Cardiac Surgery-Specific Screening Tool identifies preoperative undernutrition in cardiac surgery

Lenny M.W. van Venrooij
Marlieke Visser
Rien de Vos
Paul A.M. van Leeuwen
Ron J.G. Peters
Bas A.J.M. de Mol

Abstract

Background: Loss of body tissue resulting in undernutrition can be caused by reduced food intake, altered metabolism, ageing, and physical inactivity. The predominant cause of undernutrition before cardiac operations is unknown. First, we explored the association of reduced food intake and inactivity with undernutrition in patients before elective cardiac operations. Second, we assessed if adding these reversible, cause-based items to the nutritional screening process improved diagnostic accuracy.

Methods: A prospective observational study was performed. Undernutrition was defined by low fat-free mass index (LFFMI) measured by bioelectrical impedance spectroscopy and/or unintended weight loss (UWL). Reduced food intake was defined as the patient having a decreased appetite over the previous month. Patients admitted to hospital preoperatively were assumed to be less physically active than patients awaiting cardiac operations at home. Using these data, we developed a new tool and compared this with an existing cardiac surgery–specific tool (Cardiac Surgery–Specific Malnutrition Universal Screening Tool [CSSM]).

Results: A total of 325 patients who underwent open cardiac operations were included. Reduced food intake and inactivity were associated with undernutrition (odds ratio [OR], 4.2; 95% confidence interval [CI], 2.1– 8.5 and OR, 2.0; 95% CI, 1.0–4.0). Reduced food intake and inactivity were integrated with body mass index (BMI) and UWL into a new scoring system: the Cardiac Surgery–Specific Undernutrition Screening Tool (CSSUST). Sensitivity in identification of undernourished patients was considerably higher with the CSSUST (90%) than with the CSSM (71%) (receiver operating characteristic [ROC] curve–based area under the curve [AUC], 0.79; 95% CI, 0.73– 0.86 and ROC AUC, 0.71; 95% CI, 0.63– 0.80).

Conclusions: Results suggest that reduced food intake and inactivity partly explain undernutrition before cardiac operations. Our new cause-based CSSUST, which includes reduced food intake and inactivity, is superior to existing tools in identifying undernutrition in patients undergoing cardiac operations.
Introduction

Disease-related undernutrition is present in 10% to 25% of patients undergoing cardiac operations [1–5]. Undernutrition results in a higher risk of the patient experiencing postoperative infections and noninfectious complications, as well as higher mortality rates, prolonged hospital and intensive care unit stays, and a poorer quality of life [1–5]. It is beyond dispute that patients with undernutrition before cardiac operations have to be identified and treated [6–8].

Quick-and-easy screening tools to identify undernourished patients are required in daily practice [9, 10]. Nutrition screening is the process of identifying those individuals or groups who may have a nutritional status that is less than optimal and who would benefit from nutritional assessment and intervention by a registered dietitian [9, 11, 12]. Consequently it can be concluded that high sensitivity and, to a lesser extent high specificity, is important in nutritional screening. It has been demonstrated in patients undergoing cardiac operations that the frequently used screening tools, the Malnutrition universal Screening Tool (MUST) and Short Nutritional Assessment Questionnaire, are not sufficiently accurate in identifying undernourished individuals [13]. The accuracy of the existing Cardiac Surgery–Specific MUST (CSSM), which adds a score for advanced age and female sex to the MUST, appeared better than the accuracy of the MUST but still remained marginal (sensitivity 74% and specificity 70% vs. 59% and 83%, respectively) [13].

To further increase the accuracy of screening tools to identify undernourished patients before cardiac operations, it is logical to look in more detail at the cause of preoperative undernutrition before cardiac operations. Generally, loss of body tissue resulting in undernutrition is caused by reduced food intake, altered metabolism, ageing, and physical inactivity [14–16]. However the predominant cause of undernutrition before cardiac operations is unknown. This study explored the association between undernutrition before cardiac operations with the items reduced food intake and physical inactivity because these 2 items are reversible. Furthermore, we examined the possibility of integrating these items into a CSSM undernutrition screening tool, the Cardiac Surgery–Specific Undernutrition Screening Tool (CSSUST), to see if it would be more accurate than the CSSM. Finally, the association of the CSSUST with adverse outcomes after cardiac operations was explored.

Patients and Methods

Patients and Design

This study used data from a prospective observational cohort study that was performed between February 2008 and December 2009 at the Department of Cardiothoracic Surgery at the Academic Medical Center of the University of Amsterdam, The Netherlands [4]. We selected patients (≥18 years) who were admitted to this department for elective coronary artery bypass grafting and/or heart valve operations with extracorporeal circulation.
Chapter 2

Exclusion criteria were not being willing or able to give written informed consent, presence of a pacemaker or congenital heart abnormality, or having undergone an open cardiac operation within the preceding 3 months. This study was approved by the Medical Ethics Committee of the Academic Medical Center.

Reference Standard for Undernutrition
In accordance with the recent literature on cardiac operations, preoperative undernutrition was defined as a low fat-free mass index (FFMI) (kilograms per square meter) and/or unintended weight loss (UWL) in the preceding months [3, 4]. A low FFMI was set at \( \leq 14.6 \text{ kg/m}^2 \) in women and \( \leq 16.7 \text{ kg/m}^2 \) in men [4]. UWL was defined as \( \geq 10\% \) weight loss in the preceding 6 months [3].

The Cardiac Surgery–Specific Malnutrition Screening Tool
The Cardiac Surgery–Specific Malnutrition (CSSM) tool is a nutritional screening tool that integrates a score for advanced age (\( \geq 65 \) years) and female sex with the frequently used screening tool MUST, which includes BMI, UWL, and an acute disease effect score [13] (An Appendix for this article is available in the Auxiliary Annals section of the STS website: http://www.sts.org/auxiliaryannals/vanVenrooij-2013-95-2-642-Appendix.pdf.) A CSSM score of 2 or more indicates a high risk of undernutrition, and a score of less than 2 indicates a low risk of undernutrition.

Assessment of Reduced Food Intake, Physical Inactivity, Body Weight, and Fat-Free Mass
On admission to the cardiothoracic surgical ward, information on nutritional data such as reduced food intake and body weight 1 month and 6 months before the surgical procedure was obtained from the patients. To get information on reduced food intake, patients were asked if their appetite had decreased over the preceding month.

Patients who had been admitted to hospital with cardiac disease and as a consequence of the severity of their disease had to stay in hospital while awaiting a cardiac operation were assumed to be less physically active than patients awaiting cardiac operations at home. Patients admitted to hospital the night before operation were counted as patients awaiting cardiac operations at home.

Actual body weight (kilograms), height (centimeters) and fat-free mass (FFM) (kilograms) were measured with patients barefoot and in their underwear. Body weight was measured to the nearest 0.1 kg using an electronic beam scale with digital read-out (Inventum Scala PW200; Inventum Group BV, Veenendaal, The Netherlands). Height was measured to the nearest 0.5 cm using a stadiometer (Seca, Hamburg, Germany). FFM was determined by bioelectrical impedance spectroscopy (BIS) (BodyScout; Fresenius Kabi, Bad Homburg van der Hohe, Germany). This impedance technique introduces a brief electrical current (5–1,000 kHz) into the body, after which tissue resistance is measured. Because water-containing tissue (ie, FFM) has a low resistance and fat-containing tissue has an
Cardiac surgery-specific screening tool identifies preoperative undernutrition

infinitely high resistance, FFM can be calculated. BIS calculates FFM using body weight, height, and sex [17]. After 10 minutes of relaxation, BIS measurements were obtained. Patients were lying in the supine position with legs apart and arms abducted [18]. Measurements were taken on the right side of the body using 4 electrodes (3M Red Dot; 3M Health Care, Neuss, Germany); 2 electrodes were placed on the dorsum of the hand and 2 were placed on the dorsum of the foot. To adjust for differences in body height, FFMI and BMI were calculated by dividing FFM (kilograms) and body weight (kilograms), respectively, by meters squared height (m²).

Patient Characteristics and Adverse Postoperative Outcome
Additional data describing patient-related, cardiac-related, and operation-related characteristics and postoperative adverse outcomes were extracted from the standard electronic database of the Cardiothoracic Surgery Department and from medical files. The database included the European System for Cardiac Operation Risk Evaluation (EuroSCORE) [19]. This preoperative risk evaluation includes patient-related and cardiac-related factors—age, sex, and comorbidities such as chronic obstructive pulmonary disease or recent myocardial infarction—as well as operation-related factors. A Euro-SCORE of 6 or higher indicates patients with a high operative risk; a score of less than 6 indicates patients with a low or medium operative risk.

Postoperative adverse outcomes included the occurrence of postoperative infection and/or death during the period of hospitalization in the hospital in which the operation was carried out. Postoperative infection was defined as a composite of septicemia, respiratory tract infection, mediastinitis, deep sternal wounds, and leg wound infection. These infectious complications were in accordance with the definitions of The Society of Thoracic Surgeons (version 2.61, 2007; www.sts.org).

Statistical Analyses
First, the association of reduced food intake and physical inactivity with undernutrition (low FFMI and/or UWL) was explored using univariate logistic regression analysis. Odds ratios (ORs) and 95% confidence intervals (95% CIs) were calculated. Using these data, the Cardiac Surgery– Specific Undernutrition Screening Tool (CSSUST) was developed (Table 1). To compare the diagnostic accuracy of the new CSSUST with that of the CSSM [13, 19], sensitivity and specificity and other test characteristics (ie, positive and negative predictive values, positive likelihood ratios, and area under the curve [AUC]) were calculated for both tools. Finally, the association of the CSSUST with postoperative adverse outcomes was explored using logistic regression analyses. OR and 95% CI were calculated. A p value of less than or equal to 0.05 was considered statistically significant. All statistical analyses were performed with SPSS, version 16.0 (IBM Corp, Armonk, NY).
Table 1 The etiology-based Cardiac Surgery-Specific Undernutrition Screening Tool (CSSUST)

<table>
<thead>
<tr>
<th>BMI (kg/m²)</th>
<th>Score*a</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 30</td>
<td>0</td>
</tr>
<tr>
<td>21-30</td>
<td>1</td>
</tr>
<tr>
<td>&lt; 21</td>
<td>2</td>
</tr>
</tbody>
</table>

Unintended weight loss in the past 3-6 months

<table>
<thead>
<tr>
<th>Weight loss</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 5%</td>
<td>0</td>
</tr>
<tr>
<td>5-10%</td>
<td>1</td>
</tr>
<tr>
<td>&gt;10%</td>
<td>2</td>
</tr>
</tbody>
</table>

Did the patient experience a decreased appetite over the last month? 1
Is the patient preoperatively hospitalized? 1

*aScore ≥ 2; high-risk for undernutrition, score <2; low risk for undernutrition

BMI = body mass index.

Results

Patients

A total of 396 patients were asked to participate. Of these patients, 17.9% (n = 71) refused. These patients were older and when assessed using the EuroSCORE, they had a higher operative risk than did those who gave informed consent (p = 0.01 and p < 0.005, respectively). The remaining data from 325 patients were analyzed. Preoperative patient characteristics are summarized in Table 2.

Association of Reduced Food Intake and Physical Inactivity With Undernutrition

Undernutrition defined by low FFMI and/or 10% or more weight loss during the 6 months preceding a surgical procedure was present in 12.7% of participants (n = 41). A low FFMI was present in 8.3% (n = 27) and weight loss in 5.2% (n = 17). Reduced food intake was present in 19.3% (n = 62) of patients and physical inactivity in 28.0% (n = 90). Both reduced food intake and physical inactivity were associated with undernutrition (OR, 4.2; 95% CI,
Cardiac surgery-specific screening tool identifies preoperative undernutrition

2.1–8.5; p < 0.001 and OR, 2.0; 95% CI, 1.0–4.0; p = 0.04, respectively). No associations were found between C-reactive protein values greater than or equal to 5 mg/L or albumin levels less than or equal to 39 g/L and undernutrition.

Table 2 Perioperative characteristics of patients undergoing cardiac surgery (n=325)

<table>
<thead>
<tr>
<th>Patients profile</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female gender</td>
<td>90 (27.7)</td>
</tr>
<tr>
<td>Age in years (mean ± SD)</td>
<td>65.7 ± 10.1</td>
</tr>
<tr>
<td>Age ≥ 65 y</td>
<td>186 (57.2)</td>
</tr>
<tr>
<td>BMI (kg/m²) (mean ± SD)</td>
<td>27.2 ± 4.1</td>
</tr>
<tr>
<td>BMI ≤ 21 kg/m²</td>
<td>13 (4.0)</td>
</tr>
<tr>
<td>BMI ≥ 30 kg/m²</td>
<td>63 (19.4)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Operative risk using EuroSCORE</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0-2 (low risk)</td>
<td>89 (27.4)</td>
</tr>
<tr>
<td>3-5 (medium risk)</td>
<td>109 (33.5)</td>
</tr>
<tr>
<td>≥ 6 (high risk)</td>
<td>127 (39.1)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Laboratory</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>NT pro BNP ≥ 600 ng/L</td>
<td>107 (32.9)</td>
</tr>
<tr>
<td>CRP c ≥ 5 mg/L</td>
<td>53 (16.3)</td>
</tr>
<tr>
<td>Albumin ≤ 39 g/L</td>
<td>12 (3.7)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Operative procedure</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CABG</td>
<td>168 (51.7)</td>
</tr>
<tr>
<td>Heart valve surgery</td>
<td>105 (32.2)</td>
</tr>
<tr>
<td>Both</td>
<td>52 (16.0)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Duration extracorporeal circulation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CPB ≥ 130 min</td>
<td>106 (32.6)</td>
</tr>
<tr>
<td>ACC ≥ 95 min</td>
<td>96 (29.5)</td>
</tr>
</tbody>
</table>

ACC = aortic cross-clamp time; BMI = body mass index; CABG = coronary artery bypass grafting; CPB = cardiopulmonary bypass time; CRP = C-reactive protein; EuroSCORE = European System for Cardiac Operation Risk Evaluation; NT pro BNP = NT prohormone brain natriuretic peptide.
Chapter 2

Accuracy of the CSSUST
The next step was to develop the cause-based CSSUST. This screening tool contains scores for reduced food intake, physical inactivity, BMI, and UWL (Table 1). The weight of scoring each item of the CSSUST is based on the recent literature about undernutrition in patients undergoing cardiac operations [3, 4, 13, 20] and on information from research on undernutrition screening tools in other populations [10, 21]. A score of 2 or greater by the CSSUST indicates a high risk for undernutrition, and a score less than 2 indicates a low risk for undernutrition. The diagnostic accuracy of the newly developed cause-based CSSUST was higher than the accuracy of the CSSM (Table 3; Fig 1). The sensitivity of the CSSUST (score ≥ 2) was 90% with a specificity of 68% (AUC, 0.79; 95% CI, 0.73–0.86). For the CSSM (score ≥ 2) sensitivity and specificity were 71% and 72%, respectively, with an AUC of 0.71 (95% CI, 0.63–0.80). The CSSM scored 33.6% (n = 108) on high risk for undernutrition compared with 38.8% (n = 126) using the CSSUST.

Association of CSSUST and Adverse Outcome After Cardiac Operations
During the stay at the operating hospital, the incidence of postoperative infection was 5.8% (n = 19) and mortality was 2.5% (n = 8). The cumulative incidence of postoperative infection and/or death was 7.7% (n = 25). In contrast to the reference standard for undernutrition (low FFMI and/or UWL; OR, 3.0; 95% CI 1.2–7.7), the CSSUST score was not associated with a higher risk for the occurrence of postoperative infections and/or death (OR, 1.1; 95% CI, 0.5–2.4).
Table 3 Diagnostic accuracy for identifying undernutrition of the CSSUST and the CSSM in patients undergoing cardiac operations

<table>
<thead>
<tr>
<th></th>
<th>Prevalence *</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
<th>NPV</th>
<th>LR +</th>
<th>AUC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% (n)</td>
<td>% (n)</td>
<td>% (n)</td>
<td>% (n)</td>
<td>% (n)</td>
<td>% (n)</td>
<td>[95% CI]</td>
</tr>
<tr>
<td>CSSUST ≥ 2</td>
<td>12.7 (41/322)</td>
<td>90.2 (37/41)</td>
<td>68.3 (192/281)</td>
<td>29.4 (37/126)</td>
<td>97.8 (192/196)</td>
<td>2.8</td>
<td>0.79 [0.73-0.86]</td>
</tr>
<tr>
<td>CSSM ≥ 2</td>
<td>12.7 (41/322)</td>
<td>70.7 (29/41)</td>
<td>71.8 (201/280)</td>
<td>26.9 (29/108)</td>
<td>94.4 (201/213)</td>
<td>2.5</td>
<td>0.71 [0.63-0.80]</td>
</tr>
</tbody>
</table>

* The reference standard for undernutrition was; low fat-free mass index and/or unintended weight loss.

AUC = area under the curve; CI = confidence interval; CSSM = Cardiac Surgery–Specific Malnutrition Universal Screening Tool; CSSUST = Cardiac Surgery–Specific Undernutrition Screening Tool; LR+ = positive likelihood ratio; NPV = negative predictive value; PPV = positive predictive value.
Comment

As hypothesized, both reduced food intake and physical inactivity were associated with the presence of preoperative undernutrition in patients undergoing cardiac operations. As a result, the diagnostic accuracy of the newly developed CSSUST, which includes reduced food intake and physical inactivity, was considerably higher than the accuracy of the existing CSSM. The CSSUST identified 90% of undernourished patients awaiting cardiac operations compared with only 71% identified by the CSSM.

The CSSUST and the CSSM classified about one third of preoperative patients undergoing cardiac operations as being at high risk for undernutrition. Using the reference standard low FFMI and/or UWL, undernutrition was apparent in 12.7%. Thus both screening tools overestimated the presence of undernutrition (low FFMI and/or UWL). This overestimation is congruent with the higher sensitivity of these tools. Furthermore, an overestimation, ie, a false-positive score, resulting in a lower specificity, does little harm to the patient. This is because patients at high risk for undernutrition are not treated immediately [11]. After nutritional screening, further diagnostic assessment by a registered dietitian takes place before an intervention is prescribed. However overestimation should also be avoided because the more false-positive screening results, the higher the workload for the dietitian. With a sensitivity of 90% and specificity of 68%, the cause-based CSSUST—containing a score for BMI, UWL, reduced food intake, and...
physical inactivity—is of sufficient accuracy to screen for undernutrition in patients waiting for cardiac operations. Apart from its higher accuracy, another advantage of the CSSUST compared with the CCSM [13] is that it immediately provides information on the cause of undernutrition in the individual patient, ie, reduced food intake and/or physical inactivity. This benefits patient-tailored dietary treatment. After a patient is scored at high risk for undernutrition by the CSSUST, referral to the dietitian has to take place. The dietitian further assesses nutritional status using a combination of comprehensive instruments such as the Subjective Global Assessment, FFMI using bioelectrical impedance techniques, and dietary history methods [14, 22, 23]. After calculating nutritional requirements, preoperative patient-tailored dietary treatment is prescribed and evaluated by the dietitian. To evaluate changes in nutritional status, items from the diagnostic assessment, such as calculated food intake and FFMI, are used. The CSSUST is a highly accurate tool for preoperative screening in patients undergoing cardiac operations but is not intended to evaluate their improvement during or after nutritional intervention.

Since half of the undernourished patients undergoing cardiac operations are obese, BMI lacks the accuracy to detect undernutrition [4, 20, 23]. Therefore it is recommended that in patients undergoing cardiac operations, body composition should be measured, thus quantifying the level of FFM [20, 23, 24]. However this study clearly demonstrates that the quick-and-easy CSSUST, in contrast to BMI, is capable of identifying 90% of undernourished patients undergoing cardiac operations without the measurement of FFMI. Thus using the CSSUST overcomes the extra workload and the level of expertise required of actually measuring body composition in all patients undergoing cardiac operations. After screening with the CSSUST, only about one third of patients who score as high risk for undernutrition have to undergo comprehensive body composition measurements as part of the diagnostic assessment by the dietitian.

In contrast to the reference standard for undernutrition (low FFMI and/or UWL), a high CSSUST score (≥ 2) was not associated with a higher risk for adverse outcomes after cardiac operations. In light of the relatively low specificity (ie, AUC) of the CSSUST, this is easily understood. The accompanying misclassifications (falsepositive results) showed that the CSSUST is not specific enough to predict adverse outcomes, although its reference standard for undernutrition (low FFMI and/or UWL) is also independent of other risk factors such as operative risk and advanced age [3, 4]. Moreover, a strong association of an undernutrition screening tool with adverse outcomes does not necessarily mean that these patients benefit more from nutritional intervention [12]. In conclusion, although the CSSUST is not associated with adverse outcomes after cardiac operations, the tool has been demonstrated to be highly accurate in preoperatively identifying those patients undergoing cardiac operations who are at high risk for undernutrition. After further diagnostic assessment by the dietitian, those patients who are truly undernourished (low FFMI and/or UWL) and who would benefit from nutritional treatment are identified and
treated. As a result, further weight and/or FFM loss might be hampered, thereby reducing the risk for adverse postoperative outcomes.

In general, 10 to 14 days of preoperative nutritional support is recommended to improve postoperative outcomes in undernourished patients [6]. However, nutritional therapy is probably particularly effective in the context of anabolic interventions such as physical exercise [15, 25–28]. In patients undergoing cardiac operations, the combination of nutrition with physical exercise to treat undernutrition might be of interest, since the results of our study suggest that both reduced food intake and physical inactivity explain part of the etiology of undernutrition. Although physical exercise has been shown to be safe in the setting of cardiac rehabilitation and in the elderly [29, 30], results of clinical studies comparing the effect of nutrition and physical exercise on body composition and clinical outcome are lacking.

This study had some limitations. It cannot be excluded that the results are context specific. Therefore, studies reproducing and cross-validating our preliminary findings are needed. In addition, although it is reasonable to assume that BIS accurately measured FFM in patients awaiting cardiac operations [4, 13, 24, 31, 32], it should be realized that BIS is sensitive to hydration abnormalities. This may have resulted in some bias and overestimation of the metabolically active part of FFM and, thus, in underestimation of undernutrition.

For now, since the majority of patients who are to undergo cardiac operations have to wait several weeks, effective nutritional treatment to improve nutritional status could easily be started in the period before the operation. The CSSUST overcomes the extra workload and the level of expertise required for measuring body composition in all patients undergoing cardiac operations. If positively screened—ie, classified as being at high risk for undernutrition—referral to the dietitian for further diagnostic assessment and treatment takes place to optimize postoperative recovery. Further research to evaluate CSSUST-initiated referrals and intervention in relation to costs and outcome after cardiac operations is now needed.

We would like to thank Dr Mieke Borgmeijer-Hoelen, the nursing team, and the secretarial staff of the department of Cardiothoracic Surgery at the Academic Medical Center, University of Amsterdam, for their assistance in instructing the participants. We also would like to thank Cees Haaring, Trial office, Department of Radiology, University Medical Center Utrecht, for his technical assistance in organizing and linking the preoperative and postoperative databases. Further, we thank Liesbeth Mosman, Evelien Zijlstra, Danja Donkervoort, Denise van Pierre, Wendy Hopmans, and Liska Vulperhorst, all students at the time of the project, for their assistance in collecting data. We also would like to thank Daphne Lees, the authors’ editor, for her critical reading of this paper. Last, we would like to thank all participants willing to participate despite the stressful events in their lives.
References