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ASSESSING PRE-OPERATIVE CARDIAC RISK IN ADULT SPINAL DEFORMITY SURGERY: CORRELATION BETWEEN MODIFIED FRAILTY SCORE AND REVISED CARDIAC RISK INDEX

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ABSTRACT

Objective: Cardiac complications are one of the most important causes of death after major spinal surgery. This study aimed to evaluate the correlation between the 11-item and 5-item modified frailty index (mFI) and the revised cardiac risk index (RCRI) for predicting major adverse cardiac events (MACEs) after adult spinal deformity (ASD) corrective surgery.

Materials and Methods: This retrospective study analyzed the records of 20 adult patients who underwent spine surgery for ASD between 2022-2023. The patients' frailty and comorbidities were assessed using the mFI-5, mFI-11, and the American Society of Anesthesiologists Physical Status Classification System. RCRI was calculated to stratify the risk for predicting MACEs during hospitalization. The primary outcome was the presence of specific cardiac events within 30 days of surgery.

Results: The study found that there was a significant positive correlation between RCRI and both mFI-5 and mFI-11 scores in terms of predicting MACEs. Three out of the 20 patients had MACEs postoperatively, and among them, one patient had an RCRI score of 1 but had a higher mFI score, indicating frailty. The other two patients had low RCRI scores but were considered prefrail according to the mFI scores.

Conclusion: RCRI, mFI-5, and mFI-11 are correlated in terms of predicting cardiac risk after ASD surgery. Adding frailty scores to traditional risk estimation may provide additional prognostic information. However, this needs further investigation.

Keywords: Adult spinal deformity surgery, modified frailty index, revised cardiac risk index, major cardiac adverse events

INTRODUCTION

Even though patients undergo surgery to maintain or increase life expectancy or to improve health related quality of life, surgery is not without risks. Increasing numbers of patients need surgery at older ages and with more medical comorbidities as the population continues to age[1,2]. Among wide range of surgeries, adult spinal deformity (ASD) corrective surgery involves a significant amount of dissection, multilevel instrumentation and fusion, osteotomy, and blood loss with a considerable risk of perioperative complications[1-3].

Recent research has shown that frailty is a useful predictor of severe adverse outcomes when considering surgery for elderly patients[4,5]. Frailty is a syndrome associated with aging that is characterized by a decline in physiological reserve across a number of organ systems, which leads to a reduction in stress resistance[6] and an increased threshold for compensatory mechanisms[7]. Risk stratification using a frailty index offers a promising tool to identify patients most likely to experience complications such as neurological, implant related, surgical site infection, cardiopulmonary (hemodynamic instability, myocardial infarction, congestive heart failure, pulmonary embolism), gastrointestinal and renal. Among several assessment tools reported, 11-item modified frailty index (mFI-11), Charlson comorbity index, ASD Frailty Index and Cervical Deformity Frailty Index are among the leading frailty indices in the spine literature[8]. On the other hand, in the study by Laverdière et al.[9] where correlation between frailty status and postop outcomes were assessed in 12 studies, mFI-11-item and -5 item were the most frequently used frailty indices.

Although cardiac complications are the leading cause of death after non-cardiac surgery[10,11] there is a paucity of extensive cohort studies assessing cardiac problems in patients having spine surgery[12]. Among several tools evaluated to predict preoperatively in-hospital major adverse cardiac events (MACE), revised cardiac risk index (RCRI) is a widely utilized one[13] and along with pre-operative B-type natriuretic peptides[14,15] is currently the gold standard of risk stratification. However, these measurements do not capture or account for frailty.

The aim of this study was to evaluate the correlation between widely used mFI 11-and 5 -item and RCRI for prediction of cardiac MACEs after ASD surgery.

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MATERIALS AND METHODS

Patients

This retrospective study analyzed the records of 20 adult (age 57-83) patients who underwent spine surgery for ASD in our institution between 2022-2023. The study included patients who underwent preoperative cardiac evaluation. Frailty and comorbidities were assessed by the mFI-5, mFI-11, and American Society of Anesthesiologist Physical Status Classification System (ASA) respectively. RCRI was calculated to stratify the risk for prediction of MACEs during hospitalization. Demographical and clinical data were retrieved from patient records. The study protocol was approved by the Anadolu Medical Center Ethic Committee and the study was conducted in accordance with the Declaration of Helsinki (no: ASM-EK-23/224, date: 14.06.2023).

Frailty Risk Score and RCRI Score Calculation

The 5-item mFI-5 was validated and developed from the previously established mFI-11. The mFI-5 has five National Surgical Quality Improvement Program variables: 1) history of severe chronic obstructive pulmonary disease (COPD), 2) congestive heart failure within 30 days before surgery, 3) functional health status prior to surgery (independent versus partially or totally dependent), 4) hypertension (HT) requiring medication, and 5) diabetes mellitus (DM) with oral agents or insulin. A combined mFI score is calculated for each patient by adding the number of frailty variables present (one point per variable). The mFI-5 was categorized as 0, 1, or ⩾2. The mFI-11 item, in addition to the previous 5 parameters, included, 6) history of myocardial infarction, 7) peripheral vascular disease, 8) history of percutaneous transluminal coronary angioplasty (PTCA), coroner artery bypass grafting or angina, 9) impaired sensorium, 10) transient ischemic attack (TIA) or cerebrovascular attack (CVA) without residual deficit, 11) CVA with residual deficit. Patients were classified as robust: mFI-5, -11=0, prefail: mFI-5=1 or -11<3, frail: mFI-5⩾2 or-11⩾3[8,16].
Briefly, the RCRI was calculated by 1-point assignments for the presence of each of the following variables[17]: 1) history of ischemic heart disease, 2) heart failure, 3) CVA or TIA, 4) DM on insulin, 5) creatinine >2 mg/dL and 6) high-risk surgery (intra-thoracic, vascular, and intra-peritoneal), for a maximum score of 6. The patients were considered very very low risk (0.04%) if 0 over 6 parameters exists, low risk (0.9%) for 1-point, moderate risk (6.6%) for 2 points, high risk (>11%) for 3 points.

Outcomes

Our primary outcome was the presence a MACE defined as; ST elevation myocardial infarction, pulmonary edema, ventricular fibrillation, acute coronary syndrome with troponin elevation and complete heart block at or before 30-days.

Statistical Analysis

In the descriptive statistics of the data, mean, standard deviation, median minimum, maximum, frequency and ratio values were used. The distribution of variables was measured with the Kolmogorov-Smirnov test. The Mann-Whitney U test was used in the analysis of quantitative independent data. Chi-square test was used in the analysis of qualitative independent data, and Fisher's exact was used when the chi-square test conditions were not met. Spearman correlation analysis was used in the correlation analysis. The effect level and cut-off value were investigated with the receiver operating characteristic curve. SPSS 28.0 program was used in the analysis.

RESULTS

Patients

A total of 20 patients were included in the study. The average age of the patients was 68.3±8.8 and 70% were male. All patients underwent corrective ASD surgery through posterior approach. The average duration of the operation was 4-6 hours. Demographical and clinical data of the patients are shown in Table 1. The majority of the patients (13) had an RCRI score of 0 with an estimated very low risk (0.04%) of MACE with non-cardiac surgery. On the other hand, 12 patients were categorized as prefrail with mFI-5=1 and mFI-11=1 (Table 1).

Outcomes with RCRI and mFI

The age and gender distribution of the patients did not differ significantly between the groups with very low RCRI and low-intermediate risk RCRI ($p>0.05$). The ASA score was significantly ($p<0.05$) higher in the RCRI low-intermediate risk group than the very low RCRI risk group. There was no significant difference between the groups with very low RCI and low-intermediate RCI ($p>0.05$) in terms of history of HT, coronary artery disease, COPD, smoking status, ejection fraction, troponin levels, blood loss and replacement. The DM rate was significantly ($p<0.05$) higher in the group with low-intermediate risk RCRI than in the group with very low RCRI. There was no significant difference between the groups with very low RCRI and low-intermediate RCRI ($p>0.05$) for readmission, postoperative complications, and hospital stay (Table 2).
Three of 20 patients had MACEs postoperatively with one patient having an acute myocardial infarction with primary PTCA and stent implantation a week after discharge and 2 patients with troponin elevations without major ischemic electrocardiography changes treated with medical therapy. Of these 3 patients, one patient had RCRI of 1 with low risk (0.9%) however 3 with mFI-5 and mFI-11, considered frail. The other 2 patients had an RCRI of 0 with very low risk (0.04%) and 1 with mFI-5 and mFI-11 considered as prefrail.
In patients with RCRI low to moderate risk (1 to 2 points), the average of mFI-5 was 2.0±1.15 and mFI-11 was 2.29±0.95. The mFI-5 and -11 score distributions in the RCRI low-intermediate

Table 1. Demographical and clinical data of the patients

		Min-max	Average	Mean ± SD/n-%	
Age		50-83	70	68±8.8	
Gender	Female			6	30.0%
	Male			14	70.0%
HT				15	75.0%
DM				5	25.0%
CAD				2	10.0%
Smoking status				9	45.0%
EF	Normal			15	75.0%
	Reduced <55%			1	5.0%
Troponin	(-)			8	40.0%
	(+)			2	10.0%
COPD	(-)			18	90.0%
	(+)			2	10.0%
ECG: SR				20	100.0%
Blood loss		50-2500	275	557±592	
Blood usage	(-)			13	65.0%
	(+)			7	35.0%
mFI-5	0			2	10.0%
	I			12	60.0%
	II			3	15.0%
	III			3	15.0%
mFI-11	I			13	65.0%
	II			3	15.0%
	III			4	20.0%
ASA	II			13	65.0%
	III			7	35.0%
Readmission	(-)			19	95.0%
	(+)			1	5.0%
Postoperative complication	(-)			17	85.0%
	(+)			3	15.0%
Length of stay		3-20	6	6.5±3.78	
Revised cardiac risk index		0.40-6.60	0.40	0.86±1.37	
Revised cardiac risk index	Very low			13	65.0%
	Low			6	30.0%
	Moderate risk			1	5.0%

HT: Hypertension, DM: Diabetes mellitus, CAD: Coronary artery disease, EF: Ejection fraction, COPD: Chronic obstructive pulmonary disease, ECG: Electrocardiography, SR: Sinus rhythm, mFI-5: Modified frailty index-5, mFI-11: Modified frailty index-11, ASA: American Society of Anesthesiologist Physical Status Classification System, SD: Standard deviation, Min-max: Minimum-maximum

group were significantly ($p<0.05$) higher than the very low RCI group (Table 3 and Figures 1a, b). A significant positive correlation was observed between both the RCRI and mFI-5 ($r=0.533/p=0.016$) and mFI-11 ($r=0.655/p=0.002$) (Table 4). Significant effectiveness of mFI-5 scores [Area under the curve 0.780 (0.508-1.000)] and mFI-11 scores [Area under the curve 0.824 (0.599-1.000)] were observed in the discrimination between groups with very low RCRI and low-intermediate RCRI. Among the groups with very low RCI and RCI low-moderate, the sensitivity of mFI-5 below or above 1 was 71.4%, positive prediction was 83.3%, specificity was 92.3%, and negative prediction was 85.7% while the sensitivity was 71.4%, positive prediction was 71.4%, specificity was 84.6% and negative prediction was 84.6% for mFI-11 (Table 5).

DISCUSSION

ASD surgery carries a considerable risk for postoperative serious adverse effects because of its invasive nature[1-5]. Considering that more elderly and frail patients with several comorbidities undergo this operation, this presents unique challenges to spine surgeons and risk stratification is important to identify patients most likely to experience complications. Among the several tools evaluated to quantify the risk prediction in terms of frailty, mFI-11 and mFI-5 are among the most widely acknowledged ones[9,18]. On the other hand, RCRI has been used extensively as a prognostic model to estimate the risk of developing postoperative cardiac major adverse events in noncardiac surgery including spinal surgery[13]. Here in this study, we have found a significant positive correlation between RCRI, MFI-5 and mFI-11 with mF-11 more with RCRI in terms of MACE prediction.

A consensus conference in December of 2012, led by the International Association of Gerontology and Geriatrics and World Health Organization, defined frailty as "a medical syndrome with multiple causes and contributors that is characterized by diminished strength, endurance and reduced physiological function that increases an individual's vulnerability for developing increased dependency and/or death"[18,19]. Elevated frailty index scores have been shown as an independent predictor of surgical complications in spine surgeries[9]. Even though many assessment tools were developed to quantify risk for postoperative outcomes, unfortunately they are not without limitations in terms of feasibility and reliability. The Adult Deformity Surgery Complexity Index is a reliable instrument for calculating the complexity of ASD surgery, predicting surgical blood loss, time, and postoperative problems[20]. It was, however, developed based on expert consensus and included solely surgical data, with no frailty variables. Moreover, this index consists of 42 independent parameters which is significantly a large number causing a major limitation. The Seattle Spine Score which predicts the 30-day complication risk after ASD surgery and used frailty parameters, lacked external validation[3]. mFI is the most frequently used frailty index in spine literature,

Table 2. Groups with very low RCRI and low-intermediate RCRI

		RCRI very low			RCRI low-moderate				
		Mean ± SD/n-%		Median	Mean ± SD/n-%		Median	p	
Age		67.9±8.9		70.0	69.0±9.2		70.0	0.874	m
Gender	Female	4	30.8%		2	28.6%		1.000	X^2
	Male	9	69.2%		5	71.4%			
ASA	II	11	84.6%		2	28.6%		0.022	X^2
	III	2	15.4%		5	71.4%			
HT	(-)	3	23.1%		2	28.6%		1.000	X^2
	(+)	10	76.9%		5	71.4%			
DM	(-)	13	100%		2	28.6%		0.001	X^2
	(+)	0	0.0%		5	71.4%			
CAD	(-)	13	100%		5	71.4%		0.111	X^2
	(+)	0	0.0%		2	28.6%			
Smoking status	(-)	7	53.8%		4	57.1%		0.888	X^2
	(+)	6	46.2%		3	42.9%			
EF	Normal	11	84.6%		4	57.1%		0.313	X^2
	Low (<55%)	0	0.0%		1	14.3%			
Troponin	(-)	3	23.1%		5	71.4%		0.444	X^2
	(+)	2	15.4%		0	0.0%			
COPD	(-)	12	92.3%		6	85.7%		1.000	X^2
	(+)	1	7.7%		1	14.3%			
Blood usage	(-)	7	53.8%		6	85.7%		0.329	X^2
	(+)	6	46.2%		1	14.3%			
Blood loss		662±684		500	364±333		200	0.379	m
Readmission	(-)	13	100%		6	85.7%		0.350	X^2
	(+)	0	0.0%		1	14.3%			
Postoperative Complication	(-)	11	84.6%		6	85.7%		1.000	X^2
	(+)	2	15.4%		1	14.3%			
Length of stay		5.8±2.2		5.0	7.9±5.7		6.0	0.522	m

X^2: Chi-square test, m: Mann-Whitney U test, RCRI: Revised cardiac risk index, HT: Hypertension, DM: Diabetes mellitus, CAD: Coronary artery disease, EF: Ejection fraction, COPD: Chronic obstructive pulmonary disease, ECG: Electrocardiography, SR: Sinus rhythm, mFI-5: Modified frailty index-5, mFI-11: Modified frailty index-11, ASA: American Society of Anesthesiologist Physical Status Classification System, SD: Standard deviation

Table 3. The mFI-5 and -mFI-11 score distributions in the RCRI groups

		RCRI very low			RCRI low-moderate				
		Mean ± SD/n-%		Median	Mean ± SD/n-%		Median	p	
mFI-5		1.00±0.41		1.00	2.00±1.15		2.00	0.022	m
mFI-5	0	1	7.7%		1	14.3%		0.007	X^2
	I	11	84.6%		1	14.3%			
	II	1	7.7%		2	28.6%			
	III	0	0.0%		3	42.9%			
mFI-11		1.15±0.38		1.00	2.29±0.95		3.00	0.006	m
mFI-11	I	11	84.6%		2	28.6%		0.022	X^2
	II	2	15.4%		1	14.3%			
	III	0	0.0%		4	57.1%			

X^2: Chi-square test, m: Mann-Whitney U test, mFI-5: Modified frailty index-5, mFI-11: Modified frailty index-11, RCRI: Revised cardiac risk index, SD: Standard deviation

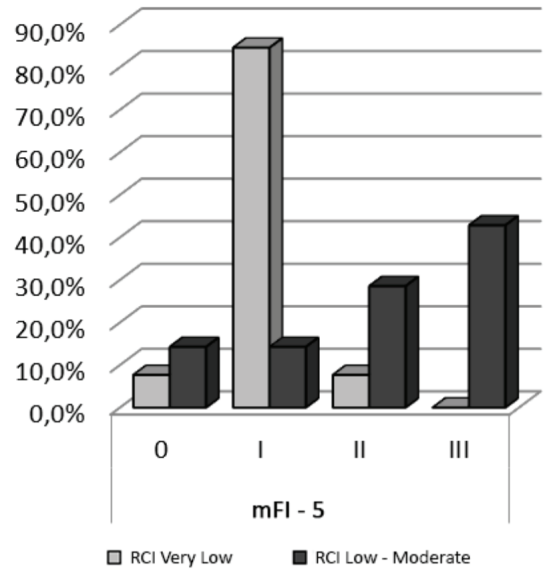

Figure 1a. The mFI-5 score distributions in the RCRI very low and low-intermediate group
RCRI: Revised cardiac risk index, mFI: Modified frailty index

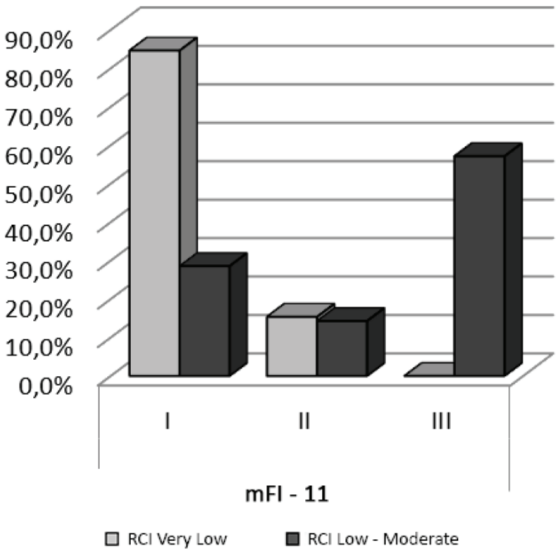

Figure 1b. The mFI-11 score distributions in the RCRI very low and low-intermediate group
RCRI: Revised cardiac risk index, mFI: Modified frailty index

consisting of 11 parameters regarding the dependency of the functional status and history of other concomitant diseases. mFI-5, the abbreviated and condensed form if mFI-11 was demonstrated to be equally effective for serious adverse event prediction in ASD surgery[21]. In our study we used mFI-5 and mFI-11 as risk assessment tools.

Among various complications after spine surgery, the rate of MACEs has been reported to range from 0.67% to 1.6 %[22-24]. Lee et al.[25] reported a 0.8% incidence of cardiac complications after lumbar fusion whereas in the study by Guyot et al.[11] this rate was 6.7%. This wide variation may result from the fact

Table 4. Correlation between RCRI, mFI-5 and mFI-11

		mFI-5	mFI-11
Revised cardiac risk index	r	0.533	0.655
	p	0.016	0.002

Speraman correlation, mFI-5: Modified frailty index-5, mFI-11: Modified frailty index-11, RCRI: Revised cardiac risk index

Table 5. Areas under the curve

	Area under the curve	95% confidence interval			p
mFI-5	0.780	0.508	-	1.000	0.043
mFI-11	0.824	0.599	-	1.000	0.019

ROC curve, ROC: Receiver operating characteristic

that different definitions of MACEs have been used, data from single institutions were collected and post discharge follow-up data were missing. Even though RCRI is widely accepted and used as a predictive tool to estimate risk of MACEs, it does not always make accurate assessments. Of the 3 patients with MACEs in our study, one patient had RCRI of 1 with low risk (0.9%) however 3 points with mFI-5 and mFI-11, considered frail. The other 2 patients had an RCRI of 0 with very low risk (0.04%) and 1 with mFI-5 and mFI-11 considered as prefrail. In a recent large cohort study by Gouda et al.[17], 712,808 patients were evaluated for validation of the hospital frailty risk score. The primary outcome was a composite of death, myocardial infarction or cardiac arrest at 30-days. The hospital frailty score provided additional prognostic information to traditional RCRI risk estimation. For example, for patients with an RCI of 1, the risk of 30-day death, MI and cardiac arrest ranged from 0.35% in the low frailty group to 2.12% in the high frailty group. This is similar to our finding in 1 over 3 patients with MACE who had an RCRI of 1, but 3 with mFI-5 and -11. In the other 2 patients risk scores with similar. As a single institution our sample size was too small to make such a validation.

In our study a significant positive correlation was observed between both the RCRI and mFI-5 (r=0.533/p=0.016) and mFI-11 (r=0.655/p=0.002). Of 5 parameters in mFI, insulin dependent DM and a history of congestive heart failure agree with RCRI. On the other hand, along with the parameters just mentioned, history of myocardial infarction, PTCA, ACBG (coronary artery disease) and CVA are additionally shared with RCRI in mFI-11. That might explain the slightly increased positive correlation of mFI-11 with RCRI.

Study Limitations

Findings of this study needs to be evaluated within the context of some limitations. Firstly, retrospective design limits its generalizability. Secondly, as the data of a single institution is evaluated in this study, the sample size is too small to compare or validate the frailty scores with cardiac risk scores for postoperative cardiac complications in ASD surgeries.

CONCLUSION

RCRI, mFI-5 and mFI-11 are correlated in terms of cardiac risk prediction after ASD surgery. The addition of these frailty scores may increase the prognostic information to traditional risk estimation but this needs further investigation with prospective studies with larger sample sizes and multicenter data.

Ethics

Ethics Committee Approval: The study protocol was approved by the Anadolu Medical Center Ethic Committee and the study was conducted in accordance with the Declaration of Helsinki (no: ASM-EK-23/224, date: 14.06.2023).
Informed Consent: Retrospective study.
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Authorship Contributions

Surgical and Medical Practices: A.K., S.K., Concept: A.K., S.K., Design: A.K., S.K., Data Collection or Processing: A.K., S.K., Analysis or Interpretation: A.K., S.K., Literature Search: A.K., S.K., Writing: A.K., S.K.
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