European Journal of Cardio-Thoracic Surgery 56 (2019) 1124–1130
doi:10.1093/ejcts/ezz240 Advance Access publication 9 September 2019

ORIGINAL ARTICLE

Cite this article as: Minol J-P, Dimitrova V, Petrov G, Langner R, Boeken U, Rellecke P *et al.* The age-adjusted Charlson comorbidity index in minimally invasive mitral valve surgery. Eur J Cardiothorac Surg 2019;56:1124–30.

The age-adjusted Charlson comorbidity index in minimally invasive mitral valve surgery

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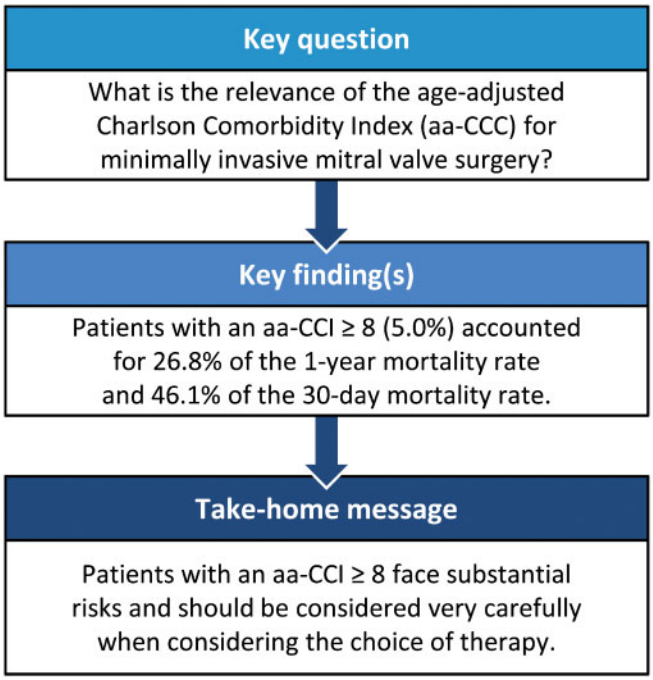
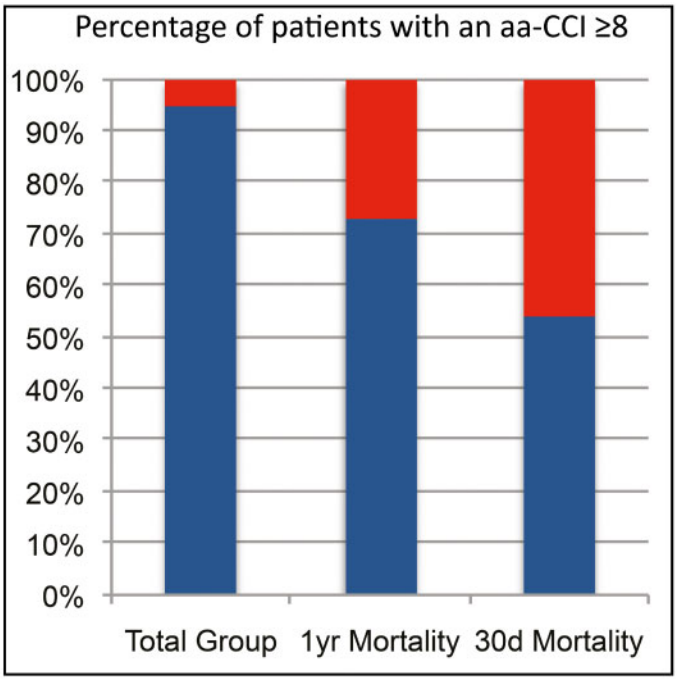
Received 6 February 2019; received in revised form 3 August 2019; accepted 6 August 2019





Abstract

OBJECTIVES: Mitral valve repair is the preferred method used to address mitral valve regurgitation, whereas transcatheter mitral valve repair is recommended for high-risk patients. We evaluated the risk-predictive value of the age-adjusted Charlson comorbidity index (aa-CCI) in the setting of minimally invasive mitral valve surgery.

METHODS: The perioperative course and 1-year follow-up of 537 patients who underwent isolated or combined minimally invasive mitral valve surgery were evaluated for 1-year mortality as the primary end point and other adverse events. The predictive values of the EuroSCORE II and STS score were compared to that of the aa-CCI by a comparative analysis of receiver operating characteristic curves. Restricted cubic splines were applied to find optimal aa-CCI cut-off values for the increased likelihood of experiencing the predefined

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adverse end points. Consequently, the perioperative course and postoperative outcome of the aa-CCI ≥8 patients and the remainder of the sample were analysed.

RESULTS: The predictive value of the aa-CCI does not significantly differ from those of the EuroSCORE II or STS score. Patients with an aa-CCI ≥8 were identified as a subgroup with a significant increase of mortality and other adverse events.

CONCLUSIONS: The aa-CCI displays a suitable predictive ability for patients undergoing minimally invasive mitral valve surgery. In particular, multimorbid or frail patients may benefit from the extension of the objectively assessed parameters, in addition to the STS score or EuroSCORE II. Patients with an aa-CCI ≥8 have a very high surgical risk and should receive very careful attention.

Keywords: Minimally invasive surgery • Mitral valve surgery • EuroSCORE • STS score • Charlson comorbidity index

INTRODUCTION

Surgical mitral valve repair (MVr) is the preferred approach for treating mitral valve regurgitation, ideally via a minimally invasive approach (minimally invasive mitral valve surgery, MIMVS). However, for patients with an elevated profile of perioperative risk, transcatheter mitral valve repair (TMVr) has been developed as an alternative to decrease periprocedural adverse events in high-risk patients [1]. One of the main drawbacks of TMVr that remains is the inferiority regarding the achieved reduction in mitral valve regurgitation [2]. Likewise, in the current guidelines, a 'surgery-first strategy' is recommended, and TMVr should be primarily considered in patients with inoperable disease or patients who are judged to be at high surgical risk by the heart team [3]. In daily practice, the European System for Cardiac Operative Risk Evaluation II (EuroSCORE II) and the Society of Thoracic Surgeons (STS) score are commonly applied to predict the perioperative risk in patients undergoing various cardiovascular procedures.

However, the prediction of perioperative risk can be quite challenging at times, as particular factors, such as frailty, may not be adequately represented by these 2 models, and minimally invasive surgery is gaining importance, especially in multimorbid patients.

The Charlson comorbidity index (CCI) [4] and its modified form, the age-adjusted CCI (aa-CCI) [5], are established tools used to assess the patient's comorbidity profile and are also represented by a freely accessible online calculator [6]. Originally established in the field of oncology, several studies have demonstrated the applicability of the CCI in the cardiovascular field [7, 8]. In a recent study, the suitability of aa-CCI to predict long-term mortality after TMVr [9] was evaluated. Considering the trade-off between the periprocedural risk of mortality and morbidity, on the one hand, and the functional efficacy, on the other, there is a clinical demand for more advanced tools for the improved prediction of perioperative adverse events associated with MIMVS. Here, we analysed data collected in a sample of 537 consecutive patients who underwent isolated or combined MIMVS to evaluate the predictive value of aa-CCI regarding mortality at 1 year and 30 days as well as key postoperative adverse events. Moreover, we compared the performance of aa-CCI with the predictive power of the EuroSCORE II and the current STS score.

MATERIALS AND METHODS

Five hundred and thirty-seven consecutive patients undergoing MIMVS as an isolated procedure ($n = 414$; 77.1%) or in combination with tricuspid valve surgery ($n = 123$; 22.9%) between 2009 and 2016 at a single institution were included in this study. Data on the clinical course were prospectively entered in an institutional data system as well as 1-year follow-up data that were systematically obtained via telephone interview and additional on-site echocardiography were retrospectively analysed. The data included preoperative characteristics, information on the perioperative clinical course and postoperative outcomes. All patients received a minimally invasive surgical approach via right anterolateral minithoracotomy as described in detail before [10]. At the 1-year follow-up, rehabilitation status and current activity level were assessed, and patients were invited for an on-site echocardiographic examination. Echocardiographic follow-up was performed by the attending cardiologist in selected cases for whom a visit to our centre was not possible. Analysing the postoperative outcome, we considered the 1-year mortality (a) as the primary end point. Secondary end points following adverse events in the early postoperative course were defined as follows: 30-day mortality (b); need for ventilation longer than 12 h (c); need for reintubation (d); new-onset haemodialysis (e); stay in the intensive care unit (ICU) for longer than 5 days (f); need for an intra-aortic balloon pump due to any reason (g); any stroke that was detected by a CT scan and was clinically apparent (h); need for cardiopulmonary resuscitation for any reason (i); and need for an extracorporeal life support system (ECLS) for any reason (j). Moreover, we calculated the EuroSCORE II, STS score and aa-CCI for each patient as previously described [4–6]. Regarding the STS score, a differentiated investigation of the end points was required, with separate models for mortality and postoperative complications [11]. The STS score model 'risk of mortality' was attributed to the end points (a) and (b). The STS score model 'risk of prolonged ventilation' was attributed to (c) and (d). The STS score model 'risk of renal failure' was attributed to (e). The STS score model 'risk of long length of stay' was attributed to (f). The STS score model 'risk of renal failure' was attributed to (e). The STS score model 'risk of morbidity or mortality' was attributed to (g), (i) and (j). The STS score model 'risk of permanent stroke' was attributed to the end point (h).

Furthermore, the predictive values of the EuroSCORE II and STS score were compared to that of the aa-CCI as a reference. Thereafter, the associations between the clinical outcome parameters and the aa-CCI scores were analysed.

Based on our results and recommendations by others [9], we performed a special analysis of the group of patients with high aa-CCI scores (score ≥8) compared to the remainder (score ≤7).

Consequently, the display of the patients' characteristics, the perioperative course and postoperative outcome (Tables 1–3) was complemented by a comparative description of these subgroups.

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Table 1: Differentiated preoperative patient characteristics

N	Total 537	aa-CCI ≤7 510	aa-CCI ≥8 27	aa-CCI ≤7 vs ≥8 P-value
aa-CCI, median (IQR), mean ± SD	4 (2–5)	3 (2–5)	9.4 ± 0.9	<0.0001[a]
EuroSCORE II (%), median (IQR)	1.7 (0.9–3.3)	1.6 (0.9–3.0)	7.8 (3.0–12.6)	<0.0001[a]
STS score, median (IQR)	0.7 (0.4–1.7)	0.6 (0.3–1.4)	2.8 (1.9–7.1)	<0.0001[a]
NYHA, median (IQR), mean ± SD	2 (2–3)	2 (2–3)	2.9 ± 0.7	<0.001[a]
Age (years), median (IQR), mean ± SD	67.2 (55.2–74.4)	66.5 (54.4–74.1)	75.3 ± 5.7	<0.0001a
Female gender, *n* (%)	265 (49.3)	251 (49.2)	14 (51.9)	0.845[b]
BMI ≥30 (kg/m^2), *n* (%)	77 (14.3)	65 (12.8)	12 (44.4)	<0.001[b]
Atrial fibrillation, *n* (%)	206 (38.4)	190 (37.3)	16 (59.3)	0.026[b]
Hypertension, *n* (%)	365 (68.0)	341 (66.9)	24 (88.9)	0.018[b]
COPD, *n* (%)	60 (11.2)	50 (9.8)	10 (37.0)	<0.001[b]
Pulmonary hypertension, *n* (%)	221 (41.2)	204 (40.0)	17 (63.0)	0.026[b]
IDDM, *n* (%)	20 (3.7)	7 (1.4)	13 (48.2)	<0.001[b]
RF > II, *n* (%)	59 (11.0)	31 (6.1)	18 (66.7)	<0.001[b]
LVEF (%), median (IQR)	60 (56–65)	60 (57–65)	60 (55–62)	0.032[a]
Previous neurological event, *n* (%)	33 (6.2)	26 (5.1)	7 (25.9)	<0.001[b]
Previous cardiac surgery, *n* (%)	25 (4.7)	22 (4.3)	3 (11.1)	0.124[b]

[a]Mann–Whitney test.

[b]Fisher's exact test.

aa-CCI: age-adjusted Charlson comorbidity index; BMI: body mass index; COPD: chronic obstructive pulmonary disease; EuroSCORE II: European System for Cardiac Outcome Risk Evaluation; IDDM: insulin-dependent diabetes mellitus; IQR: interquartile range; LVEF: left ventricular ejection fraction; NYHA: New York Heart Association index; RF: renal failure, grading according to Levin *et al.* [18]; SD: standard deviation.

Table 2: Mitral valve pathology and surgical procedures

N	Total 537	aa-CCI ≤7 510	aa-CCI ≥8 27	aa-CCI ≤7 vs ≥8 P-value
Mitral valve pathology, *n* (%)				
MR > I°	517 (96.3)	493 (96.7)	24 (88.9)	0.073[a]
MS > I°	31 (5.8)	25 (4.9)	6 (22.3)	0.003[a]
Endocarditis	42 (7.8)	39 (7.7)	3 (11.1)	0.460[a]
AML prolapse	115 (21.4)	114 (22.4)	1 (3.7)	0.016[a]
PML prolapse	289 (53.8)	284 (55.7)	5 (18.5)	<0.001[a]
Ruptured chordae AML	27 (5.0)	26 (5.1)	1 (3.7)	1.000[a]
Ruptured chordae PML	170 (31.7)	169 (33.1)	1 (3.7)	<0.001[a]
Dilated MV annulus	230 (42.8)	225 (44.1)	5 (18.5)	0.009[a]
Calcified MV	127 (23.6)	119 (23.3)	8 (29.6)	0.487[a]
Previous MV replacement	2 (0.4)	1 (0.2)	1 (3.7)	0.098[a]
Previous MV reconstruction	8 (1.5)	7 (1.4)	1 (3.7)	0.340[a]
Previous MV clipping	7 (1.4)	4 (0.8)	3 (11.1)	0.004[a]
Surgical procedure, *n* (%)				
Isolated MV surgery	414 (77.1)	395 (77.5)	19 (70.4)	0.480[a]
MV+TV surgery	123 (22.9)	115 (22.6)	8 (29.6)	0.035[a]
MV replacement	124 (23.1)	107 (21.0)	17 (63.0)	<0.001[a]
MV reconstruction	413 (76.9)	403 (79.0)	10 (37.0)	<0.001[a]
Annuloplasty ring/band	411 (76.5)	401 (78.6)	10 (37.0)	<0.001[a]
Partial resection AML	12 (2.2)	12 (2.4)	0	1.000[a]
Partial resection PML	132 (24.6)	129 (25.3)	3 (11.1)	0.110[a]
Chordae surg.	233 (43.4)	230 (45.1)	3 (11.1)	<0.001[a]
ASD closure	43 (8.0)	41 (6.0)	2 (7.4)	1.000[a]
LAA closure	154 (28.7)	150 (29.4)	4 (14.8)	0.127[a]
Ablation	63 (11.7)	62 (12.2)	1 (3.7)	0.350[a]

[a]Fisher's exact test.

aa-CCI: age-adjusted Charlson comorbidity index; AML: anterior mitral leaflet; ASD: atrial septal defect; Chordae surg.: reimplantation, transfer or replacement of chordae; LAA: left atrial appendage; MR: mitral valve regurgitation, grading according to Lancellotti *et al.* [19]; MS: mitral valve stenosis, grading according to Baumgartner *et al.* [20]; MV: mitral valve; PML: posterior mitral leaflet; TV: tricuspid valve.

This study was approved by the local ethics committee (Approval No. 3650). The authors had full access to the data and take full responsibility for the integrity of the manuscript. All authors have read and agreed to the manuscript as written.

Statistics

The statistical analysis was performed using InStat3 and Prism7 (Graph Pad Software, La Jolla, CA, USA) as well as STATA

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Table 3: Differentiated postoperative course

N		Total 537	aa-CCI ≤7 510	aa-CCI ≥8 27	aa-CCI ≤7 vs ≥8 *P*-value
(a)	1-Year mortality, *n* (%)	41 (8.2)	30 (6.4)	11 (45.1)	<0.0001[a]
(b)	30-Day mortality, *n* (%)	13 (2.5)	7 (1.4)	6 (22.2)	<0.0001[a]
(c)	Ventilation >12 h, *n* (%)	119 (22.2)	112 (22.0)	7 (25.9)	0.636[b]
(d)	Reintubation, *n* (%)	32 (6.0)	28 (5.5)	4 (14.8)	0.069[b]
(e)	NO HD, *n* (%)	25 (4.7)	15 (2.9)	10 (37.0)	<0.001[b]
(f)	ICU>5 days, *n* (%)	54 (10.1)	45 (8.8)	9 (33.3)	<0.001[b]
(g)	IABP, *n* (%)	18 (3.4)	17 (3.3)	1 (3.7)	0.611[b]
(h)	Stroke, *n* (%)	6 (1.1)	5 (1.0)	1 (3.7)	0.267[b]
(i)	CPR, *n* (%)	5 (0.9)	4 (0.8)	1 (3.7)	0.228[b]
(j)	ECLS, *n* (%)	6 (1.1)	4 (0.8)	2 (7.4)	0.032[b]

[a]Log-rank test.
[b]Fisher's exact test.
aa-CCI: age-adjusted Charlson comorbidity index; CPR: cardiopulmonary resuscitation; ECLS: extracorporeal life support system; IABP: intra-aortic balloon pump; ICU: intensive care unit; NO HD: new-onset haemodialysis.

software, version 10.1 (StataCorp, College Station, TX, USA). Throughout the article, categorical variables are expressed as proportions. Continuous variables are given as the mean ± standard deviation after having passed the D'Agostino–Parson normality test. Non-normally distributed, continuous variables are expressed as the median (25th–75th percentile).

For the above-mentioned events (a–j), receiver operating characteristic (ROC) curves were established regarding aa-CCI values and are paralleled regarding the EuroSCORE II and STS score, as described elsewhere [12–15]. For each ROC curve, the area under the curve and its corresponding asymptotic confidence interval (CI) and *P*-value were computed. Multiple ROC curves were compared as recommended by Hanley and McNeil [16], considering the aa-CCI as a reference.

To assess log-linear associations between aa-CCI scores and clinical outcome parameters, we generated piecewise restricted cubic splines with knots corresponding to the 5th, 35th, 65th and 95th percentiles of the aa-CCI distribution [17].

For detailed comparisons of the subgroups, we additionally used the Mann–Whitney test and Fisher's Exact test according to the requirements. The follow-up results were subjected to a Kaplan–Meier analysis, supported by the log-rank test.

The correlations between the aa-CCI and the other risk scores are expressed by Pearson's correlation coefficient for normally distributed variables and by Spearman's correlation coefficient for non-normally distributed variables. Differences were considered significant at *P*-value <0.05.

RESULTS

The preoperative patient characteristics, perioperative course and postoperative outcome of the total group are described in Tables 1–3.

The results of the comparative ROC curve analysis of the EuroSCORE II, STS score and aa-CCI are described in Table 4. Regarding the end points of the events (a)–(g), the respective ROC curves differed significantly from the null hypothesis for the EuroSCORE II, STS score and aa-CCI, suggesting that these 3 scoring systems are suitable predictive instruments. Regarding the secondary end points of stroke (h), postoperative cardiopulmonary resuscitation (i) and postoperative ECLS (j), none of the ROC curves differed significantly from the null hypothesis for the EuroSCORE II, STS score or aa-CCI. The comparative analysis of the paired ROC curves revealed no significant difference between the EuroSCORE II and aa-CCI or between the STS score and aa-CCI for any event.

The spline curves displayed distinctively increased odds ratios for patients with high aa-CCI (≥8) regarding 1-year and 30-day mortality and adverse events such as new-onset haemodialysis; ICU <5 days and ECLS application (Fig. 1 and Supplementary Material, Fig. S1).

In the total group, we found significant correlations between the EuroSCORE II and aa-CCI ($r = 0.52$, 95% CI 0.46–0.58; $P < 0.0001$), as well as between the STS score and aa-CCI ($r = 0.58$, 95% CI 0.53–0.64; $P < 0.0001$). In contrast, no significant correlation between the high aa-CCI variables (≥8) and the corresponding EuroSCORE II ($r = 0.19$, 95% CI -0.20 to 0.53; $P = 0.340$) or between the high aa-CCI variables (≥8) and the corresponding STS score ($r = 0.37$, 95% CI -0.67 to 0.02; $P = 0.057$) was observed.

The preoperative clinical characteristics of the special subgroup of patients with high aa-CCI scores (≥8) were compared to the remainder (Table 1). Among other aspects, the most striking differences among those with high aa-CCI scores were a significantly increased age and significantly higher rates of a 'body mass index ≥30 kg/m^2', 'chronic obstructive pulmonary disease', 'insulin-dependent diabetes mellitus', 'renal failure > II°' and 'previous neurological events'. This profile is represented by a significant increase in all 3 analysed risk scores and the New York Heart Association index.

The aa-CCI ≤7-patients suffered significantly higher rates of 'ruptured chordae of the posterior mitral leaflet' and 'prolapse of the anterior and/or posterior mitral leaflet', whereas the mitral valve pathology of the aa-CCI ≥8-patients was distinguished from the others by significantly increased rates of 'mitral valve stenosis (MS >I°)' and 'previous MV clipping' (Table 2). Accordingly, the aa-CCI ≥8 patients received significantly fewer MV reconstructions and associated procedures such as 'annuloplasty ring/band implantation' or 'chordae surgery', but significantly more MV replacements or combined surgery targeting the tricuspid valve.

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Table 4: Postoperative course and detailed display of the comparative ROC curve analysis

Events		Rate, *n* (%)	EuroSCORE II			STS score			Age-adjusted Charlson comorbidity index (aa-CCI)			EuroSCORE II vs aa-CCI	STS vs aa-CCI
			AUC	*P*-value[a]	95% CI	AUC	*P*-value[a]	95% CI	AUC	*P*-value[a]	95% CI	*P*-value[b]	*P*-value[b]
(a)	1-Year mortality	41 (8.2)	0.78	<0.0001	0.67–0.85	0.78	<0.0001	0.73–0.86	0.77	<0.0001	0.69–0.84	0.636	0.347
(b)	30-Day mortality	13 (2.5)	0.87	<0.0001	0.78–0.96	0.86	<0.0001	0.78–0.95	0.84	<0.0001	0.75–0.93	0.332	0.595
(c)	Ventilation >12 h	119 (22.2)	0.65	<0.0001	0.58–0.71	0.65	<0.0001	0.60–0.70	0.61	<0.001	0.56–0.66	0.084	0.069
(d)	Reintubation	32 (6.0)	0.63	0.013	0.53–0.74	0.64	0.006	0.54–0.75	0.65	0.004	0.56–0.75	0.612	0.854
(e)	NO HD	25 (4.7)	0.85	<0.0001	0.79–0.91	0.84	<0.0001	0.75–0.92	0.84	<0.0001	0.76–0.92	0.764	0.903
(f)	ICU> 5 days	54 (10.1)	0.73	<0.0001	0.66–0.81	0.75	<0.0001	0.68–0.82	0.73	<0.0001	0.66–0.81	0.978	0.580
(g)	IABP	18 (3.4)	0.81	<0.0001	0.74–0.87	0.75	<0.001	0.67–0.83	0.72	0.002	0.62–0.81	0.075	0.464
(h)	Stroke	6 (1.1)	0.67	0.149	0.51–0.84	0.69	0.107	0.55–0.83	0.72	0.059	0.61–0.84	0.457	0.519
(i)	CPR	5 (0.9)	0.57	0.607	0.34–0.80	0.53	0.810	0.29–0.78	0.57	0.601	0.30–0.83	0.989	0.691
(j)	ECLS	6 (1.1)	0.50	0.982	0.28–0.73	0.52	0.841	0.24–0.80	0.54	0.721	0.24–0.84	0.679	0.825

[a]Regarding the difference to the null hypothesis.
[b]Regarding the difference between the paired ROC curves.
aa-CCI: age-adjusted Charlson comorbidity index; AUC: area under the curve; CPR: cardiopulmonary resuscitation; ECLS: extracorporeal life support system; EuroSCORE II: European System for Cardiac Operative Risk Evaluation II; IABP: intra-aortic balloon pump; ICU: intensive care unit; NO HD: new-onset haemodialysis; ROC: receiver operating characteristic; STS: Society of Thoracic Surgeons.

The comparative survival curves displayed a significant difference for the subgroups of patients according to their aa-CCI scores (Fig. 2). Moreover, the aa-CCI ≥8 patients displayed significantly higher rates of new-onset haemodialysis, prolonged ICU stays and the need for ECLS (Table 3).

Reflecting the impact on the outcome in the total group, the small group of patients with aa-CCI ≥8 (5.0%; 27/537) accounted for 46.1% (6/13) of those who died within 30 days and 26.8% (11/41) of those who died within 1 year. Additionally, these patients accounted for 40.0% (10/25) of those with new-onset haemodialysis and 33.3% (2/6) of those who needed ECLS.

DISCUSSION

This study evaluates the performance of the aa-CCI as a preoperative tool to predict mortality and morbidity outcomes in patients undergoing MIMVS. After analysing 537 consecutive patients, our data demonstrate a good overall performance of the aa-CCI in terms of the prediction of postoperative mortality as well as certain postoperative adverse events. We also confirmed that the current mortality finding is in line with previous analyses, focusing on the predictive value of the CCI or aa-CCI in the field of cardiac surgery and interventional cardiology [7–9].

In this study, we demonstrated the current STS score of 2.9 as a valid predictor of mortality and morbidity despite a very heterogeneous sample of MIMVS. This is in line with the findings of previous studies, which demonstrated that the former STS score is a satisfactory predictor of mortality and morbidity in isolated MV surgery [21].

The EuroSCORE was established in 1999 [22] and has since been subject to continuous discussion regarding its suitability and subsequent improvement, resulting in the logistic EuroSCORE [23] and the more advanced current version, the EuroSCORE II [24]. A recent meta-analysis of 22 studies including 145 592 cardiac surgery procedures displayed a good overall performance of the EuroSCORE II in predicting postoperative mortality [25]. This is in accordance with the results of our present study, which show that the EuroSCORE II is a suitable predictor of postoperative morbidity and mortality in a mixed MIMVS sample. Nevertheless, the above-mentioned meta-analysis regarding the EuroSCORE II revealed a distinctive underestimation of predictions in high-risk patients [25].

This issue is a problem in 2 aspects. On the one hand, the proportion of older patients suffering from multiple chronic comorbid conditions implies that the perioperative risk is increasing. On the other hand, in the current era of joint decision-making among the heart team, the clinical recommendation of the pro-surgical MVr approach demands a sustainable basis. A recent study revealed that in 57% of the patients with TMVr, the indication was primarily driven by the factor of 'frailty', although as a parameter, it is neither displayed by the standard cardiac risk scoring systems nor is there a standard definition for frailty in the particular population of patients with mitral valve regurgitation [26]. Saji *et al.* [9] discussed the coincidence of the subjective factor 'frailty' and the related comorbidities, which are more likely to cause poor outcomes [9, 27].

The aa-CCI has the potential to assess a variety of comorbidities that are not displayed by the EuroSCORE II or the STS score, thereby enabling the evaluation of the patient from a non-cardiac perspective [9]. Compared to the EuroSCORE II, the aa-CCI enlarges the preoperative risk assessment regarding the

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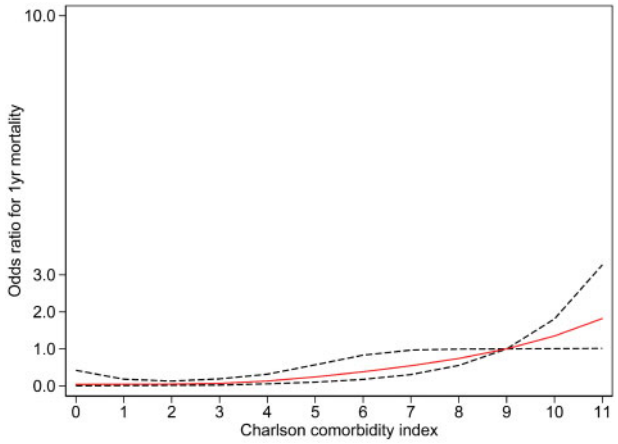

Figure 1: The spline curve analysis displayed an odds ratio that increased distinctively in the area of high aa-Charlson comorbidity index scores (≥8) regarding the adverse events of 1-year and 30-day mortality; new-onset haemodialysis; intensive care unit <5 days and extracorporeal life support system application.

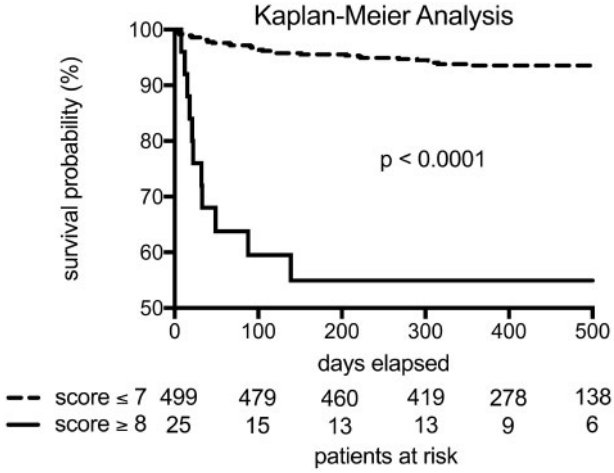

Figure 2: Comparing the survival curves for the subgroups of patients with low (≤7) and high (≥8) aa-Charlson comorbidity index scores, a significant difference was noted ($P < 0.0001$).

following 8 parameters: tumour, leukaemia, lymphoma, AIDS, connective tissue disease, peptic ulcer disease, liver disease and dementia. With respect to the STS score, the aa-CCI provides additional benefits regarding the following 6 parameters: 'lymphoma', 'leukaemia', 'hemiplegia', 'connective tissue disease', 'peptic ulcer disease' and 'dementia'.

To analyse this potential of the aa-CCI, we had to face the challenges of a small number of patients, on the one hand, and an inherent heterogeneity, on the other hand. Regarding these aspects, we employed the method of ROC curves, supported by the generation of piecewise restricted cubic splines. Both methods can analyse the total group without the need to establish subgroups. The establishment of categorized subgroups according to a ranking order of a certain parameter is very common in descriptive studies. Nevertheless, this approach is repeatedly blamed as methodological drawback causing biases and should be avoided, especially in small sample sizes [28].

The results of our non-categorizing approach suggested a special consideration of patients with an aa-CCI ≥8. Coincidentally, Saji *et al.* performed a categorization according to subgroups of the aa-CCI score and thereby identified the patients with an aa-CCI ≥8 as high-risk group [9]. Therefore, we provided a detailed analysis of the preoperative characteristics, perioperative course and postoperative outcome according to the subgroups (aa-CCI ≤7; ≥8).

The current study demonstrates the overall suitability of the aa-CCI for risk prediction in MIMVS patients. More interestingly, the presented results displayed a distinctively increased risk for patients with an aa-CCI score ≥8.

Accordingly, the presented results suggest that excluding the 5.0% (27/537) of the patients who displayed an aa-CCI score ≥8 would have reduced the 1-year mortality by 26.8% (11/41) and the 30-day mortality by 46.1% (6/13) and would have removed 40.0% (10/25) of the cases of new-onset haemodialysis and 33.3% (2/6) of the postoperative ECLS applications. Based on these considerations, it might be a reasonable clinical approach to apply the aa-CCI in addition to the EuroSCORE II or STS score when discussing patient eligibility for MIMVS. At the very least, multimorbid patients whose risk profiles might not be matched by the parameters of the EuroSCORE II and STS score as described above would benefit from this approach. Moreover, more objective decision-making might be facilitated for patients whose preoperative constitution is described as 'frail' when including the aa-CCI to enlarge the number of assessed factors that are covered by the validated scoring systems.

According to the current guidelines, patients with a high-risk for complications during surgical MVr should be considered for TMVr [3]. However, whether TMVr may be a better option for these high-risk patients remains to be determined by further studies, as Saji *et al.* [9] have already demonstrated that these particular patients experience a lower survival rate after TMVr than they do after medical therapy and therefore do not benefit from it. This emphasizes that every risk score is only an estimate that comes with its own limitations. The final decision in favour of surgery, intervention or conservative medical treatment has to be made individually, respecting the patient's choices.

Limitations

Our study is limited by being a retrospective, single-centre investigation with a small number of patients.

CONCLUSION

The aa-CCI score may represent a valuable system for predicting perioperative and 1-year outcomes after MIMVS, especially in multimorbid patients. Patients with aa-CCI scores ≥8 face substantial risks and should be considered very carefully when discussing the choice of therapy.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *EJCTS* online.

Conflict of interest: none declared.

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