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Validation of VO_2 Max with STS

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VALIDATION OF MAXIMUM OXYGEN CONSUMPTION (VO_2 MAX) WITH SOCIETY OF THORACIC SURGEON (STS) RISK SCORE IN PREOPERATIVE ASSESSMENT OF PATIENTS UNDERGOING CORONARY ARTERY BYPASS GRAFT (CABG) SURGERY: A PILOT STUDY

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ABSTRACT

Objective: To validate VO_2 max testing with society of thoracic surgeon (STS) score in the preoperative assessment of patients undergoing coronary artery bypass graft surgery.

Study Design: This was a single center and observational study.

Place and Duration of Study: Armed Forces Institute of Cardiology and National Institute of Heart Diseases, Rawalpindi

Methodology: Forty four adult patients undergoing elective on pump coronary artery bypass graft surgery with an EF of >45% were included in this study as per inclusion criteria through non probability consecutive sampling. Five patients were lost to follow up. In 39 patients preoperative society of thoracic surgeons scoring was done and VO_2 max of these patients was calculated. After coronary artery bypass graft surgery these patients were followed for mortality and morbidity. The discriminative capacity of VO_2 max was compared with the STS risk scoring system using Receiver Operating Characteristic curves (ROC-curves).

Results: We analyzed the data of 39 patients male 35 (89.7%), female 4 (10.3%). Mean age of our study population was 55.0 ± 10.2 years and a mean BMI of 26.8 ± 3.81. There were 20 (54.1%) hypertensives, 2 (5.4%) diabetics and 5 (13.5%) smokers. There was only one patient with a history of previous myocardial infarction. Majority of the patients belonged to NYHA class II 30 (76.9%) with a mean EF of 56.6 ± 5.17. Prolonged Ventilation (>24 hrs) was significantly associated with lesser values of VO_2 max with a p-value of 0.01. Similarly, post-operative mortality and prolonged hospital stay in the low VO_2 max groups correlated with the trends predicted by the society of thoracic surgeons scoring system.

Conclusion: We conclude from this study that low preoperative VO_2 max levels correlated well with STS scoring system for predicting mortality, ventilation time and length of hospital stay.

Keywords: Cardiopulmonary exercise testing, Coronary artery bypass grafting surgery, Peak oxygen uptake (VO_2 peak), Society of thoracic surgeon score.

INTRODUCTION

Coronary artery bypass graft (CABG) surgery is a widely used modality of treatment for coronary artery disease for the last few decades since it was first introduced in early nineteen sixties[1]. Postoperative outcomes of CABG have progressively improved as a consequence of new technologies, surgical techniques, postoperative care, but alsobecause of better control of specific risk factors, before, during and after surgery[2].

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Risk stratification for cardiac surgery is done to improve cardiac surgical outcomes. Various risk assessment models have been developed overtime to try to assess perioperative morbidity and mortality for patients undergoing surgery. The European system for cardiac operativerisk evaluation (Euro SCORE) has been usedfor many years since its introduction in1999[3]. Euro SCORE II was developed in 2011 to overcome short comings oforiginal Euro SCORE[4]. The Society of Thoracic Surgeons (STS) 30-day riskmodels were developed to provide clinicians andhospitals with a tool to evaluate risk-adjusted mortality as well as major morbidities[5].

Cardiopulmonary exercise testing is a vigorous assessment tool that gives an objective extent of functional capacity and aerobic fitness. Patient's risk of post-operative morbidity and mortality can be forecasted by cardiopulmonary exercise testing as it offers an individualized assessment of the patient's fitness for surgery[6,7]. This expertise can therefore be used to advise collective decision-making and patient accord, to triage the patient to a suitable perioperative care setting, to detect unexpected complications, to improve clinical comorbidities preoperatively, and to direct personalized preoperative exercise plans[8]. We designed our study to compare VO_2 max values of preoperative cardiac surgical patients and benchmark them with those predicted with the STS score predictive model.

METHODOLOGY

This was a single center observational study, performed on consecutive 44 patients who underwent elective coronary artery bypass surgery at Armed Forces Institute of Cardiology and National Institute of Heart Diseases, Rawalpindi. The study was submitted to the Institutional Ethics Review Board committee that works in consonance with the Declaration of Helsinki, and approved as presented herein. Written and signed informed consent was taken from all the enrolled patients. A total number of 44 adult patients undergoing cardiac surgery requiring cardiopulmonary bypass (CPB), having an EF of >45% were recruited in the study as per inclusion criteria through non probability consecutive sampling, Out of which 05 patients were unable to complete the test. Emergency operations and patients with critical Left Main Stem Disease (LMSD), Chronic Obstructive Pulmonary Disease (COPD), musculoskeletal disorder, intermittent claudication, acute heart failure,unstable angina, valve replacement along with CABG surgery and EF <45% were excluded from the study. The patients according to inclusion criteria were divided into four groupsdepending upon VO_2 max readings.

Data Management

Almost two hundred distinctive parameters of demographic, clinical and diagnostic nature are routinely collected for each patient who had undergone cardiac surgery in our hospital by a team of research managers that feed an institutional database of cardiac surgery on a daily basis. Data collection is performed ahead of the procedure, but also along the hospital stay and after hospital discharge, by telephone in the late postoperative period. Information from this institutional database is regularly used to detect possible errors in the treatment and to plan strategies to improve clinical practice. Based on these data, STS scores are calculated online in the website as previously cited for each patient and stored as well in the database. The website calculator returns a list of estimated risk rates for nine distinct endpoints during the postoperative period, which are defined as follows: 1) operative mortality: death during the in-hospital stay following surgery, and within 30 days of surgery; 2) permanent stroke (cerebrovascular accident): a central neurologic deficit persisting longer than 72 hours; 3) renal failure: requirement for dialysis or an increase of the serum creatinine to >2.0 mg/dL or double the most recent preoperative creatinine level; 4) prolonged mechanical ventilation (longer than 24 hours); 5) deep sternal wound infection (mediastinitis); 6) reoperation for any cause; 7) major morbidity or mortality that include any of the above mentioned events; 8) prolonged post-operative length of stay (PLOS): length of stay (LOS) longer than 14 days; and 9) short postoperative LOS (SLOS): LOS shorter than 6 days with patient alive at discharge. We assessed all nine endpoints as cited for the studied population.

For the purpose of this study, a structured paper questionnaire was filled in for each patient; data for the maximum oxygen consumption were collected preoperatively by the cardiac surgeon in charge of the patient and research team at the time of hospital admission. VO_2 max test was conducted by using Brilliance 19S Medisoft cardio respiratory instrumentation as per standard (modified Mc Naughten) protocol. The pulmonary gas exchange parameters recorded were VO_2 max in mL/kg/min, $VeCO_2$ and VeO_2.

We also recorded administrative data (dates of surgery and discharge and vital status at discharge), general information (gender, height, weight and BMI), preoperative variables (hypertension, diabetes, chronic pulmonary disease, smoking status, cerebrovascular disease, coronary artery disease, chronic heart failure, recent myocardial infarction, previous cardiac intervention, angina class, NYHA class, ejection fraction, and intraoperative variables Intra-aortic balloon pump (IABP), cross clamp time (CXP) and bypass time (CPB). Post-operative parameters include ICU stay, ventilation time, ionotropic requirement, postoperative BIPAP usage, respiratory rate, FiO2, PEEP, arrhythmia, infection, re-exploration and in hospital mortality. Postoperative in hospital pulmonary complication (PPC) were defined as the occurrence of at least one event during hospital stay. In order to minimize bias and to improve the authenticity of our study results we divided our study population into four groups depending upon VO_2 max readings as:

Group A <5 ml/kg/min = 02 (5.2%)

Group B 6-10 ml/kg/min = 12 (30.8%)

Group C 11-15 ml/kg/min = 18 (46.1%)

Group D 16-20 ml/kg/min = 07 (17.9%)

Statistics

Continuous variables are shown as mean (standard deviation) if normally distributed or median (25-75 percentile) in the cases they don't fit normality; categorical variables are displayed as absolute number and percentages. The accuracy (sensitivity and specificity) of the STS scores was tested in our population for each individual endpoint using the method of receiver operating characteristic (ROC) curve as described elsewhere. In brief, sensitivity is plotted against "one minus specificity" (1-specificity) for each value of a specific prognostic score. Area under the curve (AUC) is then calculated and statistically compared with a baseline AUC of 0.50 that indicates prediction no better than chance, and is represented by a diagonal line crossing the graphic area.

The larger is the AUC (closer to 1.0), the higher is considered the capability of the method to predict outcomes. We considered AUC above 0.70 as the limit for adequate discrimination in our analysis. Endpoints that reached a low number of events (5 or less) were excluded from the analysis given the significantly high probability of methodological errors with low number of events. We used ROC for comparing STS predicted scores with our findings. Low VO_2 max groups were strong predictors of mortality & morbidity, when validated with STS scores. The Area Under the Curve (AUC) is the measure of the ability of a classifier to distinguish between classes and is used as a summary of the ROC curve. The higher the AUC, the better the performance of the model at distinguishing between the positive and negative classes.

RESULTS

We analyzed the data of 39 eligible patients (Male 35 (89.7%), Female 4 (10.3%)). Mean age of our study population was 55.0 ± 10.2 years and a mean BMI of 26.8 ± 3.81. There were 20 (54.1%) hypertensives, 2 (5.4%) diabetics and 5 (13.5%) smokers. There was only one patient with a history of previous myocardial infarction (MI). Majority of the patients belonged to NYHA class II 30 (76.9%) with a mean EF of 56.6 ± 5.17. The demographic and preoperative data is summarized in table-I.

In our study we evaluated STS risk score for prolonged ventilation, prolonged hospital stay and mortality. Prolonged ventilation (>24 hrs) was significantly associated with lesser values of VO_2 max with a *p*-value of 0.01. Similarly, post-operative prolonged Bi-PAP usage (>50 hrs) was reported more in group A as compared to other groups as shown in fig-1. Our study findings document a higher mortality in patients with lesser values (fig-3 & 4) of VO_2 max readings as mentioned in fig-2.

We used ROC for comparing STS predicted scores with our findings. Lessor VO_2 max groups

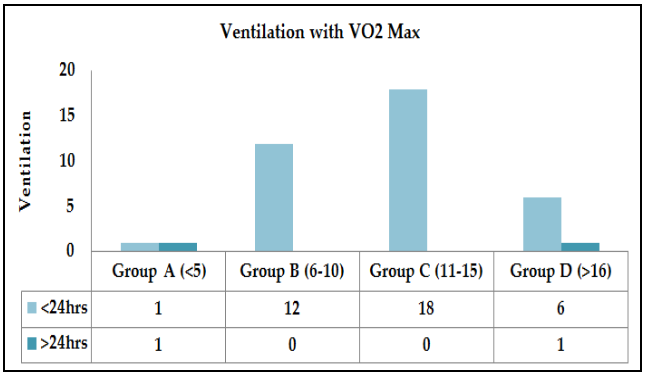

Figure-1: Association of prolong ventilation with VO_2 max readings n=39.

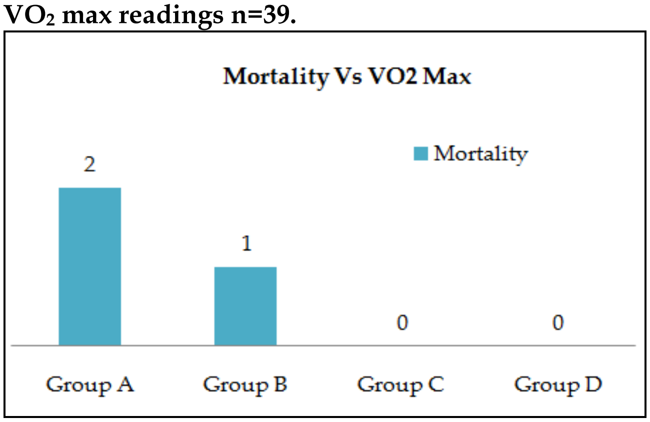

Figure-2: Association of in-hospital mortality with VO_2 max readings.

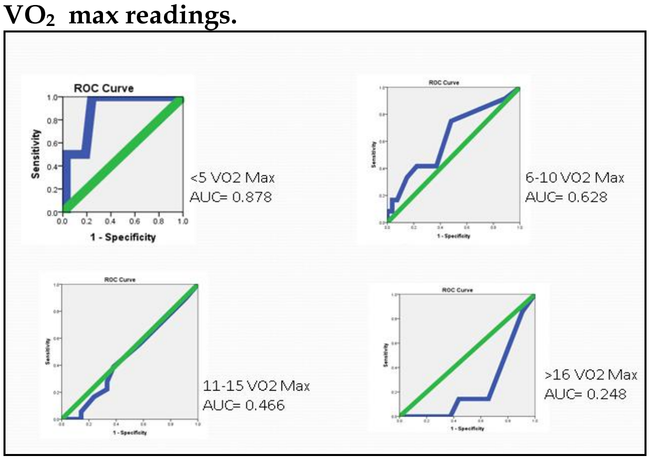

Figure-3: Comparison of VO_2 max patient groups. With STS mortality risk.

were strong predictors of mortality & morbidity, when validated with STS scores. The Area Under the Curve (AUC) is used as a summary of the ROC curve. The higher the AUC, the better the performance of the model. As shown in fig-3, AUC was higher in low VO_2 max value so it predicts high mortality rate in low VO_2 max group.

Similarly low VO_2 max groups were strong

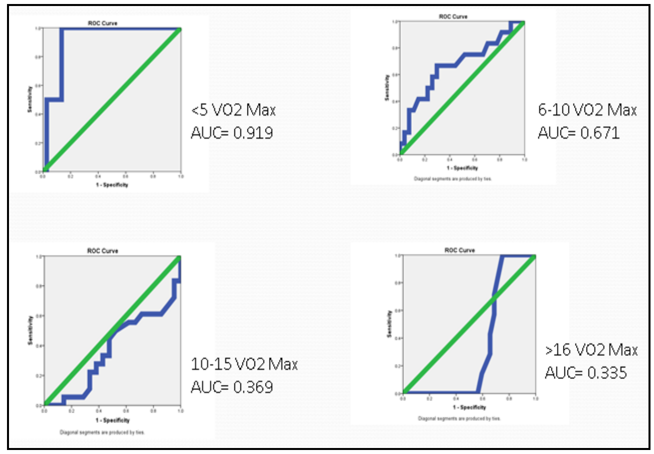

Figure-4: Comparison of VO_2 max patient group with STS prolong ventilation risk.

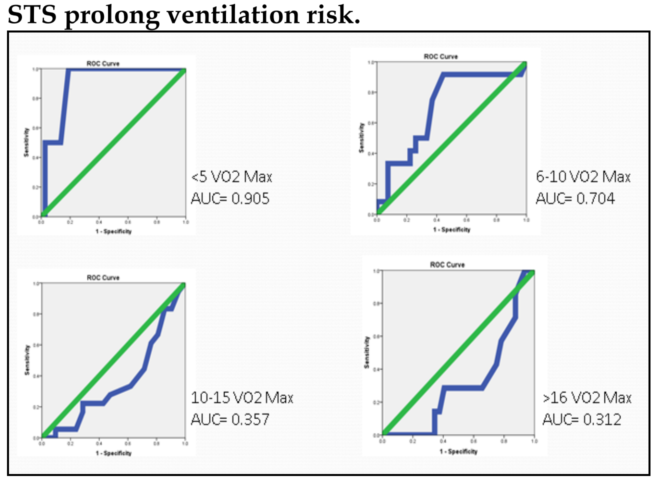

Figure-5: Comparison of VO_2 max patient group with STS prolonged hospital stay risk.

predictors of prolonged ventilation risk as AUC value is higher in <5 VO_2 max group, which predicts high rate of ventilation as shown in fig-4. Likewise low VO_2 max groups were strong predictors of prolonged hospital stay risk as the AUC for prolong hospital stay was 0.905 in <5 VO_2 max group as mentioned in fig-5. So by applying ROC curves we determined that low VO_2 max groups were strong predictors of mortality & morbidity, when validated with STS scores.

DISCUSSION

Coronary artery bypass graft surgery is associated with significant morbidity and mortality[9], when compared to other non-cardiac surgical procedures. Various risk stratification models have been developed over the years, to understand and predict the risks and there associationin patients undergoing coronary artery disease[10-17]. Preoperative risk scores are an essential for risk assessment and cost benefit analysis and indecision making for the most appropriate management strategy.

Table-I: Baseline demographic and clinical characteristics of patients n=39.

Variables	Data (n=39)
Age (years) (Mean ± SD)	55.05 ± 10.12 Minimum =38 Maximum = 74
Height (cm) (Mean ± SD)	167.8 ± 6.31
Weight (kg) (Mean ± SD)	75.3 ± 12.3
BMI Kg/m^2 (Mean ± SD)	26.8 ± 3.81
CXP in minutes (Mean ± SD)	57.9 ± 27.2
CBP in minutes (Mean ± SD)	98.8 ± 40.6
ICU stay (in hrs) (Mean ± SD)	61.9 ± 65.9
Post-op BIPAP use (Mean ± SD)	62.7 ± 38.6
PEEP (Positive End Expiratory Preserve) (Mean ± SD)	6.31 ± 1.25
Respiratory Rate (Mean ± SD)	24.3 ± 8.84
FiO2 (Mean ± SD)	50.9 ± 3.2
Gender n (%)	Male= 35 (89.7%) Female=4 (10.3%)
Per-op IABP , n (%)	6 (15.4%)
Ventilation (hours), n (%)	<24 hrs= 37(94.9%) >24hrs= 2(5.1%)
Ionotropic Requirement n (%)	Without Ionotrope = 3 (7.7%) Mild= 31 (79.5%) Moderate= 4 (10.3%) Heavy = 1 (2.6%)
Re-operation , n (%)	1 (2.6%)
Arrhythmia, n (%)	22 (56.4%)
Infection, n (%)	1 (2.6%)
Mortality, n (%)	3 (8.1%)

Although most of the risk systems were primarily designed to predict mortality, post operative morbidity has been acknowledged asthe major determinant of hospital cost and quality of life after surgery[18]. Our study focuses on the preoperative functional status of the patient and evaluates the early postoperativeoutcomes and validating them with the predicted results of the STS model.

The values of VO_2 max in our study fall inthe lower range as compared to the general population. Patients in our study had significant coronary artery disease (CAD), 28 (71.8%) had triple vessel, 9 (23.1%) had double and 2 (5.1%) had single vessel coronary artery disease. Similar results were shown by Winter *et al*[19], in their workon patients with coronary artery disease wherethey demonstrated the extent of reduction in VO_2 max had correlation with the extent of coronaryartery disease.

Short postoperative ventilation times are accepted as a marker of quality. Prolonged postoperative ventilation time (>24 hours) after isolated CABG is a component of the publicly reported STS CABG composite score and is considered to be an unfavorable outcome[20]. We found a strong association between low preoperative VO_2 max levels and the post-operative ventilation times (*p*-value 0.011). The ROC curves fig-2, revealed strong correlation with the STS predicted results in the low VO_2 max groups.

Patients with low reserves VO_2 max levels (VO_2 max less than 10 ml/kg/min) had a poor post-operative prognosis in our study population. We found a strong correlation between VO_2 max levels and mortality (*p*-value 0.001). The ROC curves fig-1, revealed strong correlation with the STS predicted results in the low VO_2 max groups. Similar results have been published in a review articleby Paul *et al*. Older and Denny ZH Levett[21]. In asystematic review of the literature Roberto Benzo, George A. Kelley, Recchi *et al*[22], found that exercise capacity expressed as VO_2 max, is lowerin patients that develop clinically relevant complications after curative lung resection.

Accurate preoperative risk stratification is important to direct perioperative care. We found apositive correlation between VO_2 max values and hospital stay (*p*-value 0.029). The ROC curves fig-3, revealed strong correlation with the STS predicted results in the low VO_2 max groups. Published workon colorectal surgery[23], major hepatobiliary surgery[24], abdominal aortic surgery[25], and with preoperative cardio-pulmonary exercise testing have linked low VO_2 max and anaerobic threshold with prolonged hospital stay. Similarly published research on major urological surgery also show low maximum oxygen extraction during preoperative CPET as a determinant for prolonged length of hospital stay[23,25].

LIMITATION OF STUDY

As no relevant literature was available utilizing CPET in coronary artery disease, a stringent selection criterion was used and we only studied the patients who had stable coronary artery disease. Due to the small sample size we could not draw conclusive results on the impact of respiratory equivalents (VeO_2 and VCO_2) on respiratory complication. Finally, the study's single-center pilot study and we cannot generalize the results however the study it is ongoing.

CONCLUSION

We conclude from this study that low preoperative VO_2 max levels correlated well with STS scoring system predicted mortality, ventilation time and length of hospital stay.

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CONFLICT OF INTEREST

This study has no conflict of interest to be declared by any author.

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