EFFECTIVENESS OF MAXIMUM FUNCTIONAL CAPACITY AS AN ASSESSMENT TOOL FOR PREOPERATIVE ASSESSMENT FOR CARDIAC SURGERY: AN INITIAL ANALYSIS

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ABSTRACT

Objective: To evaluate the value of VO2 max testing in the preoperative assessment of patients undergoing elective cardiac surgery. To investigate whether poor preoperative cardiopulmonary reserve and comorbid state dictate high risk status and predict complications in patients undergoing elective cardiac surgery.

Study Design: Descriptive cross sectional study.

Place and Duration of Study: AFIC/NIHD Rawalpindi Pakistan, from 2016 to 2017.

Material and Methods: Total number of 44 adult patients undergoing coronary artery bypass graft surgery (CABG) requiring cardiopulmonary bypass (CPB), having an EF of >45% were recruited in the study as per inclusion criteria through nonrandom consecutive sampling.

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. Prolonged ventilation (>24 hrs) was significantly associated with lesser values of VO2max with a p-value of 0.01.Similarly, post-operative prolonged BiPAP usage (>50hrs) was reported more in group I as compared to other groups. The incidence of postoperative pulmonary complications was significantly associated with lower values of VO2 max with a p-value=0.039.

Conclusion: We conclude from this study that VO2 max levels are correlated with postoperative outcome. Patients with cardiopulmonary fitness below the recommended cut-points are susceptible to postoperative complications and mortality.

Keywords: Cardiopulmonary exercise testing, Cardiac surgery, Peak oxygen uptake (VO2peak).

INTRODUCTION

The cardiac surgical patient group is progressively more aged and comorbid and show cases challenges to physicians and surgeons. Correct preoperative risk stratification is imperative to undeviating perioperative care. Postoperative morbidity and mortality are reduced aerobic fitness1,2.

Cardiopulmonary exercise testing is an assimilated and vigorous assessment tool that gives an objective extent of functional capacity and aerobic fitness and recognizes the basis of exercise intolerance. 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 surgery3,4. 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 plans5.

Functional capacity, estimated as the anaerobic threshold and peak oxygen uptake (VO2 peak) forecasts postoperative indisposition and mortality in the mainstream of surgical prospective studies. Surgical outcome in some cohort scan be predicted by The ventilatory parallels for...
carbon dioxide (an index of gas exchange efficiency). Prospective cohort studies are required to increase the precision of risk assessments for diverse patient groups and to elucidate the best grouping of variables to envisage outcome. Primary data advocates that preoperative exercise drill increases fitness, decreases the devastating effects of neoadjuvant chemotherapy, and may impact clinical outcomes positively. Added research is mandatory to ascertain the most effective category of training and the least time interval necessary for a positive outcome.

**MATERIAL AND METHODS**

**Design and Patients**

This observational, cross-sectional, single-centre study was conducted at AFIC/NIHD from 2016-2017 and a total number of 44 adult patients undergoing coronary artery bypass graft surgery (CABG) requiring cardiopulmonary bypass (CPB), having an EF of >45% were recruited in the study as per inclusion criteria through nonrandom consecutive sampling. 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 were excluded from the study. The patients according to inclusion criteria were divided into four groups. This study was carried out according to Good Clinical Practice guidelines and the Institutional ethical review board approved the study. All patients provided written informed consent before recruitment into the study.

**Study Protocol**

Patient data was recorded in our present surgery database registry, comprising of variables related to demographics, clinical history, preoperative, per operative and postoperative characteristics, presence of coexisting cardiovascular and medical conditions, medications at presentation and at discharge. Patients were characterized as having CAD if they have a history of chronic angina, a stress test positive for ischemia, a prior myocardial infarction, coronary stenosis >70%. Coronary artery on coronary angiogram, or prior coronary angioplasty or coronary bypass surgery. Cardiovascular or medical conditions that could precipitate hospitalization were recorded.

**Operational Definitions**

Max oxygen consumption (VO2) max refers to the maximum amount of oxygen that an individual can utilize during intense or maximal exercise. It is measured as "milliliters of oxygen used in one minute per kilogram of body weight."

**Positive end-expiratory pressure (PEEP)** is the positive pressure that will remain in the airways at the end of the respiratory cycle (end of

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**Table-I: Peroperative and postoperative characteristics of patients (n=39).**

<table>
<thead>
<tr>
<th>S No.</th>
<th>Variables</th>
<th>n=39</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Age (years) (Mean ± SD)</td>
<td>55.05 ± 10.12</td>
</tr>
<tr>
<td>2</td>
<td>Gender N (%)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Height (cm) (Mean ± SD)</td>
<td>167.8 ± 6.31</td>
</tr>
<tr>
<td>4</td>
<td>Weight (kg) (Mean ± SD)</td>
<td>75.3 ±12.3</td>
</tr>
<tr>
<td>5</td>
<td>BMI Kg/m² (Mean ± SD)</td>
<td>26.8 ± 3.81</td>
</tr>
<tr>
<td>6</td>
<td>Per-op IABP N (%)</td>
<td>6 (15.4%)</td>
</tr>
<tr>
<td>7</td>
<td>CXP in minutes (Mean ± SD)</td>
<td>57.9 ± 27.2</td>
</tr>
<tr>
<td>8</td>
<td>CBP in minutes (Mean ± SD)</td>
<td>98.8 ± 40.6</td>
</tr>
<tr>
<td>9</td>
<td>ICU stay (in hrs) (Mean ± SD)</td>
<td>61.9 ± 65.9</td>
</tr>
<tr>
<td>10</td>
<td>Ventilation (hours) N (%)</td>
<td>&lt;24 hrs= 37 (94.9%) &gt;24hrs= 2 (5.1%)</td>
</tr>
<tr>
<td>11</td>
<td>Ionotropic requirement N (%)</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Post-op BIPAP use N (%)</td>
<td>62.7 ± 38.6</td>
</tr>
<tr>
<td>13</td>
<td>Respiratory Rate (Mean ± SD)</td>
<td>6.31 ± 1.25</td>
</tr>
<tr>
<td>14</td>
<td>FiO2 (Mean ± SD)</td>
<td>24.3 ± 8.84</td>
</tr>
<tr>
<td>15</td>
<td>Re-operation N (%)</td>
<td>50.9 ± 3.2</td>
</tr>
<tr>
<td>16</td>
<td>Arrhythmia N (%)</td>
<td>2 (2.6%)</td>
</tr>
<tr>
<td>17</td>
<td>Infection</td>
<td>22 (56.4%)</td>
</tr>
<tr>
<td>18</td>
<td>Mortality</td>
<td>3 (8.1%)</td>
</tr>
</tbody>
</table>
Fraction of inspired oxygen (FIO2) is defined as the percentage or concentration of oxygen exhalation) that is greater than the atmospheric pressure in mechanically ventilated patients. A method of ventilation in which airway pressure is maintained above atmospheric pressure at the end of exhalation by means of a mechanical impedance, usually a valve, within the circuit8.

Fraction of inspired oxygen (FIO2) is defined as the percentage or concentration of oxygen that a person inhales (the fraction of inspired oxygen). Supplemental O2 is an FIO2 >21%. Supplemental oxygen means an FIO2 greater than the 21% oxygen in room (ambient) air.

Bi-level Positive Airway Pressure (BiPAP) usage for this study is divided into two groups as >50 hrs and <50 hrs during the intensive care stay.

Cardiopulmonary exercise testing (CPET) was conducted using Brilliance 19S Medisoft cardio respiratory instrumentation) as per standard (modified McNaughten) protocol. Maximum oxygen consumption was recorded for patients after hospital admission.

Endpoints

The primary end points of the study were and incidence of postoperative pulmonary complications (PPCs), occurring within the first 30 postoperative days, BiPAP usage & prolonged ventilation time whereas in hospital mortality was the secondary end point. PPCs were collected prospectively following preagreed definitions and included clinical diagnoses (pneumonia, bronchospasm, and/or ARD9), radiological diagnoses (presence of any degree or location of atelectasis, pneumothorax, and/or pleural effusion)10. Radiological diagnoses were reported by attending radiologists independent of the study, with the final consideration as PPC by the principle investigator.

Data Collection

A structured questionnaire was filled in for each patient; after informed written consent The clinical data was retrieved from our institutional cardiac surgery database.

Data for the (VO2 max) maximum oxygen consumption were collected preoperatively by the cardiac surgeon in charge of the patient and research team at the time of hospital admission. The pulmonary gas exchange parameters recorded were VO2 max in mL/kg/min, Ve CO2 and VeO2.

We recorded general information (gender, height, weight and BMI), preoperative variables (hypertension, diabetes, chronic pulmonary disease, smoking status, cerebrovascular disease, cerebral angiography, and coronary artery disease)10. Radiological diagnoses were reported by attending radiologists independent of the study, with the final consideration as PPC by the principle investigator.

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Table II: Radiological findings.

<table>
<thead>
<tr>
<th>Minor Findings</th>
<th>Major Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimal pleural effusion</td>
<td>Large pleural effusion</td>
</tr>
<tr>
<td>Small atelectasis</td>
<td>Large atelectasis</td>
</tr>
<tr>
<td>Minimal pulmonary congestion</td>
<td>Severe pulmonary congestion</td>
</tr>
<tr>
<td>Small consolidation</td>
<td>Large consolidation</td>
</tr>
<tr>
<td></td>
<td>Pneumothorax</td>
</tr>
</tbody>
</table>

1. Involvement of less than one lobe, and/or judged ‘normal postoperative’.
2. Involvement of one lobe or more, and/or judged ‘no normal postoperative finding’.

Figure 1: Association of Prolong Ventilation with VO2 Max readings (n=39).

We recorded 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 (Intraaortic balloon pump (IABP), cross clamp time (CXP) and bypass time (CPB). Postoperative parameters include ICU stay, ventilation time, ionotropic requirement, postoperative BIPAP usage, respiratory rate, FiO2, PEEP, arrhythmia, infection, reexploration and in hospital mortality. Postoperative inhospital pulmonary complications (PPC) were defined as the occurrence of at least one event during hospital stay.

Statistical Analysis

We summarized population characteristics, perioperative variables, PPCs, and outcomes. All values are represented as mean (SD) or number (percentage). The association between the PPCs (composite and individual PPCs) with demographic data, perioperative data, and clinical outcomes were examined with χ2 or Fisher exact tests for categorical variables and t test or Wilcoxon rank sum test for continuous variables. All analyses were performed using SPSS version 22. A 0.05 level of significance was used for all statistical tests previously mentioned.

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).
Most of the patients belonged to NYHA class II (76.9%) with a mean EF of 56.6 ± 5.17. The demographic and preoperative data is summarized in table-I.

In order to minimize bias and to improve the authenticity of our study results, we divided our study population into four groups depending upon VO2 max readings:

- Group I <5 ml/kg/min, 2 (5.4%)
- Group II 6-10 ml/kg/min, 11 (29.7%)
- Group III 11-15 ml/kg/min, 18 (48.6%)
- Group IV 16-20 ml/kg/min, 6 (16.2%).

Prolonged ventilation (>24 hrs) was significantly associated with lesser values of VO2 max with a p-value of 0.01. Similarly, postoperative prolonged BiPAP usage (>50 hrs) was reported more in group I as compared to other groups.

The incidence of postoperative pulmonary complications was significantly associated with lower values of VO2 max with a p-value of 0.039. The occurrence was more in group I and group II.

Our study findings also document a higher mortality in patients with lesser values (group I & II) of VO2 max readings.

**Discussion**

Coronary artery bypass graft surgery is associated with significant morbidity and mortality when compared to non-cardiac surgical procedures. Over the years, various risk stratification models have been developed to understand and predict the risks and their association in patients undergoing coronary artery disease 11-19. Preoperative risk scores are an essential tool for risk assessment, cost-benefit analysis, and decision making for the most appropriate management strategy.

Although most of the risk systems were primarily designed to predict mortality, postoperative morbidity has been acknowledged as the major determinant of hospital cost and quality of life after surgery 20. Our study focuses on the preoperative functional status of the patient and evaluates the early postoperative outcomes.

The values of VO2 max in our study fall in the 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* 21 in their work on patients with coronary artery disease where they demonstrated the extent of reduction in VO2 max had correlation with the extent of coronary artery 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. We found a strong association between low preoperative VO2 max levels and the postoperative ventilation times (p-value 0.011).

In cardiac surgery patients postoperative pulmonary complications are associated with increased early postoperative mortality, ICU admission, and length of stay. Atelectasis and pleural effusion are common after coronary artery bypass graft surgery. The patients with lower values of preoperative VO2 max had more early minor and major postoperative pulmonary complications as assessed clinically and postoperative x-rays (p-value 0.039). In our work BiPAP usage was a poor indicator of post-operative pulmonary function (p-value 0.460).

Patients with low reserves VO2 max levels (VO2 max less than 10 ml/kg/min) had a poor postoperative prognosis in our study population. We found a strong correlation between VO2 max levels and mortality (p-value 0.001). Similar results have been published in a review article by Paul O. Older and Denny ZH Levett. In a systematic review of the literature Roberto Benzo, George A. Kelley, Recchi et al. found that exercise capacity expressed as VO2 max, is lower in patients that develop clinically relevant complications after curative lung resection.

Accurate preoperative risk stratification is important to direct perioperative care. We found a positive correlation between VO2 max values and hospital stay (p-value 0.029). Published work on colorectal surgery, major hepatobiliary surgery, abdominal aortic surgery and with preoperative cardiopulmonary exercise testing have linked low VO2 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.

CONCLUSION

We conclude from this study that VO2 max levels are correlated with postoperative outcome. Patients with cardiopulmonary fitness below the recommended cut-points are susceptible to postoperative complications and mortality.

Preoperative exercise programmes can improve fitness before surgery. The ability of preoperative exercise interventions to improve postoperative outcome requires further validation.

LIMITATION OF STUDY

Our study presents several limitations. Our findings reflect statistical associations and do not imply cause-effect relationships. Finally, our patient population was limited to only 40 patients and may limit the generalizability of our results to other populations. There is a need for multicenter prospective cohort studies to improve the precision of risk estimates for various patient groups and to clarify the best combination of variables to predict outcome. Early data suggest that preoperative exercise training improves fitness and may improve clinical outcomes.

ACKNOWLEDGEMENT

We would like to take this opportunity to express our gratitude to all consultants and co-workers of the Department of Adult Cardiothoracic Surgery for creating healthy and conductive environment of learning, clinical problems solving and effectively working as a team.

CONFLICT OF INTEREST

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

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