Epidemiology of disease-related undernutrition and the impact on postoperative adverse outcome in cardiac surgery

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CHAPTER 7

POSTOPERATIVE LOSS OF SKELETAL MUSCLE MASS, COMPLICATIONS AND QUALITY OF LIFE IN PATIENTS UNDERGOING CARDIAC SURGERY

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Mieke MMJ Borgmeijer-Hoelen
Paul AM van Leeuwen
Bas AJM de Mol

ABSTRACT

Objective
The objective of this study was to describe postoperative undernutrition in terms of postoperative losses of appendicular skeletal muscle mass (ASMM) with respect to complications, quality of life, re-admission and one-year mortality after cardiac surgery.

Methods
Patients undergoing cardiac surgery were prospectively followed. ASMM was measured two weeks before and two months after surgery using dual-energy X-ray absorptiometry (DXA). ASMM consists of arm skeletal muscle mass (SMM) and leg SMM. The association between 5% of ASMM decline and postoperative outcome was analyzed using the Chi-square test. A similar approach was used to analyze arm SMM and leg SMM decline separately.

Results
Twenty-nine patients were included (23 male; 34.5% ≥ 65 years). Postoperatively, seven patients (24.1%) lost ≥ 5% ASMM. When analyzed separately, a ≥ 5% decline in leg SMM was associated with a decline in experienced vitality (OR 13.0 [95%CI 1.32-128.11], p=0.03). In contrast, a ≥ 5% loss of arm SMM was associated with fewer in-hospital complications (OR 0.20 [95%CI 0.04-0.98], p=0.04). These patients were characterized by a higher preoperative fat free mass index (FFMI, kg/m²) (p=0.01).

Conclusions
The results suggest that a preoperatively higher FFMI indicates better ability to cope with operative stress, resulting in fewer complications. In addition, postoperative loss of muscle mass was associated with decreased vitality. We advocate further research investigating the effect of preoperative and postoperative nutritional intervention combined with physical exercise programs to increase lean body mass and thereby improve postoperative recovery after cardiac surgery.
**Introduction**

Preoperatively approximately 10-25% of patients undergoing cardiac surgery are undernourished\(^1\)-\(^3\). This preoperative undernutrition is related to adverse postoperative outcome\(^1\)-\(^2\). However, data on postoperative undernutrition in relation to clinical outcome after cardiac surgery are limited\(^4\),\(^5\).

Body composition alters after surgery and lean body mass or i.e., metabolically-active fat-free mass (FFM) is diminished\(^6\)-\(^9\). The largest component of FFM is skeletal muscle mass (SMM) which can be subdivided into appendicular SMM (i.e. limbs) and axial SMM (i.e. trunk). In turn, appendicular SMM can be subdivided into leg SMM and arm SMM. SMM is the component of FFM most sensitive to losses in disease and ageing\(^10\). Severe loss of SMM is associated with postoperative complications such as infection and prolonged hospital stay\(^11\),\(^12\). Loss of SMM is also associated with long-term impairments such as prolonged periods of immobilization, persistent muscle weakness and problems with the reestablishment of daily life to preoperative level\(^13\),\(^14\).

The duration of the catabolic phase after surgery depends on the severity of the injury and is gradually replaced by a convalescent anabolic phase\(^6\). In older patients undergoing a coronary artery bypass graft (CABG), a mean weight loss of 5% has been reported six weeks after surgery\(^5\). Eighteen months after surgery, 36% of these patients still had a body weight that was \(\geq 4\%\) below their preoperative body weight. The interpretation of this weight loss was hampered by the lack of specification, i.e. loss of the metabolically and functionally active FFM, fat mass or fluid loss because of prior fluid retention due to heart failure. The specification of weight loss, however, is essential for a better understanding of the impact of postoperative weight loss on clinical outcome. Therefore, the aim of this study was to evaluate the development of undernutrition after cardiac surgery in terms of postoperative SMM loss with respect to postoperative complications, quality of life, re-admission and one-year mortality.

**Patients and Methods**

**Study design**

In this single-center prospective study, all adult patients (\(\geq 18\) y) visiting the preoperative outpatient clinic of the department of cardiothoracic surgery at the Academic Medical Center were asked to participate. Patients were scheduled for elective open-heart surgery (isolated CABG or heart valve surgery) and had no existing organ failure other than their heart disorder. Patients with pacemakers were excluded.

Two weeks prior to elective surgery, body composition was measured, SF-36 quality of life questionnaires were completed, and blood samples drawn. Postoperative in-hospital complications were registered, and two months after surgery body composi-
tion measurements, quality of life questionnaires and blood samples were repeated. One year after surgery re-admission and mortality data were collected. The study protocol was approved by the institutional review board and all participants gave written informed consent.

**Patient characteristics**

Patient-, cardiac-, and operation-related preoperative baseline characteristics and the European System for Cardiac Operation Risk Evaluation score (EuroSCORE)\(^{15}\), were extracted from medical records and from the database of the department of cardiothoracic surgery.

**Body composition parameters of interest**

Main parameters of interest were changes in body weight, whole body FFM and total SMM, from two weeks before to two months after cardiac surgery. Appendicular SMM (limbs SMM) is assumed to be a constant proportion, approximately 75%, of total SMM (limbs and axial SMM)\(^{16}\). Therefore, the relative changes of appendicular SMM undergoing cardiac surgery can be interpreted as changes of total SMM. For that reason, not the total SMM but the more directly available data of appendicular SMM was analyzed in this study. In addition, also site-specific changes of appendicular SMM, i.e., arm SMM and leg SMM were explored separately. To correct for differences in body height, body mass index (BMI) and FFM index were calculated by dividing weight (kg) by body height squared (m\(^2\))\(^{17}\).

**Body composition measurements**

Pre and postoperatively, patients were asked about their usual weight and any weight changes during the preceding six months. Body weight was measured using an electronic beam scale with digital readout to the nearest 0.1 kg (SECA, Hamburg Germany) with all patients barefoot and in their underwear. Body height was measured to the nearest 0.5 cm (SECA, Hamburg Germany). FFM and appendicular, leg and arm SMM were calculated from dual-energy X-ray absorptiometry total-body scans (DXA) (model QDR 4500 W; Hologic, software for windows XP 12.4, Waltham, MA). The test-retest variation of measuring FFM using the DXA is \(<2.0\%\)\(^{18}\). To decrease inter-operator variability DXA scans were always performed by the same operator. The DXA produces two X-ray beams at 100 and 140 kVp. Attenuation of these two beams depends on mass and type of tissue. DXA measures whole body lean tissue, mineral bone content, fat mass, lean arm tissue and lean leg tissue calculated according to computerized algorithms provided by the manufacturer. Whole body FFM was recalculated by adding whole body lean tissue and mineral bone content. Because lean arm tissue and lean leg tissue approximate arm SMM and leg SMM, appendicular SMM could be calculated by adding arm SMM and leg SMM\(^{16,19}\).
Definition of undernutrition

Preoperative undernutrition in cardiac surgery was defined as ≥ 5% weight loss in the preceding month and/or ≥ 10% weight loss in the preceding 6 months and/or BMI ≤ 21.0 kg/m² and/or FFMI ≤ 14.6 kg/m² in women and ≤ 16.7 kg/m² in men. Postoperative undernutrition was defined as ≥ 5% postoperative loss of appendicular SMM and/or BMI ≤ 21.0 kg/m² and/or FFMI ≤ 14.6 kg/m² in women and ≤ 16.7 kg/m² in men. Since there is no consensus on a cut-off point for the clinically relevant amount of SMM loss, a postoperative loss of ≥ 5% two months after cardiac surgery of total or site-specific SMM was assumed to be clinically relevant. This cut-off point was on one hand based on the commonly used parameter unintended WL of ≥ 5-10% as relevant to identify the undernourished, and on the other hand on the fact that a decrease of ≥ 5% SMM most likely represents real SMM loss, and is not due to imprecision since the test-retest variation in measuring FFM by DXA is <2%.

Postoperative in-hospital complications

The adverse postoperative outcome in-hospital complication was an aggregate of 1) infectious and non-infectious complications, 2) prolonged ICU and hospital stay, and 3) operative mortality. Infectious complications included; respiratory tract and urinary tract infections, and sternal wound and leg wound infections. Non-infectious complications included myocardial infarction (CK-MB ≥ 100 µg/L or ischemic changes on ECG), acute renal failure (postoperative serum creatinine ≥ 200 µmol/L and postoperative creatinine serum values twice as high as preoperative creatinine serum values, or dialysis started postoperatively), CVA and re-operation for bleeding. Prolonged ICU stay was defined as postoperative ICU stay ≥ 48 h (re-admission hours excluded). Prolonged hospital stay was defined as postoperative hospital stay ≥ 7d (re-admission days excluded). All in-hospital outcome data were registered at discharge from the cardiothoracic surgery unit. Operative mortality was defined as mortality up to 30 days postoperatively.

Quality of life

The SF-36 is a multi-item scale measuring eight health concepts (physical functioning, physical and emotional role performance, bodily pain, general health perception, vitality, social functioning and mental health). The items are standardized with scores ranging from 0 to 100. A score of 100 reflects a positive and favourable state of health. The standard SF-36 uses a four-week recall period. In all items, a decrease was defined as a postoperative score lower than the preoperative score.
Re-admission and mortality one year after cardiac surgery

Data on hospital re-admission and mortality one year after cardiac surgery were obtained from general practitioners.

Statistical analyses

Pre- to post surgery body composition changes were analyzed by use of the paired t-test or, if not normally distributed, the non-parametric Wilcoxon signed ranks test was used. The association between a decrease of $\geq 5\%$ of appendicular SMM, arm SMM or leg SMM two months after cardiac surgery and the occurrence of in-hospital complications was analyzed using the Chi-Square test or, if necessary, the Fisher Exact test. Subsequently, odds ratios (OR) with their 95\% confidence intervals (CI) were calculated. A similar approach was used to analyze the association between $\geq 5\%$ appendicular SMM, arm SMM and leg SMM decline and decline of all eight separate domains of the SF-36 quality of life questionnaire, one-year re-admission and mortality rates. Differences in baseline characteristics between those with and without $\geq 5\%$ of appendicular SMM, arm SMM or leg SMM were analyzed by use of the unpaired t-test or, if not normally distributed, the non-parametric Mann-Whitney U test was used. A $p$ value $\leq 0.05$ was considered to indicate statistical significance. Normality was tested using the Kolmogorov-Smirnov test.

Results

Subjects

Between October 2006 and December 2007, 84 patients undergoing cardiac surgery were eligible for inclusion. In December 2006 and January 2007, and between July and September 2007 no patients could be included because no research capacity was available (n=28). Twenty-three patients refused to participate. After inclusion two patients withdrew informed consent, one patient was lost to follow-up and one patient was not operated on. The remaining 29 patients were included and analyzed. Their preoperative baseline characteristics are summarized in table 7.1. In addition, baseline characteristics (i.e. age, gender or operation procedure) did not differ between those patients who did participate and those who were not willing to participate ($p>0.20$).

Preoperative and postoperative undernutrition

Preoperative undernutrition was present in one male patient. He had a BMI $\leq 21$ kg/m$^2$ in combination with a low FFMI (16.5 kg/m$^2$). None of the patients had lost $\geq 5\%$ of body weight in the preceding month or $\geq 10\%$ weight loss in the preceding 6 months. Postoperative undernutrition was present in 27.6\% (n=8); seven patients (24.1\%) lost $\geq 5\%$ appendicular SMM and one patient had a low FFMI.
Table 7.1 Preoperative baseline characteristics of the study cohort (n=29).

<table>
<thead>
<tr>
<th>Patients profile</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender: female</td>
<td>6</td>
<td>20.7</td>
</tr>
<tr>
<td>Age: ≥ 65 y</td>
<td>10</td>
<td>34.5</td>
</tr>
<tr>
<td>BMI ≥ 30.0 kg/m²</td>
<td>10</td>
<td>34.5</td>
</tr>
<tr>
<td>LVEF&lt;sup&gt;a&lt;/sup&gt; &lt; 50%</td>
<td>6</td>
<td>20.7</td>
</tr>
</tbody>
</table>

**EuroSCORE<sup>d</sup>**

<table>
<thead>
<tr>
<th>Risk Level</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-2 (low risk)</td>
<td>16</td>
<td>55.2</td>
</tr>
<tr>
<td>3-5 (medium risk)</td>
<td>11</td>
<td>37.9</td>
</tr>
<tr>
<td>≥ 6 (high risk)</td>
<td>2</td>
<td>6.9</td>
</tr>
</tbody>
</table>

**Laboratory**

<table>
<thead>
<tr>
<th>Test</th>
<th>Value</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemoglobin ≤ 7.0 mmol/L</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>CRP&lt;sup&gt;b&lt;/sup&gt; ≥ 5 mg/L</td>
<td>2</td>
<td>6.9</td>
</tr>
<tr>
<td>Albumin ≤ 39 g/L</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Pre-Alb ≤ 0.19</td>
<td>1</td>
<td>3.7</td>
</tr>
</tbody>
</table>

**Operative procedure**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>CABG&lt;sup&gt;c&lt;/sup&gt;</td>
<td>23</td>
<td>79.3</td>
</tr>
<tr>
<td>Heart valve surgery</td>
<td>6</td>
<td>20.7</td>
</tr>
</tbody>
</table>

**Duration of extracorporeal circulation**<sup>e</sup>

<table>
<thead>
<tr>
<th>Procedure</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiopulmonary bypass time ≥ 120 min</td>
<td>13</td>
<td>44.8</td>
</tr>
<tr>
<td>Aortic cross clamp time ≥ 95 min</td>
<td>7</td>
<td>24.1</td>
</tr>
</tbody>
</table>

<sup>a</sup> LVEF; left ventricle ejection fraction, <sup>b</sup> CRP; C-reactive protein, <sup>c</sup> CABG; coronary artery bypass graft, <sup>d</sup> EuroSCORE; European system for cardiac operative risk evaluation, <sup>e</sup> Two patients underwent off pump surgery.

Postoperatively none of the patients had a BMI ≤ 21 kg/m². The patient with a low FFM1 postoperatively was the same patient as mentioned preoperatively. Two months postoperatively his BMI finally rose above 21 kg/m². Overall, from two weeks pre- to two months post-cardiac surgery, mean body weight, whole body FFM, appendicular SMM and arm SMM decreased (Table 7.2). In turn, mean leg SMM and fat mass did not change significantly.
Table 7.2 Body composition changes 2 months after cardiac surgery.

<table>
<thead>
<tr>
<th>Body composition</th>
<th>Before surgery (mean±SD)</th>
<th>After surgery (mean±SD)</th>
<th>25th</th>
<th>50th</th>
<th>75th</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body weight (kg)</td>
<td>87.2±16.2</td>
<td>85.9±15.9 *</td>
<td>-3.6</td>
<td>-1.8</td>
<td>0.3</td>
</tr>
<tr>
<td>DXA Whole body FFM a (kg)</td>
<td>60.2±10.3</td>
<td>59.4±10.1 *</td>
<td>-3.4</td>
<td>-1.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Appendicular SMM e (kg)</td>
<td>24.9±4.8</td>
<td>24.3±4.9 *</td>
<td>-5.2</td>
<td>-2.3</td>
<td>1.9</td>
</tr>
<tr>
<td>Arm SMM e (kg)</td>
<td>6.6±1.8</td>
<td>6.3±1.6 *</td>
<td>-9.6</td>
<td>-5.4</td>
<td>0.9</td>
</tr>
<tr>
<td>Leg SMM e (kg)</td>
<td>18.3±3.1</td>
<td>18.0±3.4</td>
<td>-5.2</td>
<td>-0.8</td>
<td>2.6</td>
</tr>
<tr>
<td>Whole body fat mass (kg)</td>
<td>24.4±10.0</td>
<td>24.1±9.0</td>
<td>-5.5</td>
<td>-0.7</td>
<td>6.8</td>
</tr>
</tbody>
</table>

*Median preoperative days was 19 d (25th percentile 12, 75th percentile 26), b Median post-operative days was 62 d (25th percentile 48, 75th percentile 69), c %Δ = change from preoperative baseline (((body composition after surgery minus body composition before surgery) divided by body composition before surgery) multiplied with 100), d FFM; fat free body mass, e SMM; skeletal muscle mass, * p ≤ 0.05, paired t-test; p ≤ 0.05 was considered statistically significant.

Postoperative loss of SMM, in-hospital complications and one-year follow-up

Seven patients (24.1%) lost postoperatively ≥ 5% appendicular SMM. Eight patients (27.6%) lost ≥ 5% leg SMM and 16 patients (55.2%) lost ≥ 5% arm SMM. In addition, all seven patients who lost ≥ 5% appendicular SMM also lost ≥ 5% leg SMM. In total eight patients (27.6%) lost ≥ 5% leg SMM. Six of the seven patients who lost ≥ 5% appendicular SMM also lost ≥ 5% arm SMM. Thus, almost all (6/7) patients who lost ≥ 5% appendicular SMM, also lost ≥ 5% arm SMM and ≥ 5% leg SMM. In total 16 patients (55.2%) lost ≥ 5% arm SMM. More than half of patients (10/16) who lost ≥ 5% arm SMM, did not lose ≥ 5% appendicular SMM or leg SMM.

Postoperative in-hospital complications were present in 48.3% of the cardiac surgery patients (Table 7.3). None of the patients was re-admitted after initial hospitalization nor died within one year of cardiac surgery.

No associations were detected between ≥ 5% postoperative loss of appendicular SMM and the occurrence of in-hospital complications. When leg and arm SMM were analyzed separately, patients with ≥ 5% loss of arm SMM two months after cardiac surgery experienced less postoperative in-hospital complications (33.3%) compared to patients without ≥ 5% loss of arm SMM (69.2%) (odds ratio (OR): 0.20 [95%CI 0.04-0.98], p = 0.048). Further, patients with ≥ 5% loss of arm SMM postoperatively, had preoperatively a higher FFMI (20.7±2.2 kg/m²) than those patients without
Table 7.3 In-hospital complications after cardiac surgery.

<table>
<thead>
<tr>
<th>Complication</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>In-hospital complications</td>
<td>14</td>
<td>48.3</td>
</tr>
<tr>
<td>Medical complications</td>
<td>6</td>
<td>20.7</td>
</tr>
<tr>
<td>Non infectious complications</td>
<td>3</td>
<td>10.3</td>
</tr>
<tr>
<td>Infectious complications</td>
<td>4</td>
<td>13.8</td>
</tr>
<tr>
<td>Prolonged stay ≥ 48h</td>
<td>11</td>
<td>37.9</td>
</tr>
<tr>
<td>ICU stay ≥ 48h</td>
<td>7</td>
<td>24.1</td>
</tr>
<tr>
<td>Hospital stay ≥ 7d</td>
<td>5</td>
<td>17.2</td>
</tr>
<tr>
<td>Operative mortality</td>
<td>0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

≥ 5% loss of arm SMM (18.6±1.7 kg/m²) (p=0.010). No other differences in gender, age, operation risk or other preoperative patient baseline characteristics were found between patients with and without ≥ 5% postoperative loss of arm SMM.

Postoperative loss of SMM and quality of life two months after cardiac surgery

Overall, the mean score of three of the eight domains of the SF-36 scoring list changed between the preoperative and postoperative visit. Bodily pain increased (p=0.038) but mental and general health perceptions improved two months after surgery (p=0.006 and p=0.020, respectively). Mean scores of physical functioning, physical and emotional role performance, vitality and social functioning did not change.

When leg and arm SMM were analyzed separately, it was seen that two months after cardiac surgery 88% of patients with ≥ 5% postoperative loss of leg SMM experienced a decline in vitality compared to only 35% of patients without ≥ 5% postoperative loss of leg SMM (OR 13.0 [95%CI 1.32-128.11], p=0.033) (Table 7.4). This same trend was seen for patients with ≥ 5% postoperative loss of appendicular SMM, although not statistically significant (Table 7.4). No differences in gender, age, operation risk, or other preoperative patient characteristics were found between patients with ≥ 5% postoperative loss of leg SMM compared to those without ≥ 5% postoperative loss of leg SMM.
Surgery-induced protein catabolism is a considerable problem after major surgery. In line with this we found that two months after cardiac surgery one-quarter of our patients still had a SMM that was ≥ 5% below their preoperative value. This deterioration of SMM, specifically loss of leg SMM, was associated with a decline in experienced vitality. The same trend, although not statistically significant, was seen between postoperative loss of SMM and decline in perception of general health. On the other hand, in contrast to our hypothesis, it was specifically those patients who lost postoperatively ≥ 5% of arm SMM who experienced fewer in-hospital complications.

There are several partly overlapping explanations for the found association between arm SMM decline and the lower in-hospital complication rate. First, ≥ 5% postoperative loss of arm SMM tended to be more present in patients who underwent CABG than in patients who underwent heart valve surgery, although this difference was not statistically significant (p = 0.06). CABG-surgery is known to be associated with a lower complication rate than heart valve surgery. In general patients indicated for CABG have less severe heart failure and CABG-procedures are related to shorter operation duration compared to heart valve surgery. In our CABG-patients the aortic cross clamp time but not cardiopulmonary bypass time was less than in patients who underwent heart valve surgery (p = 0.02). Severity of heart failure did not differ. Another not inconceivable explanation for the association found between arm muscle degradation and fewer complications after cardiac surgery might be that those patients who lost postoperatively 5% arm SMM had preoperatively a higher FFMI. A low FFMI is known to be associated with an increased occurrence of complica-

Table 7.4 Postoperative skeletal muscle mass decline ≥ 5% and the occurrence of worsen quality of life after cardiac surgery.

<table>
<thead>
<tr>
<th>Worsen GH&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Worsen VT&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>n (%)</td>
<td>n (%)</td>
</tr>
<tr>
<td>7 (24.1)</td>
<td>14 (50.0)</td>
</tr>
<tr>
<td>n (%)</td>
<td>OR [95%CI]</td>
</tr>
<tr>
<td>≥ 5% loss of ASMM&lt;sup&gt;c&lt;/sup&gt;</td>
<td>7</td>
</tr>
<tr>
<td>≥ 5% Leg SMM&lt;sup&gt;d&lt;/sup&gt;</td>
<td>8</td>
</tr>
<tr>
<td>≥ 5% Arm SMM&lt;sup&gt;d&lt;/sup&gt;</td>
<td>16</td>
</tr>
</tbody>
</table>

<sup>a</sup> GH; general health perception, <sup>b</sup> VT; vitality, <sup>c</sup> ASMM; appendicular skeletal muscle mass, <sup>d</sup> SMM; skeletal muscle mass, * p ≤ 0.05, Chi-Square test; p ≤ 0.05 was considered to indicate a statistical significance.
A higher FFMI indicates a higher reserve capacity of muscle proteins. Mobilization of muscle protein is necessary to adequately respond to operative stress. More than two decades ago research of Clowes et al. showed that in patients with severe trauma early in the course before onset of infection, those patients with a more pronounced accelerated synthetic rate of proteins, determined by visceral amino acid clearance (CPCR-AA), survived while those patients with lower synthetic rate of proteins ultimately died. In our study, the favourable more pronounced accelerated synthetic rate of proteins might have been reflected by the more pronounced postoperative decline of arm SMM in those patients with a higher reserve capacity, i.e. a higher FFMI. As a result, fewer in-hospital complications after cardiac surgery occur. In contrast, a postoperative decline of leg SMM was associated with less experienced vitality. We assume that these site-specific differences in SMM loss and their consequences are an effect of site-specific immobilization after cardiac surgery. After cardiac surgery specifically regaining arm SMM is hampered by inactivity of the arms due to pain and the anxiety that moving them may hurt the sternum wound. The finding of a significant postoperatively lower arm SMM but not leg SMM due to site-specific disuse after cardiac surgery was also seen by Miller et al. One may hypothesize that two months after cardiac surgery lost arm SMM still reflects the early postoperative phase in which SMM decline is a consequence of the desirable accelerated synthetic rate of proteins while lost leg SMM two months after cardiac surgery seems to reflect more the current postoperative phase and thereby the not desirable inability to regain postoperatively muscle mass. It would be of interest to identify those patients who are unlikely to adequately regain their SMM within several months after surgery. However, for this purpose a larger study is necessary.

In general, the adverse association found between postoperative loss of leg SMM decline, experienced vitality, i.e. postoperative fatigue, and general health perception can be explained by the catabolic effect of surgical stress followed by impaired nutritional intake and decreased mobility. However, one meta-analysis shows that there is no evidence to support the theory that nutritional interventions alone affect postoperative fatigue. In the setting of cardiac rehabilitation and in elderly patients, early postoperative resistance exercise training has been shown to be safe and of additional value to aerobic regimes to increase muscle strength and mass, clinical status, exercise capacity and quality of life. It has also been shown that mobilization improves nutrition utilization and that specific amino acid supplements increase muscle mass. Therefore, it might be of value to integrate an early training program during hospitalization that focuses on resistance training combined with specific nutritional interventions to overcome the surgery-induced catabolic effect on muscle mass. As a result, recovery and quality of life can be improved. In view of the association found between preoperative FFMI, arm SMM decline and
fewer in-hospital complications, it might be even more effective to increase muscle mass before cardiac surgery. We hypothesize that a combination of preoperative nutritional and physical exercise interventions started during the waiting period before elective surgery and re-started during the early postoperative phase will improve patient’s reserve capacity of metabolically-active muscle mass and accelerate recovery in patients undergoing cardiac surgery. However, studies investigating the effect of this combined intervention are currently lacking.

Our study had some limitations. The sample size of this study was relatively small and was primarily based on the power to detect changes in SMM. Other clinically relevant associations between SMM decline and the occurrence of in-hospital complications and quality of life decline might therefore be underestimated. As can be expected the selection of patients visiting the preoperative outpatient clinic resulted in a lower prevalence of undernutrition and a lower operation risk. Although the sample was quite inhomogeneous, the results of our study seemed not highly vulnerable to confounding. There were no differences shown for gender, age or other preoperative patient characteristics in those patients with ≥ 5% loss of arm SMM vs. those without ≥ 5% loss of arm SMM. Neither for patients with ≥ 5% loss of leg SMM vs. those without ≥ 5% loss of leg SMM differences in preoperative baseline characteristics were shown. Of course, a larger study including multivariate analyses has to confirm our results. Lastly, the DXA method does not distinguish between under or overhydrated lean body mass. Theoretically, SMM loss can be explained by fluid loss due to an improved postoperative cardiac function. However, in both patients with arm SMM and leg SMM decline no differences in existing preoperative heart failure, or the presence of preoperative and postoperative edema were present compared to those without SMM decline.

Since about one-quarter of patients become undernourished after cardiac surgery, care should be taken that not only the preoperative nutritional status but also postoperative nutritional status is evaluated. Practically, we recommend that all cardiac surgery patients should be preoperatively screened for undernutrition with a tool incorporating low BMI and unintended WL. In case of undernourishment, body composition should be monitored to evaluate therapeutic interventions. Future research has to reveal if postoperative recovery is accelerated when the waiting period for elective cardiac surgery and the early postoperative phase are used to increase the reserve capacity of the metabolically active muscle mass using exercise programs combined with nutritional interventions. In addition, also in absence of preoperative nutrition, postoperative nutritional status and nutritional intake should be monitored and when appropriate a dietician consulted.
**Conclusion**

The results suggest that a preoperatively higher FFMI indicates better ability to cope with operative stress, resulting in fewer complications. In addition, postoperative loss of muscle mass was associated with decreased vitality. Further research to assess the effect of preoperative and postoperative nutritional interventions combined with physical exercise programs on FFMI and recovery rates is advocated.

**References**


