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The Predictive Value and Countermeasures of Sarcopenia on the Prognosis of Postoperative Patients

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ABSTRACT

Sarcopenia is a syndrome characterized by a progressive decrease in skeletal muscle mass, strength, and function. In recent years, its significance as an important prognostic indicator in perioperative surgery management has become increasingly prominent. This article aims to explain the value of sarcopenia in predicting postoperative outcomes and propose a comprehensive intervention strategy based on existing evidence to significantly improve the postoperative prognosis of surgical patients, enhancing their quality of life and reducing the burden of medical care.

KEYWORDS

Sarcopenia; Postoperative outcome; Prognosis prediction; Countermeasure

1. INTRODUCTION

With the increasing aging of the global population, the age spectrum of surgical patients has also increased. Elderly patients are often accompanied by a variety of geriatric syndromes, among which sarcopenia has received increasing attention. Rosenberg first proposed sarcopenia in 1989, which refers to the progressive, systemic loss of skeletal muscle mass and function associated with aging [1]. In recent years, its definition has been continuously improved. Authoritative organizations such as the European Working Group on Sarcopenia in the Elderly have emphasized the simultaneous decline of muscle strength and mass as the core diagnostic criteria [2]. Sarcopenia is not only closely related to falls, disability, decreased quality of life, and increased risk of death in the elderly, but also shows crucial predictive value in the perioperative period. A large number of studies have shown that preoperative sarcopenia is a strong indicator for predicting adverse postoperative outcomes, including but not limited to increased postoperative complications, increased risk of infection, slower recovery, prolonged hospitalization, increased unplanned readmission rate, and decreased long-term survival rate [3-5]. This article systematically discusses the value of sarcopenia as a predictor of postoperative prognosis. It thoroughly explores comprehensive intervention strategies based on evidence-based medicine to provide a reference for clinical practice and improve the outcomes of surgical patients.

2. PATHOGENESIS OF SARCOPENIA AND ITS SIGNIFICANCE IN THE PERIOPERATIVE PERIOD

Sarcopenia is a progressive, age-related loss of skeletal muscle mass and function, the pathogenesis of which involves multiple alterations at the molecular and cellular levels. Current research focuses on the pathogenesis of sarcopenia, including protein homeostasis imbalance, oxidative stress and inflammation, trace element homeostasis disorders, and neuromuscular junction dysfunction, aiming to provide a theoretical basis for a deeper understanding of the disease's pathophysiology.

One core pathogenesis of sarcopenia disrupts the dynamic balance between protein synthesis and degradation. During aging, skeletal muscle develops anabolic resistance, resulting in decreased activity of the mTOR signaling pathway and reduced protein synthesis. At the same time, the protein degradation system is overactivated, especially the ubiquitin-proteasome system and the autophagy-lysosome system, which promotes the ubiquitination and degradation of muscle proteins [4]. Surgical trauma itself is a strong catabolic stimulus that can exacerbate the above-mentioned protein degradation pathways. The preoperative sarcopenia state means that the patient's muscle reserves are insufficient and more susceptible to catabolism.

Oxidative stress and chronic inflammation play an essential role in the pathogenesis of sarcopenia. The decline of mitochondrial function accompanies aging, and the generation of reactive oxygen species (ROS) increases, leading to mitochondrial DNA damage, membrane lipid peroxidation, and reduced ATP synthesis. ROS also activates inflammatory pathways such as NF-κB, promoting the release of pro-inflammatory factors such as TNF-α and IL-6, forming a vicious cycle of oxidative stress and inflammatory response. These factors directly induce protein degradation and inhibit the proliferation and differentiation of satellite cells, thereby impairing muscle regeneration potential. Perioperative ischemia-reperfusion, inflammatory response, etc., can lead to a sharp increase in oxidative stress levels, which has a greater impact on sarcopenia patients with existing mitochondrial dysfunction [4]. In addition, the chronic inflammatory state that exists before surgery makes patients more sensitive to the acute inflammatory response caused by surgical trauma and recovers more slowly.

In recent years, imbalances in trace element homeostasis have been closely related to muscle aging. Iron excess can promote muscle atrophy by inducing ferroptosis, which involves inhibiting GPX4 activity and accumulation of lipid peroxidation. Zinc deficiency affects energy metabolism pathways such as AMPK, SIRT3, and PI3K/AKT, reducing protein synthesis and increasing degradation. Manganese exposure has also been found to be associated with an increased risk of sarcopenia, and its mechanism may be related to inducing oxidative stress and DNA damage [6].

Neuromuscular junction (NMJ) degeneration is the structural basis for the decline in muscle function. With aging, NMJ structural damage leads to decreased innervation efficiency and accelerated muscle fiber denervation. Factors such as mitochondrial dysfunction, oxidative stress, and decreased neurotrophic factors contribute to the degeneration of the NMJ, leading to impaired muscle contraction and muscle fiber type conversion [7].

In summary, the pathogenesis of sarcopenia is a complex network of multi-factor and multi-pathway interactions. Patients with sarcopenia before surgery have a fragile muscle system with reduced reserve capacity and extremely poor tolerance to perioperative stress such as surgical trauma, anesthesia, fasting, and inflammatory response. This explains why it is a strong predictor of poor postoperative prognosis.

3. PREDICTIVE VALUE OF SARCOPENIA ON POSTOPERATIVE OUTCOMES

3.1. Impact on Postoperative Complications

Multiple meta-analyses have shown that preoperative sarcopenia is associated with a significantly increased overall complication rate after major abdominal surgery, including gastrointestinal cancer surgery [3, 8]. A meta-analysis of 29 studies involving 7,176 gastrointestinal cancer patients showed that patients with sarcopenia had a significantly increased risk of major postoperative complications [3].

Sarcopenia patients have a significantly increased risk of postoperative infection. Sarcopenia patients often have impaired immune function, and coupled with poor nutritional status, they are more

susceptible to surgical site infections, lung infections, urinary tract infections, and sepsis [4]. A study of liver transplant recipients showed that sarcopenia is independently associated with an increased risk of severe disease [9].

Compared with patients without sarcopenia, patients with sarcopenia have a higher risk of non-infectious complications after surgery, such as anastomotic leakage and intestinal obstruction [4, 10]. The reduced muscle mass in patients with sarcopenia may affect respiratory muscle strength and cough efficiency, increasing the risk of atelectasis and pneumonia [10].

3.2. Impact on Functional Recovery and Hospitalization Time

Sarcopenia patients have decreased skeletal muscle mass due to a decrease in the number and volume of muscle fibers in skeletal muscle, resulting in a progressive loss of overall muscle mass, strength, and function, which can affect the patient's systemic and local recovery after surgery. Patients with sarcopenia have slow physical recovery after surgery, delayed time to get out of bed, are more likely to suffer from delirium, and take longer to recover functional independence [11]. The length of hospital stay after surgery in patients with sarcopenia is significantly longer than that in the non-sarcopenic group. Multivariate analysis suggests sarcopenia is an independent predictor of prolonged hospital stay [10]. In addition, the readmission rate is also higher in patients with sarcopenia, which may be related to delayed recovery and frequent complications. Due to increased complications and slow recovery, the length of hospital stay and total hospital stay after surgery in patients with sarcopenia are usually significantly longer than those in patients without sarcopenia [3, 10]. This not only increases medical costs but also prolongs the time of exposure to risks such as hospital-acquired infections.

3.3. Impact on Survival Prognosis

Sarcopenia is not only a predictor of short-term prognosis, but is also closely related to long-term survival. In some high-risk surgeries, sarcopenia is associated with increased mortality 30 or 90 days after surgery [12]. For cancer patients, preoperative sarcopenia is an independent negative factor affecting long-term survival. Studies have shown that in various cancers, such as colorectal cancer, gastric cancer, liver cancer, and pancreatic cancer, patients with sarcopenia have shorter disease-free survival and overall survival [3, 8]. A study of 112 colorectal cancer patients found that the risk of death in patients with sarcopenia was three times that of patients without sarcopenia, and the median survival was only 14.6 months [13].

3.4. Impact on Treatment Tolerance and Efficacy

Cancer patients with sarcopenia are more likely to experience dose-limiting toxicities during chemotherapy, such as grade 3-4 bone marrow suppression and neurotoxicity, which can lead to dose reduction, delay, or interruption of chemotherapy, affecting the anti-tumor effect [13]. During radiotherapy for patients with head and neck cancer, sarcopenia is associated with more severe mucosal reactions, pain, and an increased risk of treatment interruption [13].

As an objectively assessable indicator, sarcopenia integrates multiple aspects of information, including nutritional status, inflammatory status, metabolic health, and physiological reserve, providing prognostic value beyond traditional indicators such as age and BMI. Incorporating it into preoperative risk assessment systems can help identify high-risk patients and enable risk stratification and individualized management.

4. COMPREHENSIVE INTERVENTION STRATEGIES FOR PERIOPERATIVE SARCOPENIA

4.1. Preoperative Phase

4.1.1. Nutritional intervention

It is recommended that protein intake reach 1.2-1.5 g/kg/day, and up to 2.0 g/kg/day for severe protein consumption. High-quality protein is preferred. Leucine is a potent stimulator of protein synthesis, and its metabolite HMB has been shown to enhance mTOR signaling, inhibit the ubiquitin proteasome pathway, and reduce muscle protein breakdown. Vitamin D deficiency is associated with decreased muscle strength and increased risk of falls. Vitamin D supplementation can improve muscle function and reduce the risk of falls. Omega-3 polyunsaturated fatty acids have anti-inflammatory properties and may improve the anabolic response of muscles to nutrition and exercise [14].

4.1.2. Exercise training

Resistance training is the most effective way to increase muscle mass and strength. Even short-term preoperative resistance training can be beneficial [14]. Aerobic exercise can improve cardiopulmonary function and prepare for surgery. The program should be individualized, considering the patient's baseline condition and the urgency of the surgery. Combining nutritional supplements with exercise training has a synergistic effect and can maximize the stimulation of muscle protein synthesis.

4.2. Intraoperative Management

Minimally invasive techniques, such as laparoscopy and robotic surgery, should be used whenever possible to minimize surgical trauma and stress. Multimodal analgesia should be employed to reduce opioid dosage and avoid side effects such as nausea, vomiting, and intestinal paralysis, facilitating early postoperative feeding and activity. Intraoperative hypothermia should be prevented to minimize complications.

4.3. Postoperative Period

Follow ERAS principles and resume oral intake or enteral nutrition immediately. Maintain a high protein intake. Consider oral nutritional supplementation or tube feeding for patients with inadequate oral intake. For patients with severe malnutrition or intestinal dysfunction, consider appropriate parenteral nutrition. Encourage early postoperative mobility to prevent muscle atrophy due to disuse. Progressively transition from bed rest and sitting up at the bedside to walking and resistance training. Guidance from a rehabilitation therapist is crucial.

For patients with inferior physical strength who cannot perform conventional exercise, whole-body electrical stimulation training is an alternative method that stimulates muscle contraction through electrical pulses. Studies have shown it can improve body composition, especially with protein supplementation [13]. Attention should be paid to patients' anxiety and depression to improve treatment compliance. Mind-body exercises such as Tai Chi may be beneficial [14]. Establish a multidisciplinary medical team composed of surgeons, nutritionists, rehabilitation therapists, nurses, psychologists, etc., to jointly develop and implement individualized treatment plans and conduct long-term follow-up [15].

5. SUMMARY AND OUTLOOK

Sarcopenia, as a significant geriatric syndrome and comorbidity, plays a crucial role in predicting perioperative outcomes. Preoperative identification of sarcopenia and effective perioperative

management through multimodal interventions and multidisciplinary collaboration are expected to significantly improve both short- and long-term outcomes for surgical patients, enhance their quality of life, and ultimately reduce the societal healthcare burden.

Future research and clinical practice should conduct large-scale epidemiological surveys to clarify its prevalence and prognostic value in various types of surgical patients; at the same time, conduct high-quality, large-sample randomized controlled trials to verify the effectiveness, safety, and cost-effectiveness of different postoperative rehabilitation programs and explore the optimal timing and duration of intervention.

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