Surgery-Induced Inflammation in Relation to Age, Muscle Endurance, and Self-Perceived Fatigue

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Background. Elective abdominal surgery can be considered as a model for an important acute inflammatory trigger in human participants. The aim of the study was to explore the effect of surgery-induced inflammation on muscle strength, endurance, and self-perceived fatigue and its relation with age.

Methods. Sixty-six elective abdominal surgery patients aged 24–91 years were assessed before and at the second and fourth day after surgical intervention. Outcome parameters were grip strength, muscle endurance, fatigue subscale of the Profile of Mood State and visual analog scale for pain, and the circulating inflammatory mediators C-reactive protein, interleukin (IL)-6, and tumor necrosis factor-alpha (TNF-α).

Results. All parameters worsened postoperatively (p < .01) and remained significantly (p < .05) worse until the fourth postoperative day, except for TNF-α (no significant change). Older age was related to higher surgery-induced IL-6 levels at the second (p < .05) and fourth postoperative (p < .01) day and to worse self-perceived fatigue and muscle endurance (both p < .05) at the fourth postoperative day. Higher pain levels at the second day following surgery was related to more self-perceived fatigue (p < .05). Worsening muscle endurance following surgery was significantly related to higher IL-6 release following surgery (p < .01) and self-perceived fatigue (p < .05) at the fourth day following the intervention. Age and surgery-induced increase in circulating IL-6 at Day 4 postsurgery was highest in patients showing both worsened muscle endurance and self-perceived fatigue (p = .01).

Conclusions. Surgery-induced inflammation is related to reduced muscle endurance and the sensation of fatigue. Elderly patients suffer from a higher impact of surgery on muscle endurance.

Key Words: Elderly—Surgery—Acute-phase reaction—Muscle fatigue—Grip strength.

There is strong evidence for the involvement of inflammatory cytokines, such as interleukin (IL)-6 and tumor necrosis factor-alpha (TNF-α), in the development and progression of muscle weakness and atrophy (1). Especially in the context of sarcopenia, the role of chronic low-grade elevations in circulating IL-6 has been well documented (2,3). Due to sarcopenia, most elderly persons function close to their maximal capacities (4), which is thought to contribute to the burden of fatigue in old age. Sarcopenia, inflammation, and fatigue are considered as main features of frailty, one of the major geriatric syndromes (5).

Supplementary muscle weakness induced by acute inflammatory conditions can lead very rapidly to disability at higher ages (6). Previously, we have demonstrated that hospitalized geriatric patients with inflammation due to acute infections and elevated circulating levels of IL-6 showed worse muscle strength and endurance compared with patients without inflammation (7). In another study, we found evidence for the negative impact of inflammation on muscle endurance in hospitalized geriatric patients by demonstrating that muscle fatigue resistance improves significantly (>60%) following treatment with a selective cyclooxygenase-2 (COX-2) inhibitor (8).

Research on acute inflammation in human participants is hindered by the unavailability of preonset data in most clinical conditions. Elective abdominal surgery provokes an acute inflammatory response characterized by a rapid increase in circulating IL-6 concentration, which remains significantly elevated at least up to the third postoperative day (9). The acute-phase response is proportional to the surgery-related tissue trauma, and elevations in IL-6 are related to the severity of the procedures (10). Therefore, elective abdominal surgery can be considered as a model for an important acute inflammatory trigger in human participants.

The occurrence of fatigue (11) as well as muscle weakness and reduced muscle endurance (12–15) has been described following elective surgery. In elderly patients, postoperative fatigue is a negative predictor for the functional recovery (16,17). Moreover, impaired recovery of muscle strength following abdominal surgery has been reported in elderly patients (18). However, the relationship with inflammation remains unclear.

The aim of this prospective exploratory study was to assess the relationship of the systemic inflammatory response with the evolution of muscle strength, muscle endurance, and self-perceived fatigue in the first days following elective abdominal surgery. In order to allow for sufficient variability in the severity of surgery-induced inflammation, different open and laparoscopic procedures were included in this study. Also, patients within a wide age range were
recruited in order to assess whether elderly patients would be more affected compared with younger ones.

**METHODS**

**Participants**

All adult patients (aged ≥18 years) planned for elective abdominal surgery at the Universitair Ziekenhuis Brussel (Brussels, Belgium) from February until July 2006 were eligible to participate. In order to allow for sufficient variability in the severity of surgery-induced inflammation, different open and laparoscopic abdominal procedures were allowed for inclusion in this study. Participants were excluded if they were unavailable for evaluation preoperatively and/or 4 days postoperatively. Comorbidity and cognitive decline were not considered as exclusion criteria per se, provided the patients were able to perform all preintervention testing. Each patient was screened for eligibility in a face-to-face interview during which the study purpose and test procedures were explained. Patients unable to understand or execute the test instructions during the interview were ineligible. Finally, 69 patients aged 24–91 years participated, from whom 36 underwent open and 33 laparoscopic surgery (see Figure 1 and Table 1). The study protocol was approved by the local ethical committee, and all participants gave a written informed consent.

**Postoperative Treatment**

Patients received all treatments judged as necessary by the resident and/or surgeon in charge, independent of the evaluation procedures. Depending on the needs, patients received postoperative analgesic and/or antipyretic treatment consisting in acetaminophen (N = 69), non-steroidal anti-inflammatory drugs (diclofenac or parecoxib, N = 50), Narcotic analgesics (piripamid or pethidine, N = 33; sufentanil, N = 48), and epidural anesthetics (ropivacaine, N = 41). A standard physical therapy treatment was provided.
according to the patient’s needs, which included mainly training of transfers and walking, respiratory exercises, and passive mobilizations of the limbs (i.e., for bedridden patients). In all patients, standard physical therapy was started on the second postoperative day. In general, patients were positioned upright twice a day in a comfortable seat (duration depending on their tolerance) from the second postoperative day on and started to walk on the third or fourth postoperative day (depending on the presence of, e.g., epidural catheter). No specific handgrip strength training exercises were administered. Physical therapists worked independently of the study and were unaware of the results of the measurements.

**Measurements**

Height and weight were measured on admission. Overnight fasting serum samples were collected from the non-dominant arm, and self-perceived fatigue and muscle endurance were measured in all patients 1 day before surgery and 2 and 4 days postsurgery. For each participant, the fatigue perception and endurance were measured on the same moment of the day in order to avoid bias in the repeated measures due to diurnal fluctuations. Main diagnosis, comorbidity and medication use, type of surgery (open or laparoscopic), surgical procedure, occurrence of postoperative complications (also those manifesting after the fourth postoperative day), levels of hemoglobin in peripheral blood (Cell-Dyn Sapphire; Abbott Diagnostics, Louvain-la-Neuve, Belgium), and serum concentration of albumin (nephelometry; Behring, Marburg, Germany; normal value $>3.7$ g/dL) and creatinine (Vitros 5.1 FS; Johnson & Johnson Clinical Diagnostics, Beerse, Belgium) were recorded.

**C-Reactive Protein and Cytokine Determination**

Serum was obtained from the blood and frozen at $-20^\circ$C for later simultaneous determination for the whole group. C-reactive protein (CRP) was assessed by nephelometry (Behring; normal value $<5$ mg/L); sera were assayed for IL-6 and TNF-$\alpha$ by enzyme-linked immunosorbent assay (Biosource international, Nijvel, Belgium) as reported previously (19). All determinations were done within one single assay. Intra-assay precision expressed as coefficient of variance (CV) was determined by the manufacturer for low (L), normal (N), and high (H) standards: for IL-6, CV-L = 7.7%; CV-N = 5.7%; CV-H = 5.1%; detection limit 2.0 ng/L; for TNF-$\alpha$, CV-L = 5.2%; CV-N = 4.1%; CV-H = 3.9%; detection limit 1.7 ng/L.

**Muscle Strength and Endurance**

Muscle strength and endurance were measured using the Martin vigorimeter (Elmed Inc., Addisson, IL) as described previously (7,8,20). Briefly, the shoulder was adducted and neutrally rotated, elbow flexed at $90^\circ$, forearm in neutral position, and wrist in slight extension ($0^\circ$–$30^\circ$). Then, the participant was asked to squeeze the large bulb of the vigorimeter as hard as possible. The highest of three attempts was noted as the maximal grip strength (in kilopascal). Afterward, the participant was again instructed to squeeze the bulb of the vigorimeter as hard as possible and to maintain this maximal pressure; the time (in seconds) during which grip strength dropped to 50% of its maximum was recorded as fatigue resistance. This test is highly reproducible in young as well as in elderly participants with intra-class correlation values ranging from 0.82 to 0.94 and from 0.77 to 0.91, respectively, for intraobserver and interobserver reliability (20). Grip work, an estimate of the total effort produced during the fatigue resistance test, was calculated by multiplying the fatigue resistance (in seconds) by 75% of the maximal grip strength (in kilopascal) (21). In order to avoid bias due to body composition, grip strength and grip work were expressed per kilogram body mass as described previously (21,22). The latter parameter represents the physiological work delivered by the handgrip muscles during the fatigue resistance test and correlates with self-perceived fatigue and physical functioning in healthy elderly persons (21) and frail nursing home residents (22). All muscle tests were executed with the dominant hand. During the grip tests, all patients were carefully instructed to avoid any Valsalva maneuvers or compensatory movements, which might increase intra-abdominal pressure.

**Self-Perceived Fatigue and Pain**

Patients scored their current fatigue level on the Dutch Shortened Profile Of Mood States (23) from which the fatigue subscale (six items scored on a 5-point Likert scale ranging from not at all [score 0] to extremely [score 4]) was computed (total score range from 0 to 24 with higher scores indicating worse fatigue). Pain was scored on a visual analog scale for pain (score range 0–100).

**Statistical Analysis**

Statistical analysis was performed using SPSS release 17.0.1 (SPSS Inc., Chicago, IL). Differences in age according to gender, type of surgery, occurrence of complications, and low serum albumin levels ($<3.7$ g/dL) as well as differences in age and the baseline values for the main outcome measures according to nature of surgery (cancer vs diverticulitis) were analyzed using unpaired t-tests. Changes over time in outcome measures were analyzed using analysis of variance (ANOVA) for repeated measures (preoperative values were used as reference for within-participants contrast analysis). Differences in changes following surgery for the main outcome measures according to nature of surgery (cancer vs diverticulitis) as well as for inflammatory markers according to the occurrence of postoperative complications were analyzed using ANOVA for repeated measures (preoperative values were used as reference for within-participants contrast analysis).
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contrast analysis and interaction with, respectively, nature of surgery and occurrence of postoperative complications [as between-participants factor] was computed. For all parameters, changes relative to preoperative values at Days 2 and 4 after surgery were computed. Changes in circulating levels of IL-6 were normalized by log10 transformation for parametric statistical analysis. Partial correlation coefficients controlling for postoperative medication use, occurrence of complications, and low preoperative albumin level (as an indicator of nutritional status) were computed to assess the relationships between changes over time in muscle endurance, self-perceived fatigue, and circulating inflammatory mediators. Finally, participants were divided in four groups according to their postsurgical changes (worsened vs unchanged/improved) for self-perceived fatigue and muscle endurance. Differences in age and circulating IL-6 were analyzed using ANOVA (with postoperative medication use, occurrence of complications, and low preoperative albumin level as covariates). Significance was set a priori at two-sided $p < .05$.

RESULTS

As shown in Figure 1, most patients underwent surgery for resection of malignant tumors or diverticulitis. In 33% of the participants, the postoperative phase showed some complications, however, none of which had fatal consequences. Although patients who underwent open surgery and those having complications were older, these differences were not significant ($p = .25$ and $p = .06$, respectively).

The baseline characteristics of the participants are reported in Table 1. One male (aged 77 years) and two female (aged 37 and 64 years) were unavailable for fatigue and grip strength assessment at the fourth day postsurgery due to early dismission from the hospital. All outcome parameters worsened significantly ($p < .01$) after surgery and remained significantly ($p < .05$) worse until the fourth postoperative day compared with preoperative values, except for TNF-$\alpha$ which did not change significantly ($p < .05$, repeated measures analysis of variance). Bars represent $M$ values $\pm SE$.

Figure 2. Inflammatory response and changes in muscle performance, self-perceived fatigue, and pain following abdominal surgery. Preoperative levels and values at the second and fourth postoperative day for (A) C-reactive protein (CRP), (B) interleukin (IL)-6, log 10 transformed, (C) tumor necrosis factor-alpha (TNF-$\alpha$), (D) grip strength normalized for body mass, (E) grip work normalized for body mass, (F) self-perceived fatigue (Profile Of Mood State fatigue subscale, total score range from 0 to 24 with higher scores indicating worse fatigue), (G) pain (visual analog scale for pain, score range 0–100). All parameters worsened significantly following surgery and remained significantly worse at the fourth postoperative day compared with preoperative values, except for TNF-$\alpha$ which did not change significantly ($p < .05$, repeated measures analysis of variance). Bars represent $M$ values $\pm SE$. 

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Higher age was related to less surgery-induced pain at the second \((p < .05)\) and fourth \((p < .05)\) day following the intervention (see Table 2). Also, older age was related to higher surgery-induced IL-6 levels at the second \((p < .05)\) and fourth \((p < .01)\) day after the operation and worse self-perceived fatigue and muscle endurance \((both \ p < .05)\) at the fourth day after the operation. Higher pain levels at the second day following surgery was related to more self-perceived fatigue \((p < .05)\). Worsening muscle endurance was significantly related to higher IL-6 levels \((p < .01)\) and self-perceived fatigue \((p < .05)\) at the fourth day following the intervention \(\text{(see Table 2)}\). No significant relations were found with postoperative changes in grip strength, hemoglobin, creatinine, or albumin levels \(\text{(latter results not shown)}\).

In order to investigate the interindividual differences in postoperative muscle endurance and self-perceived fatigue in relation to age and inflammation, participants were divided into four groups according to their postsurgical changes at the fourth day following the intervention \(\text{(worsened vs unchanged or improved)}\) for self-perceived fatigue and muscle endurance \(\text{(grip work corrected for body mass)}\). As shown in Figure 3A, age was significantly different between groups \(\text{(}p = .004)\). Those patients who worsened on both muscle endurance and self-perceived fatigue were older \(\text{(}67.5 \pm 13.7 \text{ years)}\) compared with those who did not worsen at all \(\text{(}57.8 \pm 15.3 \text{ years)}\). Also, changes in levels of circulating IL-6 were significantly different between groups \(\text{(}p = .02; \text{see Figure 3B)}\). Those patients who worsened on both muscle endurance and self-perceived fatigue showed the highest, and patients who did not worsen at all showed the lowest increase in circulating IL-6.

**Discussion**

In this prospective study, we have investigated the relationship of surgery-induced systemic inflammation with the

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Age</th>
<th>VAS-Pain</th>
<th>POMS-Fatigue</th>
<th>CRP</th>
<th>IL-6</th>
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<td>Changes at the second postoperative day</td>
<td></td>
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<tr>
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<td>−0.02</td>
<td>−0.02</td>
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<td>−0.02</td>
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<td>−0.00</td>
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<tr>
<td>CRP</td>
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<td>0.12</td>
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</tr>
<tr>
<td>Grip strength/kg body weight</td>
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<td>−0.20</td>
<td>−0.01</td>
<td>−0.08</td>
</tr>
<tr>
<td>Grip work/kg body weight</td>
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<td>−0.04</td>
<td>0.01</td>
<td>0.14</td>
<td>−0.09</td>
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<tr>
<td>Changes at the fourth postoperative day</td>
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<tr>
<td>VAS-pain</td>
<td>−0.29*</td>
<td>−0.02</td>
<td>−0.37†</td>
<td>−0.16</td>
<td>−0.42†</td>
</tr>
<tr>
<td>POMS-fatigue</td>
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<td>−0.13</td>
<td>0.13</td>
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<td>−0.13</td>
<td>0.13</td>
<td>−0.24</td>
</tr>
<tr>
<td>Grip work/kg body weight</td>
<td>−0.29*</td>
<td>−0.02</td>
<td>−0.37†</td>
<td>−0.16</td>
<td>−0.42†</td>
</tr>
</tbody>
</table>

*Notes:* CRP = C-reactive protein; IL = interleukin; POMS-Fatigue = fatigue subscale of the Profile Of Mood State evaluation \(\text{(higher values indicate more perceived fatigue)}\); VAS-Pain = visual analog scale for pain.

Values represent partial correlation coefficients controlling for postoperative medication use, occurrence of complications, and low preoperative albumin level \(<3.7 \text{ g/dL)}\).

*\text{\textasciitilde}p < .05, \text{\textasciitilde\textasciitilde}p < .01.*
evolution of muscle strength, muscle endurance, and self-perceived fatigue in the first days following elective abdominal surgery. Sixty-six patients within a wide age range (24–91 years) admitted for elective abdominal surgery were assessed preoperatively and at the second and fourth day of postsurgical hospitalization. A significant surgery-induced acute-phase response (CRP and IL-6) was accompanied by significant worsening of muscle strength and endurance, self-perceived fatigue, and pain, which persisted until the fourth postoperative day (all \( p < .01 \) at Day 2, and all \( p < .05 \) at Day 4). IL-6 at Day 4 remained highest compared with preoperative levels in those patients who experienced both worsened muscle endurance and self-perceived fatigue. Similarly to others (24,25), we found no significant changes in circulating levels of TNF-\( \alpha \). Also, in previous research, we observed no significant changes in circulating TNF-\( \alpha \) during hospitalization in geriatric patients with acute infections (7,8). This might be due to the fact that TNF-\( \alpha \) is mainly present at the level of the inflamed tissues and increases less in the blood circulation.

Relationships between age and surgery-induced changes in outcome parameters were analyzed by partial correlations controlling for potential confounders (occurrence of complications, postoperative medication use, and low preoperative albumin levels). The surgery-induced IL-6 level was significantly related to higher age at the second and fourth postoperative day (\( p < .05 \) and \( p < .01 \), respectively) and to worsened muscle endurance at the fourth postoperative day (compared with preoperative values, both \( p < .01 \)). Also, higher age was associated with a more important worsening in muscle endurance following the intervention. Interestingly, these relationships were not apparent at the second postoperative day, indicating that persistently (i.e., during >2 days postsurgery) high IL-6 levels affect significantly muscle endurance. Also, this phenomenon seems to occur more in patients with a higher age.

Although significantly related to IL-6, no significant relations between changes in CRP and other outcome parameters were found. Following an acute inflammatory stimulus (i.e., surgical intervention), a cascade of cytokine responses occur in which IL-6 is the chief stimulator of the production of most acute-phase proteins (26). In fact, during acute inflammation, the production of CRP in the liver is directly stimulated by IL-6 (27) and CRP will reflect rapid fluctuations in circulating IL-6 with a certain delay. Also, the half-life time for CRP is estimated on 19 days, irrespective to its circulating concentration (28). In abdominal surgery, circulating levels of IL-6 start to increase gradually after skin incision to reach a maximum value within 5 hours after the end of the procedure (9,29). After surgery, circulating IL-6 starts to gradually decrease, whereas CRP levels reach a maximum value after 24 hours and remain constant at least up to 50 hour following the intervention (29). This indicates that CRP is a less sensitive parameter for rapid changes in the acute-phase response following surgery.

Postoperative pain was inversely related to age (\( p < .05 \)) but not to the acute-phase response (CRP or IL-6 levels). Also, Watters and colleagues (18) reported less pain in elderly patients following major abdominal surgery, which they partly attributed to altered pharmacokinetics in elderly patients. Here, we controlled for postoperative medication use, eliminating differences in analgesics administration.

Two days following surgery, a significant correlation between pain and self-perceived fatigue was found (\( p < .05 \)), which disappeared at the fourth day. These results indicate that the sensation of fatigue during the first two postoperative days can be partially mediated by pain, whereas later on, it is more related to muscle endurance, reflecting the patient’s functional capacities. In fact, it is to be expected that patients are less bedridden and perform more transfers at the fourth postoperative day. By consequence, those patients with persistent deficits in muscle performance will be more rapidly fatigued following motor tasks (such as walking, transfer to the toilet, or self-care) and will probably report higher levels of self-perceived fatigue.

In clinical decision making, it is important to know whether patients complaining of subjective fatigue are also physically less resistant to fatigue. Therefore, patients were subdivided in four groups according to the changes in self-perceived fatigue and muscle endurance. Remarkably, 60% of the patients showing equal or improved self-perceived fatigue in fact worsened for muscle endurance. Those patients worsening for both subjective and physical fatigue presented a significantly higher age (up to 10 years older, \( p = .004 \)) and a significantly higher surgery-induced increase in circulating IL-6 (up to 6 times, \( p = .02 \)) compared with the other groups. Because we added, respectively, changes in IL-6 and age (besides other confounders) as covariates in the analysis, we can conclude that age and surgery-induced inflammation are independent factors influencing muscle endurance and fatigue in the first postoperative days. These results are in agreement with those of our previous study, where we demonstrated significant relationships between circulating IL-6 and muscle endurance in hospitalized geriatric patients with acute infections (7). In another study, we found evidence for the negative impact of infection-related inflammation on muscle endurance by demonstrating in elderly patients that the fatigue resistance improves significantly (>60%) following treatment with a selective COX-2 inhibitor (8). Previously, we have shown that inflammation plays a mediating role in the relationship between self-perceived fatigue and muscle endurance in community-dwelling elderly persons as well as in nursing home residents without acute conditions (21,22). It has been shown that inflammation induces a “sickness behavior” with fatigue as one of the symptoms. This phenomenon is linked to elevations in circulating cytokines that are responsible for inducing behavioral changes by both direct and indirect signal transduction to the brain. In this context, IL-6 has been recognized to
strongly potentiate the behavioral changes induced by IL-1β (30) Besides the inflammation-induced central fatigue, inflammatory cytokines can promote myofibrillar proteolysis by upregulating the ubiquitin–proteasome pathway and calcium-activated pathway of calpains. Moreover, inflammatory processes can, by increasing the cellular production of reactive oxygen species and nitric oxide, depress muscle contractibility, thus inducing weakness and reduced endurance (for review see (1)).

Overall, the severity of inactivity was comparable in all patients during the first four postoperative days. Hospitalization-related bed rest and inactivity can affect significantly muscle performance (31,32). It cannot be excluded that the short period (4 days) of reduced mobility might have interfered with the inflammation-induced worsening in muscle performance as observed in our study. In our previous work, we have described the evolution of muscle performance in geriatric patients during hospitalization using the same assessment tools as these used in the present study (7,8). We have demonstrated that in patients without inflammation, maximal muscle strength remained unchanged and muscle endurance improved significantly during the first week of hospitalization (7) In contrast, this recovery of muscle endurance was not seen in patients with inflammation due to acute infection (7), unless inflammation was countered by systematically administration of a specific COX-2 inhibitor (Celecoxib) (8). In analogy with the present study, the patients were also confronted with inactivity and/or bed rest following their admission at the hospital and all participants received comparable standard physical therapy. Given the results of our previous studies, it seems likely that the surgery-induced inflammation was the most important factor influencing muscle performance and fatigue in our study compared with the accompanying physical inactivity. However, we have not systematically measured the energy expenditure or monitored the physical activity of the patients during their stay.

Impaired recovery of maximal strength in older abdominal surgery patients compared with younger ones has been documented in an earlier report (18). To our knowledge, this is the first study demonstrating the influence of age on the postoperative evolution of muscle endurance. Because muscle endurance is significantly related to sensations of fatigue and functional mobility in older patients, it can be hypothesized that their physical dependency following surgery will be more pronounced (21,22). Because also other causes of inflammation than the initial surgical insult started to show up, this study was limited to the first postoperative days. After the fourth postoperative day, a large number of patients left the hospital and discharged patients were not further followed up. It remains unclear how long the fatigue and endurance deficits persisted. Because at discharge these parameters remained significantly worse compared with preoperative levels, rehabilitation of the muscle performance should systematically be considered, especially in the older patients.

Maximal strength might be less responsive in order to measure rapid changes in clinical condition compared with muscle endurance. In fact, maximal grip strength reflects the capacity of the muscles to generate a large force in a very short time. Grip work estimates the ability to sustain that strength in time. Specifically, the latter aspect of muscle performance is important during daily activities (e.g., when lifting, manipulating, or bearing objects). From a functional viewpoint, the generated force output of muscles is efficient when it allows performing daily activities in a comfortable manner. In this context, body mass can be of critical importance. Therefore, expressing grip work relative to body weight is an excellent parameter in order to estimate functional muscle performance.

In the present study, homogeneity of underlying pathology or surgical procedure was not a requirement. In fact, different procedures were included in order to allow for sufficient variability in the severity of surgery-induced inflammation. It cannot be denied that the severity of the condition, the general status of the patient, as well as the preferences and skills of the surgeon influence the choice for open or laparoscopic surgery. However, it is unlikely that the observed influence of age and surgery-induced inflammation on muscle endurance and self-perceived fatigue are subject to postoperative complications or treatment. Because we observed moderate, although not significant age differences, all analyses were controlled for occurrence of complications. In addition, analyses were also controlled for postoperative medication use and low preoperative levels of serum albumin, considered as an indicator of nutritional status. However, we have not assessed directly the nutritional status of the patients nor the caloric intake following surgery. Also, because we recruited patients within a wide age range (24–91 years), we have not systematically evaluated these participants using specific geriatric assessment tools (such as dependency in daily and instrumental activities or geriatric depression scale).

As a final conclusion, this study demonstrated that the severity of the surgery-induced inflammatory response is related to reduced muscle endurance and the sensation of fatigue. Elderly patients show a higher impact of surgery on muscle endurance, resulting in a higher risk for developing physical disability after surgical interventions. Strategies to counter inflammation should be considered for future studies.

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