that showed statistically significant ($p < 0.05$) associations in univariable analyses. Analyses were performed in Stata version 12.0 (Stata, College Station, Texas).

Results

Between September 1, 2009, and December 31, 2010, 213 patients at least 70 years of age with severe aortic stenosis were referred for evaluation for TAVI (Fig. 1). Of these, 93 fulfilled an exclusion criterion: 82 patients were excluded owing to treatment selection other than TAVI, 6 patients lived abroad and were not able to participate in the follow-up, and in 5 patients, TAVI was performed as an emergency procedure. An additional 10 patients were excluded because they were still waiting for TAVI after December 31, 2010, because they died before TAVI, because they crossed over to medical treatment, or because the time between baseline MGA and TAVI was >3 months. Only 10 patients were not included and did not receive MGA although they fulfilled the inclusion criteria (7 patients due to logistic problems, and 3 patients who refused MGA). The study population finally consisted of 100 patients who underwent TAVI. In 85 patients (85.0%), TAVI was introduced transfemorally, in 14 patients (14.0%) transapically, and in 1 patient (1.0%) via subclavian artery.

The baseline characteristics of the study population are shown in Table 1. Mean age was 83.7 ± 4.6 years (range:

Table 1. Baseline Characteristics (N = 100)

Age, yrs	83.7 ± 4.6
Female	60 (60.0%)
Body mass index, kg/m^2	25.6 ± 4.6
Cardiovascular risk factors	
Hypertension	87 (87.0%)
Hypercholesterolemia	67 (67.0%)
Current smoker	3 (3%)
Diabetes	26 (26.0%)
Family history of CAD	18 (18.0%)
Medical history	
CAD	66 (66.0%)
Previous myocardial infarction	13 (13.0%)
Previous stroke	4 (4.0%)
Chronic heart failure	30 (30.0%)
Symptoms	
Dyspnea NYHA functional class III or IV	50 (50.0%)
Angina CCS III or IV	19 (19.0%)
Previous syncope	11 (11.0%)
Medication	
ACEI/ARB	49 (49.0%)
Diuretic	65 (65.0%)
Beta-blocker	51 (51.0%)
Echocardiography	
LVEF, %	50.5 ± 14.1
Mean gradient aortic valve, mm Hg	43.0 ± 15.9
Aortic valve area, cm^2	0.6 ± 0.2

Values are mean ± SD and n (%).

ACEI = angiotensin-converting enzyme inhibitor; ARB = angiotensin receptor blocker; CAD = coronary artery disease; CCS = Canadian Cardiovascular Society; LVEF = left ventricular ejection fraction; NYHA = New York Heart Association.

72.5 to 93.2 years), and 60% of the patients were women. As a consequence of the age and sex distribution, the prevalence of hypertension and diabetes was rather high, whereas there were only a few current smokers (Table 1). The mean STS score was 6.3 ± 3.3% (range: 1.9% to 16.9%), and the mean logistic EuroSCORE 25.8 ± 14.9% (range: 8.0% to 75.9%).

Table 2 summarizes the results of the baseline MGA. MGA detected geriatric problems in a relevant proportion of the patients. In the MMSE, almost every third patient had findings compatible with cognitive impairment. The MNA found probable malnutrition in more than 2 of 5 patients. The TUG revealed a moderate or severe limitation of mobility in almost 2 of 5 patients. According to the frailty index, 49.0% of the patients were considered frail.

Of the 100 study participants, 19 died within 1-year follow-up, of whom 8 died during the first 30 days of follow-up. A MACCE (including the patients who experienced cardiac death) was observed in 22 patients within 1-year follow-up; the MACCE occurred during the first 30 days in 10 of these patients. STS score, logistic EuroSCORE, and MGA-based risk scores were evaluated in univariable regression models for their ability to predict all-cause mortality and the occurrence of MACCE 30 days and 1 year after TAVI (Table 3). The STS score showed a strong association with all-cause mortality and MACCE 30 days and 1 year after TAVI. The logistic EuroSCORE was not significantly associated with all-cause mortality or MACCE 30 days after TAVI. At 1 year, the logistic EuroSCORE showed evidence for an association with all-cause mortality or MACCE, but only if used as a linear measure. Of the MGA-based risk scores, MMSE, MNA, TUG, BADL, and pre-clinical mobility disability, as well as the frailty index, showed evidence of an association with all-cause mortality and MACCE 30 days and 1 year after TAVI (Table 3). IADL was not significantly associated with the outcomes at 30 days and 1 year.

Bivariable regression models were performed to examine the independent association of MGA-based risk scores with mortality and MACCE 1 year after TAVI, if combined with global risk scores in the same model (Table 4). Bivariable analyses only included MGA-based risk scores that showed statistically significant associations in univariable analyses. A strong evidence for an association of MMSE, MNA, TUG, BADL, and the frailty index with all-cause mortality and MACCE was found independent of global risk scores.

Discussion

This analysis of a prospective cohort study of elderly high-risk patients undergoing TAVI shows that MGA-based risk scores perform similar to global risk scores for the prediction of all-cause mortality and MACCE 30 days and 1 year after TAVI. Furthermore, associations of MGA-based risk scores with mortality and MACCE were independent of global risk scores. Of note, the significant associations of the MGA-based scores with all-cause mortality and MACCE were found in a small sample of 100 patients. This study, therefore, demonstrates that it is possible to develop better risk scores for elderly patients undergoing TAVI.

The development of new risk scores suitable for the assessment of old patients has been claimed for many years (9). So far, only a few studies have examined the predictive capacity of geriatric instruments to predict important outcomes such as mortality or relevant morbidity after surgery (15–20). One recent study showed that a frailty measure independently predicted post-operative complications, length of stay, and discharge to an assisted-living facility in older surgical patients (15). Two further studies found that components of the MGA may predict adverse outcomes following thoracic surgery (16,17). In accordance with these

Table 2. Baseline Results of Global and MGA-Based Risk Scores

Risk Score	Result	Interpretation	Proportion of Patients, n (%) (n = 100)
Global risk scores			
STS score	≥5%	At risk of higher mortality	56 (56.0%)
Logistic EuroSCORE	≥15%	At risk of higher mortality	72 (72.0%)
MGA-based risk scores			
MMSE	<27 points	Cognitive impairment probable	32 (32.0%)
MNA	<12 points	Malnutrition probable	44 (44.0%)
TUG	≥20 s	Moderate or severe limitation of mobility	38 (38.0%)
BADL	≥1 point	At least 1 basic activity with limitation	29 (29.0%)
IADL	≥1 point	At least 1 instrumental activity with limitation	58 (58.0%)
Pre-clinical mobility disability	Present	Pre-clinical mobility disability	60 (60.0%)
Frailty index	≥3 points	Frailty	49 (49.0%)

BADL = Basic Activities of Daily Living; IADL = Instrumental Activities of Daily Living; MGA = Multidimensional Geriatric Assessment; MMSE = Mini Mental State Examination; MNA = Mini Nutritional Assessment; STS = Society of Thoracic Surgeons; TUG = Timed Get Up and Go test.

Table 3. Univariable Associations of Global and MGA-Based Risk Scores for the Prediction of All-Cause Mortality and MACCE 30 Days and 1 Year After TAVI

	30 Days After TAVI				1 Year After TAVI			
	All-Cause Mortality		MACCE		All-Cause Mortality		MACCE	
	OR (95% CI)	p Value	OR (95% CI)	p Value	OR (95% CI)	p Value	OR (95% CI)	p Value
Global risk scores								
STS score								
Linear (OR per 5% increase)	3.16 (1.24–8.06)	0.02	2.34 (0.99–5.50)	0.05	3.63 (1.71–7.71)	0.001	2.66 (1.33–5.34)	0.01
Dichotomized (≥5% vs. <5%)	6.14 (0.73–51.95)	0.08	8.23 (1.00–67.71)	0.04	5.47 (1.48–20.22)	0.01	3.40 (1.14–10.13)	0.03
Logistic EuroSCORE								
Linear (OR per 10% increase)	1.32 (0.87–2.02)	0.20	1.27 (0.86–1.88)	0.23	1.79 (1.27–2.53)	0.001	1.57 (1.15–2.16)	0.01
Dichotomized (≥15% vs. <15%)	2.91 (0.34–24.78)	0.44	1.63 (0.32–8.17)	0.72	4.02 (0.86–18.70)	0.09	2.99 (0.81–11.04)	0.11
MGA-based risk scores								
MMSE								
Linear (OR per 3 points decrease)	2.85 (1.32–6.17)	0.01	3.67 (1.62–8.32)	0.002	2.72 (1.40–5.31)	0.003	3.04 (1.53–6.03)	0.001
Dichotomized (<27 vs. ≥27 points)	7.62 (1.44–40.19)	0.01	6.07 (1.45–25.33)	0.01	2.98 (1.07–8.31)	0.03	3.48 (1.30–9.28)	0.01
MNA								
Linear (OR per 1 point decrease)	1.30 (1.03–1.66)	0.03	1.31 (1.05–1.63)	0.02	1.27 (1.06–1.52)	0.01	1.30 (1.09–1.55)	0.004
Dichotomized (<12 vs. ≥12 points)	10.41 (1.23–88.12)	0.02	3.34 (0.81–13.77)	0.10	6.72 (2.04–22.17)	0.001	6.42 (2.14–19.31)	0.001
TUG								
Linear (OR per 5 s increase)	1.83 (1.10–3.05)	0.02	1.67 (1.08–2.60)	0.02	1.74 (1.24–2.45)	0.001	1.63 (1.19–2.24)	0.002
Dichotomized (≥20 vs. <20 s)	13.77 (1.62–117.01)	0.004	8.00 (1.60–40.03)	0.01	6.65 (2.15–20.52)	0.001	5.12 (1.85–14.22)	0.001
BADL								
Linear (OR per 1 point increase)	1.75 (1.01–3.02)	0.05	2.13 (1.27–3.56)	0.004	1.81 (1.16–2.84)	0.01	1.78 (1.15–2.77)	0.01
Dichotomized (≥1 point)	4.72 (1.05–21.27)	0.04	4.37 (1.13–16.87)	0.03	3.63 (1.29–10.23)	0.01	3.33 (1.24–8.95)	0.01
IADL								
Linear (OR per 1 point increase)	1.39 (0.91–2.11)	0.13	1.06 (0.70–1.62)	0.78	1.25 (0.92–1.70)	0.16	1.19 (0.88–1.59)	0.26
Dichotomized (≥1 point)	1.19 (0.27–5.31)	>0.999	0.53 (0.13–2.12)	0.48	1.52 (0.52–4.45)	0.44	1.55 (0.56–4.25)	0.40
Pre-clinical mobility disability								
dichotomized (present or not)	5.15 (0.61–43.59)	0.14	2.92 (0.59–14.55)	0.31	3.00 (0.92–9.83)	0.07	3.86 (1.20–12.44)	0.03
Frailty index								
Linear (OR per 1 point increase)	2.18 (1.32–3.61)	0.002	1.66 (1.14–2.44)	0.01	1.80 (1.31–2.47)	<0.001	1.80 (1.33–2.45)	<0.001
Dichotomized (≥3 vs. <3 points)	8.33 (0.99–70.48)	0.03	4.78 (0.96–23.77)	0.05	3.68 (1.21–11.19)	0.02	4.89 (1.64–14.60)	0.003

CI = confidence interval; MACCE = major adverse cardiovascular and cerebral event(s); OR = odds ratio; TAVI = transcatheter aortic valve implantation; other abbreviations as in Table 2.

studies, our study confirms the high predictive potential of MGA-based scores in patients who undergo TAVI.

The question arises why MGA-based scores have a high predictive potential in old patients. MGA consists of several well-validated screening instruments that are very sensitive to detect a functional deterioration (21–24). MGA, therefore, identifies those patients with diminished physiological reserves and reduced adaptive capacity in multiple organ systems. Therefore, the MGA has the potential to differentiate between those old patients recovering better than expected and those at risk of deteriorating after an intervention.

Study limitations. First, it has to be recognized that patients undergoing TAVI were a selection of elderly, high-risk patients with an increased logistic EuroSCORE. Old patients with a low logistic EuroSCORE were in general allocated to SAVR, whereas elderly patients with excessive risk were sometimes assigned to medical treatment. Therefore, the predictive value of MGA has to be reconfirmed in these patients with higher or lower risk, if in the future, TAVI will also be performed in these populations. Second, the findings of this study are based on data from a single center. Therefore, confirmation in an independent sample is of importance to improve generalizability of our findings. Third, the sample size was small with 100 patients. This number and the resulting number of endpoints were not sufficient to evaluate MGA-based risk scores in multivariable models involving more than 2 predictor variables. Hence, it was not possible to examine independent associations of MGA-based scores together with further scores that have been found to be predictive of outcomes after TAVI, such as cardiac-related risk predictors (e.g., aortic mean gradient or tricuspid/mitral valve regurgitation) (29). However, the number of 19 mortality and 22

Table 4. Selection of Bivariable Associations of Global and MGA-Based Risk Scores for the Prediction of All-Cause Mortality and MACCE 1 Year After TAVI

Model	Components of Model*	All-Cause Mortality		MACCE	
		OR (95% CI)	p Value	OR (95% CI)	p Value
Models with STS score					
Model 1	STS score	5.27 (1.40–19.81)	0.01	3.26 (1.06–9.97)	0.04
	MMSE	2.83 (0.97–8.23)	0.06	3.34 (1.22–9.15)	0.02
Model 2	STS score	4.01 (1.03–15.56)	0.05	2.43 (0.77–7.69)	0.13
	MNA	5.33 (1.57–18.11)	0.01	5.41 (1.76–16.64)	0.003
Model 3	STS score	4.46 (1.15–17.31)	0.03	2.75 (0.88–8.59)	0.08
	TUG	5.70 (1.79–18.14)	0.003	4.48 (1.58–12.69)	0.01
Model 4	STS score	4.40 (1.16–16.78)	0.03	2.73 (0.89–8.44)	0.08
	BADL	2.71 (0.92–7.99)	0.07	2.67 (0.96–7.42)	0.06
Model 5	STS score	4.55 (1.20–17.21)	0.03	2.68 (0.86–8.33)	0.09
	Frailty index	2.93 (0.93–9.24)	0.07	4.17 (1.37–12.72)	0.01
Models with logistic EuroSCORE					
Model 6	Logistic EuroSCORE	4.98 (1.02–24.23)	0.05	3.82 (0.97–15.00)	0.06
	MMSE	3.57 (1.22–10.42)	0.02	4.12 (1.48–11.51)	0.01
Model 7	Logistic EuroSCORE	3.68 (0.75–18.04)	0.11	2.71 (0.69–10.65)	0.15
	MNA	6.45 (1.93–21.56)	0.002	6.18 (2.03–18.78)	0.001
Model 8	Logistic EuroSCORE	3.18 (0.64–15.66)	0.16	2.39 (0.61–9.31)	0.21
	TUG	6.02 (1.92–18.82)	0.002	4.69 (1.67–13.17)	0.003
Model 9	Logistic EuroSCORE	3.42 (0.72–16.35)	0.12	2.56 (0.67–9.72)	0.17
	BADL	3.23 (1.13–9.29)	0.03	3.02 (1.11–8.23)	0.03
Model 10	Logistic EuroSCORE	3.40 (0.71–16.23)	0.13	2.44 (0.63–9.44)	0.20
	Frailty index	3.29 (1.06–10.15)	0.04	4.48 (1.48–13.53)	0.01

*The risk scores were used as dichotomized variables using the cut-points outlined in the *Methods* section.
Abbreviations as in Tables 2 and 3.

MACCE endpoints was sufficient to avoid overfitting in the performed bivariable models (30).

The present study has research implications. First, studies based on larger sample sizes are needed for the derivation and validation of risk scores combining elements of MGA-based scores and other scores that have been found to be predictive of outcomes after TAVI. In particular, this applies to the combination with cardiac-related risk predictors, such as aortic mean gradient or tricuspid/mitral valve regurgitation (29). It is likely that such risk scores may reach adequate predictive validity to justify their use in clinical practice. Second, larger studies are also needed to optimize MGA-based scores for the risk prediction after TAVI. The MGA-based scores and their cut-points used in this study were originally developed for diagnostic purposes, and the frailty index was developed based on a priori considerations. It is likely that MGA-based risk scores perform even better, if adapted for TAVI risk prediction.

This study in addition has clinical implications. MGA is still infrequently used in well-defined clinical situations, such as for operative risk assessment. In view of a growing population of old patients in industrialized nations, the implementation of MGA in such conditions and others is timely and indicated (31–33). In addition to the potential benefit of MGA to improve risk prediction, it also offers detecting modifiable risk factors amenable to targeted perioperative interventions (e.g., malnutrition). Therefore, MGA could also help improving the prognosis of patients undergoing TAVI. A recent study demonstrated that hospitalized patients, including surgical patients, benefit from programs combining geriatric assessment with geriatric management (34).

Conclusions

This study shows that MGA-based risk scores predict all-cause mortality and MACCE in elderly patients undergoing TAVI. This study also shows that risk prediction of other global risk scores may be improved using MGA-based scores. Larger studies are needed to optimize MGA-based scores for use in clinical routine.

Acknowledgments

The authors would like to thank Dr. Christoph Huber for his support when transcatheter aortic valve implantation (TAVI) was performed transapically. The authors also wish to express their gratitude to Franziska Amacker, Stephan Born, Marianne Gandon, Stefanie Kocher, Anita Mülhaupt, and Babette Wäfler for their support.

JACC: CARDIOVASCULAR INTERVENTIONS, VOL. 5, NO. 5, 2012
MAY 2012:489–96

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Key Words: aortic valve stenosis ■ geriatric assessment ■ mortality.