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Original Article

Assessment of the Functional Status, Frailty and Cognition in Elderly Patients Undergoing Cardiac Surgery

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SUMMARY

Background: With the population aging in the developed countries, there is an increase in the absolute number of people with manifested cardiovascular disease. A subset of these patients requires a surgical procedure on their heart valves and/or coronary arteries. Here we aimed to evaluate the usefulness of frailty assessment and geriatric scales in patients 75 years and older undergoing cardiac surgery.
Methods: Sixty-eight patients from our department were referred to cardiac surgery for coronary artery bypass grafting and/or heart valve surgery. Prior to referral, they were assessed by means of activities of daily living (ADL), Mini-mental State Examination (MMSE) and Edmonton Frail Scale (EFS), as well as by Euroscore II and Society of Thoracic Surgeons (STS) scores. The incidence of perioperative complications and the length of hospital stay were recorded.
Results: In the operated patients (n = 57), we identified the following parameters as contributing to the occurence of complications: arterial hypertension (perioperative arrhythmias), age and non sinus heart rhythm (neurological complications), STS score, MMSE, chronic kidney disease, time to surgery and smoking (renal complications), EFS (other complications), Euroscore II, EFS, diabetes mellitus (major complications), EFS (overall complications). Moreover, patients with a best score in ADL had a chance to have surgery without complications.
Conclusion: In our study, we found that the EFS was able to predict the incidence of other, major and overall postoperative complications. In addition, patients with a maximum ADL result had a chance to undergo surgery without any complications.

1. Introduction

With the population aging in the developed countries, there is an increase in the absolute number of people with manifested cardiovascular disease. A subset of these patients requires a surgical procedure on their heart valves and/or coronary arteries.[1–3] In aortic stenosis, frailty seems to be a contributing factor to the early manifestations of heart failure.[4] Surgical procedure can significantly improve the patient's prognosis,[5] as documented in late 1960's in patients undergoing coronary-artery bypass grafting[6] and in early 1980's in patients operated for aortic stenosis.[7] Surgical treatment also improves patient's quality of life.[8,9]

However, with increasing age, there is also a rise in multimorbidity.[10] Especially with patients who have a frailty phenotype, they have a high risk of complications related to surgery.[11] In addition, patients 70 years and older are at risk of impairment in their activities of daily living after surgery under general anesthesia.[12] The risk of cardiac surgery must be considered together with the potential benefit for the patient.

In cardiac surgery, there are well-established risk scores. Among these, the Euroscore II and the Society of Thoracic Surgeons (STS) score are among the most widely used. The Euroscore II is based on 18 variables including a yes/no question on poor mobility of the patient[13] and estimates the mortality from cardiac surgery.[14] The predictive value of Euroscore II was confirmed also in octogenarians undergoing cardiac surgery.[15]

The STS score is more complex and allows to predict not only mortality, but also various post-operative complications as well as a long or short hospital stay,[16] but does not consider patient's frailty.

Previously, Makary et al. reported frailty as an independent risk factor for postoperative complications as well as for long hospital stay in general surgical patients.[17] Similarly, sarcopenia was reported to be a risk factor of high complication rate in patients operated for non-small cell lung carcinoma.[18]

In the present study, we aim to evaluate the use of frailty scales in the prediction of perioperative complications in elderly patients operated for heart valve disease or coronary artery disease.

2. Patients and methods

2.1. Patient recruitment

The patients in this study were recruited when they were inpatients at our Cardiology Department in a regional hospital, for invasive examinations of the heart by means of a coronary angiography, either with or without having had a percutaneous coro-

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nary intervention (PCI) done.

The patients who were submitted to an interdisciplinary committee – the heart team (consisting of a non-invasive cardiologist, an invasive cardiologist and a cardiac surgeon), were asked if they would like to volunteer to being participants in the study (Figure 1). The surgery was done at one of two collaborating cardiac surgery centers. The design was approved by the Ethics committee of the Pardubice hospital.

Only patients who were willing to participate and signed an informed consent were included in the study. The recruitment was terminated in 2020 due to the "Covid era" which was accompanied by changes in examination logistics and by non-standard waiting times for surgeries,[19] which could have led to biased results.

2.2. Patient evaluation

Every recruited patient was tested by means of geriatric scales Mini-mental State Examination (MMSE), activities of daily living (ADL), Edmonton Frail Scale (EFS) and Reported Edmonton Frail Scale (REFS). We also recorded patients' age, commorbidities (hypertension, diabetes mellitus, chronic kidney disease, pulmonary disease, dyslipidemia, history of stroke), smoking status, heart team's decision on treatment (surgical, PCI, conservative), type of operation (valve surgery, coronary artery bypass grafting or both), use of extracorporeal circulation during the surgery, and timing of the operation (planned or urgent). Finally, we calculated the Euroscore II and the STS scores from the baseline data. We then evaluated the incidence of post-operative complications and assorted them into the following categories: arrhythmias, neurological (mainly stroke or delirium), renal, and others (mostly surgical site infections, remote infections, pleural effusions, bleeding, bowel paralysis). We also classified the complications according to the Clavien-Dindo system[20] and considered Grade III or Grade IV as being major complications.[21] The last outcome was the length of hospital stay.

2.3. Data analysis

We processed the data using Microsoft Excel 2010 (Microsoft Corporation, Seattle, WA, USA) and performed most of the analyses using Prism 9.1.2 (GraphPad Software, La Jolla, CA, USA). When comparing operated and not operated patients, we used simple Student's t-test for continuous variables and Fisher's exact test for frequency data. For analysis of factors affecting the rate of various post-operative complications, we used a multiple logistic regression. Similarly, the length of hospital stay was analyzed by multiple linear regression. The following variables were used for multiple regression analysis of the individual types complications: Age, gender, history of coronary artery disease, time to surgery (days), Euroscore II, operating site, use of extracorporeal circulation during surgery, history of lung disease, sinus rhythm, EFS, MMSE, ADL, history of smoking, arterial hypertension, diabetes mellitus, dyslipidemia, chronic kidney disease, STS morbidity or mortality. When the individual variable could not have been analyzed by means of multiple regression (for example due to a phenomenon of quasi-perfect separation), we used univariate Fisher's exact test or Student's t-test depending on the character of data. Additionally, we used the Likelihood ratio test in the multiple regression while omitting one variable at a time. Variables that either had a $p < 0.05$ in multiple regression or their addition made the prediction significantly more accurate, are referred to as contributing factors. For the analysis of hospital stay lengths, the following variables were used: Age, gender, history of coronary artery disease, time to surgery (days), Euroscore II, operating site, use of extracorporeal circulation during surgery, history of lung disease, sinus rhythm, EFS, MMSE, ADL, history of smoking, arterial hypertension, diabetes mellitus, previous insulin treatment, dyslipidemia, history of stroke, chronic kidney disease, STS morbidity or mortality, presence of arrhythmias, presence of neurological complications, presence of renal complications, presence of other complications, presence of major complications, presence of overall complications. Continuous variables are shown as median (interquartile range) and frequency data as absolute number (relative frequency in %). Results of multiple logistic regression are shown as odds ratio with a 95% confidence interval, results of multiple linear regression as parameter estimate (95% confidence interval). A $p < 0.05$ was set as a threshold of significance for all analyses. The asterisks mark * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

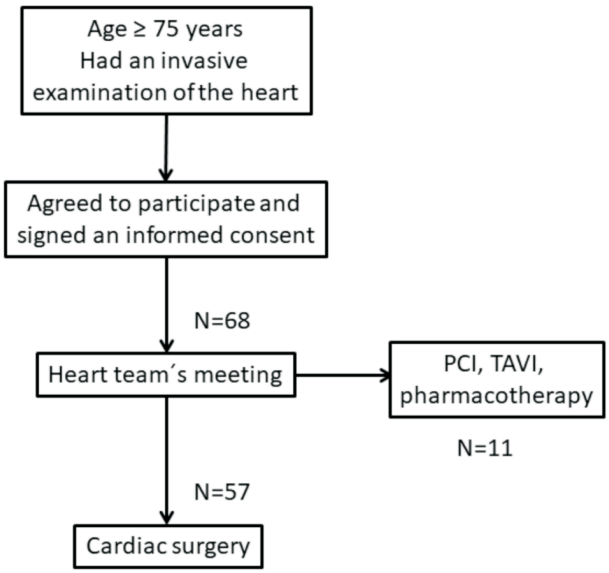

Figure 1. Consort diagram of patient recruitment. PCI = percutaneous coronary intervention, TAVI = transcatheter aortic valve implantation.

3. Results

3.1. Cohort characteristics

We recruited a total of 68 patients. Of those, 57 were operated and 11 were treated by pharmacotherapy alone or with mini-invasive non-surgical procedures (PCI, transcatheter aortic valve implantation). The patients who were not recommended by the heart team for surgery were more frail (higher EFS), had a poorer cognition (lower score of MMSE), were more dependent (lower score of ADL), had a lower likelihood of short hospital stay (parameter STS short length of stay) and more frequent history of chronic lung disease or stroke. Having chronic lung conditions, non sinus rhythm and low ADL values were predictors of not having surgery done ($p < 0.05$ for all). The detailed characteristics are provided in Table 1.

3.2. Operated patients – general observations

There was a major collinearity between EFS and REFS – this could be anticipated since these test have most of the questions in common. Therefore, we only used EFS further since it is more objective than REFS – the gait speed, which is part of EFS, was measured by the investigator. Similarly, various STS parameters displayed a significant collinearity; therefore, we decided to use only the parameter STS morbidity or mortality.

Table 1
Cohort characteristics and comparisons of operated and not operated patients.

	Operated	Not operated	P value
Number	57	11	n/a
Age	79 (5)	78 (2)	0.934
Gender			0.999
Male	40 (70%)	8 (73%)	
Female	17 (30%)	3 (27%)	
Time from referral until surgery (days)	32 (54)	n/a	n/a
Length of hospital stay at the surgical department	15 (23)	n/a	n/a
Presence of coronary artery disease	47 (82%)	8 (73%)	0.426
Euroscore II	2.36 (1.93)	4.2 (3.1)	0.345
Chronic lung conditions	8 (14%)	6 (55%)	0.007**,#
Sinus rhythm	52 (91%)	4 (67%)	0.129#
Edmonton Frail Scale	5 (3)	7 (5)	0.022*
Reported EFS	6 (4)	9 (6)	0.073
MMSE	27 (3)	25 (3)	0.049*
ADL	100 (5)	95 (7.5)	0.008**,#
Smokers (including smoking history)	23 (40%)	6 (55%)	0.509
Arterial hypertension	54 (95%)	11 (100%)	0.999
Diabetes mellitus	24 (42%)	5 (45%)	0.999
Insulin treatment	2 (4%)	0 (0%)	0.999
Hyperlipidemia	43 (75%)	8 (73%)	0.999
History of stroke	3 (5%)	4 (36%)	0.011*
Chronic kidney disease	11 (19%)	3 (27%)	0.684
STS risk of mortality	1.87 (2.46)	3.75 (1.67)	0.158
STS renal failure	1.56 (1.00)	2.31 (0.13)	0.803
STS permanent stroke	1.37 (1.06)	3.70 (2.73)	0.608
STS prolonged ventilation	7.22 (2.70)	11.58 (5.40)	0.063
STS DSW infection	0.20 (0.11)	0.25 (0.06)	0.954
STS reoperation	2.23 (1.29)	3.63 (2.03)	0.182
STS morbidity or mortality	10.77 (4.13)	13.01 (7.15)	0.102
STS short length of stay	34.96 (8.30)	23.21 (8.61)	0.032*
STS long length of stay	5.04 (1.96)	7.63 (1.63)	0.315

Continuous variables are shown as median (interquartile range) and frequency data as absolute number (relative frequency in %).
The asterisks mark * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; # Marks variables identified as being significant predictors of undergoing surgery using multivariate analysis.
ADL = activities of daily living; DSW infection = deep sternal wound infection; EFS = Edmonton Frail Scale; MMSE = Mini-Mental State Examination; STS = Society of Thoracic Surgeons.

3.3. Postoperative complications – arrhythmias

Postoperative arrhythmias occured in 32 out of 57 operated patients (56 %). The presence of arterial hypertension was the only factor recognized as contributing to the occurence of postoperative arrhythmias (odds ratio 31.9, 95% confidence interval 1.13 to 2640, p = 0.061). Overall, the prediction of postoperative arrhythmias was relatively poor with an area under the receiver operating characteristic (ROC) curve of 0.811 and a Tjur's R squared of 0.272.

3.4. Postoperative complications – neurological

Neurological complications occured in 12 out of 57 operated patients (21%). Most of these were perioperative delirium (n = 7; 12%) and only 2 patients developed stroke (3.5%). Patient's age (odds ratio 1.51, 95% CI 1.04 to 2.48, p = 0.059) and baseline heart rhythm (odds ratio 0.0208, 95% CI 1.56×10^{-4} to 0.726, p = 0.059) were found as major contributing factors to neurological complications after the surgery. Time to surgery was just at a border of significance: comparison of a simpler model without it and of a more complex model with it had a p = 0.050. The odds ratio of time to surgery was 1.02 (95% CI 1.00 to 1.04, p = 0.055) for every day till the surgery. When completing the analysis, we obtained a separation with a 100% positive predictive value, an area under the ROC curve of 0.861 and a Tjur's R squared of 0.355.

3.5. Postoperative complications – renal

There were six patiens who had documented acute kidney injury in the postoperative period (10.5%). This time, there were several factors which made the prediction more accurate, even though none of them had a $p < 0.05$. This time, the area under the ROC curve was 0.974 and a Tjur's R squared of 0.622. Patients who had an acute kidney injury had also higher proportion of diabetes mellitus (83%) than those with no injury (37%), but this difference did not reach statistical significance (p = 0.073).

3.6. Postoperative complications – other

Twenty-seven patients had complications assorted as "other" (47.4%). For other complications, the EFS was the only significant predictor: odds ratio 1.99, 95% CI 1.19 to 4.18, p = 0.026. This time, we obtained an area under the ROC curve of 0.852 and a Tjur's R squared of 0.373. In addition, when performing univariate analysis, the patients with other complications had a higher Euroscore II than patients with no other complication: 3.93 ± 3.85 vs. 2.24 ± 1.31, $p < 0.05$.

3.7. Postoperative complications – major

We identified a total of 11 patients as having major complications according to the Clavien-Dindo system, i.e. Grade III or Grade IV; no Grade V was found since all patients survived the postopera-

tive period. We completed the multiple logistic regression using the following variables: age, gender, history of coronary artery disease, elective surgery, time to surgery, Euroscore II, EFS, MMSE, ADL, history of diabetes mellitus, STS morbidity and mortality. We obtained an ROC of 0.970 and a Tjur's R squared of 0.681. For the major complications, none of the variables appeared to be significant. By using univariate analysis, the following were found as being predictors of major complications: having diabetes mellitus ($p = 0.0052$), a high Euroscore II ($p = 0.0002$) and a high EFS ($p = 0.0360$).

3.8. Postoperative complications – overall

A total of 47 patients had some postoperative complication (82.4%) whereas 10 patients had no complications (17.5%). Again, the EFS appeared as a predictor, together with the parameter STS morbidity or mortality (Table 2). This time, we obtained an area under the ROC curve of 0.934 and a Tjur's R squared of 0.480. In addition, ADL was higher in patients who had no complications (100 ± 0 points) than in those who had at least one perioperative complication (96.4 ± 5.0 points, $p = 0.026$).

3.9. Length of hospital stay

Next, we analyzed the factors contributing to the length of hospital stay. Having a Clavien-Dindo Grade III or Grade IV complication was the strongest predictor of a long hospital stay, followed by the occurence of complications from the group "other". Interestingly, dyslipidemia was calculated as being a variable associated with shortened hospital stays (Table 3). We are not able to explain this phenomenon. Patients with dyslipidemia had lower Euroscore II than those without it, but had comparable age, percentage of use of extracorporeal circulation and of heart valve surgery. Using all parameters, we obtained an R^2 of 0.7785.

4. Discussion

In the present study, we found a potential use of geriatric scales, especially Edmonton Frail Scale and activities of daily living, in predicting perioperative complications. Namely, frailty as identified by the EFS, was associated with the incidence of other and overall postoperative complications. An EFS of 6 points (which is interpreted as a "vulnerable patient") can be considered a cut-off since more than 75% of the patients without complications had lower values and 50% of the patients with complications had equal or higher values. Patients who were self-sufficient (as identified by maximum ADL score) had a lower risk of overall complications.

In Chen's review, he suggested using gait speed as a marker of frailty in risk stratification before cardiac surgery. Additionally, he mentioned that frailty may in the future assist in choosing among therapies.[10] Based on the work of Sepehri et al., frail patients had a higher likelihood of mortality, morbidity and functional decline following cardiac surgery; this was observed regardless of definition of frailty.[22] Interestingly, patients with sarcopenia benefited significantly 12 months after the cardiac surgery, comparable to other patients.[23]

In our work, having major complications (Clavien-Dindo Grade III or Grade IV) has been identified as the strongest predictor of a long hospital stay. None of the evaluated geriatic scales were able to predict the length of hospital stay. In the study of Wiorek et al., the authors reported a correlation between EFS and the length of hospital stay. However, their patients were about 4 years younger than ours and had a higher EFS.[24] Similarly, Teng et al. reported a longer hospital stay for patients with sarcopenia compared with control patients.[23]

On the other hand, arrhythmias and neurological complications in our patients were predicted by the well-known risk factors of arterial hypertension respectively age and pre-existing cardiac conduction abnormalities. Our findings of age as a risk factor for neurological complications is in accord with the works of Aikawa et al. and Nicolini et al. who found a higher prevalence of perioperative stroke in patients over 65 years than in younger patients.[25,26] Similarly, Jeon and Sohng observed higher incidences in delirium with increasing age during the post operation period.[27] The incidence of stroke in our cohort was smaller than in the work of Malhotra et al. despite patients in our cohort being older.[28]

The incidence of postoperative arrhythmias was much higher in our study than in the work of Moreira at all[29] but the age of patients in their cohort was lower by almost 35 years. Our results differ from Lemaire et al., who found higher age to increase the risk of cardiac and renal complications,[2] which was not the case of our cohort. The EFS appeared as a protective factor from renal complications. However, we assume that this is because frail patients have low creatinine due to low muscle mass and any rise in creatinine might thus go unnoticed.

Table 2
Predictors of overall complications.

Parameter	Odds ratio	95 % CI	p value
Age	1.125	0.6260 to 1.876	0.6348
Gender	0.2322	0.002057 to 18.55	0.4959
History of coronary artery disease	0.04547	6.155e-005 to 3.168	0.2587
Time to surgery (days)	0.9866	0.9430 to 1.032	0.5179
Euroscore II	0.7521	0.3133 to 8.260	0.6527
Operating site	6.451	0.2939 to 309.8	0.2598
Use of extracorporeal circulation during surgery	0.5624	0.008394 to 21.91	0.7560
Sinus rhythm	24.01	0.07248 to 18419	0.2704
EFS	2.394	1.053 to 9.981	0.1210#
MMSE	0.7980	0.4751 to 1.229	0.3214
History of smoking	0.4390	0.008610 to 13.10	0.6390
Arterial hypertension	59.16	0.2126 to 108856	0.1949
Diabetes mellitus	0.2049	0.004922 to 6.723	0.3695
Chronic kidney disease	8.084	0.3643 to 460.0	0.2242
STS morbidity or mortality	2.243	1.059 to 7.205	0.0771#

Results of multiple logistic regression are shown as odds ratio with a 95% confidence interval.
The "#" symbol, marks the variables that are identified as being significant contributors using the likelihood ratio test.
CI = confidence interval; EFS = Edmonton Frail Scale; MMSE = Mini-Mental State Examination; STS = Society of Thoracic Surgeons.

Table 3
Predictors of hospital stay length.

Parameter	Parameter estimate	95 % CI	p value
Age	1.708	-0.1125 to 3.528	0.0649
Gender	5.188	-5.747 to 16.12	0.3403
History of coronary artery disease	-0.9368	-15.30 to 13.43	0.8949
Time to surgery (days)	-0.1065	-0.2164 to 0.003338	0.0569
Euroscore II	-0.2757	-2.599 to 2.047	0.8102
Operating site	-3.549	-15.53 to 8.435	0.5499
Use of extracorporeal circulation during surgery	8.968	-7.662 to 25.60	0.2795
History of lung disease	-8.385	-29.07 to 12.30	0.4142
Sinus rhythm	-9.368	-29.99 to 11.25	0.3608
Presence of arrhythmias	5.170	-7.470 to 17.81	0.4101
Presence of neurological complications	6.550	-6.545 to 19.65	0.3152
Presence of renal complications	7.248	-11.58 to 26.07	0.4378
Presence of other Complications	12.27	0.9893 to 23.56	0.0340*
Presence of Overall complications	2.480	-16.38 to 21.34	0.7902
EFS	0.3596	-2.621 to 3.340	0.8071
Presence of major complications	29.23	11.99 to 46.48	0.0016**
MMSE	0.06519	-1.952 to 2.082	0.9478
ADL	-1.215	-2.596 to 0.1648	0.0822
History of smoking	2.777	-8.920 to 14.47	0.6313
Arterial hypertension	8.227	-14.77 to 31.22	0.4707
Diabetes mellitus	1.994	-9.763 to 13.75	0.7315
Previous insulin treatment	-18.42	-49.81 to 12.97	0.2403
Dyslipidemia	-16.26	-30.65 to -1.864	0.0282*
History of stroke	-7.273	-38.24 to 23.69	0.6350
Chronic kidney disease	7.183	-5.204 to 19.57	0.2456
STS morbidity or mortality	-0.9474	-2.312 to 0.4177	0.1667

Results of multiple linear regression are shown as parameter estimate with a 95 % confidence interval.
The asterisks mark * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
ADL = activities of daily living; CI = confidence interval; EFS = Edmonton Frail Scale; MMSE = Mini-Mental State Examination; STS = Society of Thoracic Surgeons.

We agree with the statement of Wanamaker et al. that age alone should not be a contraindication for cardiac surgery.[30] Rather than using geriatric scales as a tool for decision, we suggest it as a tool to estimate perioperative risks. Such information can be valuable for both surgeons and the patients. It was previously recommended to add a geriatrician to the heart team by Ungar et al.[31]

In conclusion, we found that the Edmonton Frail Scale was able to predict the incidence of other and overall postoperative complications, independently on age or Euroscore II. In addition, patients who had a maximum possible score in self-sufficiency had a good chance in undergoing surgery without any complications. These scales might be useful in perioperative risk assessment.

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Declaration

None of the authors has any conflict of interest do declare.

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