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Clinical Research Progress on the Role of Body Composition in the Occurrence of Pulmonary Complications after Radical Resection of Esophageal Cancer

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Abstract

Radical resection of esophageal cancer is a crucial treatment modality for early-stage or locally advanced esophageal cancer. Although surgical techniques have been continuously advancing, due to the complexity of this operation, poor postoperative prognosis frequently occurs. Postoperative complications often have an impact on patients' quality of life and survival time, with pulmonary complications being relatively common. This article reviews the research literature at home and abroad in recent years regarding the role of body composition in the occurrence of pulmonary complications after radical resection of esophageal cancer, and deeply explores the key role of body composition parameters (such as skeletal muscle mass, fat distribution, and body mass index) in predicting postoperative prognosis and guiding clinical interventions. Sarcopenia is associated with adverse prognoses like pulmonary complications and can weaken the immune response. Abnormal visceral fat distribution can trigger systemic inflammation, affect metabolic recovery, and increase the risk of postoperative complications. Tools such as imaging techniques (CT, MRI), non-invasive methods (bioelectrical impedance analysis, dual-energy X-ray absorptiometry), and functional assessments (grip strength test, walking test) can provide data support for patient risk stratification and the development of personalized intervention plans. This review aims to promote the optimization of esophageal cancer treatment plans and the improvement of patients' prognoses. Meanwhile, it points out that current related research faces challenges in terms of research methods, control of individual differences, and standardization of intervention measures.

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Keywords

Post-Esophagectomy, Pulmonary Complications, Body Composition, Sarcopenia, Visceral Fat

1. Introduction

Esophageal cancer is a common digestive tract malignancy with a high incidence and mortality rate globally [1]. Radical surgery remains an important treatment approach for early-stage or locally advanced esophageal cancer [2]. This surgery involves the resection of the tumor and surrounding lymph nodes, offering the most effective long-term survival opportunity for resectable cases. However, it is complex, and the incidence of postoperative complications is high, including pulmonary complications, anastomotic leakage, and nutritional deficiencies, among which pulmonary complications are particularly common [3]. Factors such as pre-existing comorbidities (such as cardiovascular diseases, chronic obstructive pulmonary disease), advanced age, and physical frailty can significantly affect the postoperative prognosis [4] [5]. Nevertheless, traditional prediction facts have difficulty covering the complexity of individual patients [6]. Apparently, more comprehensive assessment tools are needed to identify high-risk patients before surgery and guide the development of personalized intervention measures to improve the prognosis.

In recent years, an increasing number of studies have focused on the important role of body composition in the occurrence, development, treatment, and prognosis of various diseases [7]. Body composition mainly includes adipose tissue, skeletal muscle, water, etc., and changes in its composition and distribution are closely related to the body's nutritional status, metabolic function, immune state, etc. In patients with esophageal cancer, due to factors such as tumor consumption, decreased appetite, and dysphagia, there are often varying degrees of changes in body composition, such as skeletal muscle loss and abnormal fat distribution. These changes in body composition may have an important impact on the prognosis of radical resection of esophageal cancer and the occurrence of pulmonary complications by affecting the patient's nutritional reserve, immune function, and metabolic regulation [8]. In-depth exploration of the role of body composition in the occurrence of pulmonary complications after radical resection of esophageal cancer is of great theoretical and clinical significance for optimizing the treatment strategy of esophageal cancer and improving the patient's prognosis. This article reviews the relevant clinical research progress.

In this context, a deep exploration of the role of body composition in the occurrence of pulmonary complications after radical resection of esophageal cancer is of great theoretical and clinical significance for optimizing the treatment strategies of esophageal cancer and improving the prognosis of patients. This review aims to summarize the progress of relevant clinical studies and specifically discuss the following key issues: Among patients who have received radical resection of esophageal cancer, what is the impact of the changes in specific body composition indices (such as the psoas major muscle area measured by CT and the ratio of visceral fat to subcutaneous fat) on the incidence and severity of postoperative pulmonary complications? What are the respective accuracies and limitations of the body composition indices measured by different assessment methods in predicting the risk of postoperative pulmonary complications? Can more effective preoperative risk stratification and postoperative management strategies be formulated based on the results of body composition assessment, so as to reduce the risk of pulmonary complications and improve the prognosis of patients?

2. Definition and Assessment Methods of Body Composition

Body composition refers to the proportion of fat, muscle, bone, and other tissues that make up the human body. It is of great significance in the treatment of esophageal cancer, and its changes affect the postoperative recovery of patients. It encompasses lean body mass, fat mass, and water content. These components interact with each other, influencing metabolism, immunity, and physical function, all of which are crucial for cancer patients undergoing surgery [9]. Sarcopenia (SMI), characterized by the loss of skeletal muscle mass and function, is a condition that often affects the prognosis of cancer patients [10]. In the study by Elliott *et al.*, SMI was defined as the skeletal muscle area at the L3 level/H^2 [11]. Currently, the critical values and conditions set in various studies for SMI vary. Among different working groups, for example, the criteria of the European Working Group on Sarcopenia in Older People (EWGSOP) may include low muscle mass combined with low muscle strength or low physical performance, while the criteria of the Asian Working Group for Sarcopenia (AWGS), tailored to the Asian population, also include similar indicators and specific critical values [12]. Sarcopenia has been identified as an important predictor of complications (such as pneumonia) in esophageal cancer patients after esophagectomy [13]. Fat distribution is divided into subcutaneous fat (SAF) and visceral fat (VAF) [14]. There are numerous clinical measurement methods, mostly by measuring the cross-sectional area through imaging techniques. These two types of fat have significant differences in metabolic and physiological effects. In particular, visceral fat is associated with systemic inflammation and metabolic disorders. Excessive visceral fat leads to an increase in the production of inflammatory cytokines. In Sakai's study, high visceral fat was linked to a poor prognosis after esophagectomy, emphasizing the need to assess the amount and distribution of fat in these patients [15]. Therefore, evaluating fat distribution, especially visceral fat, is of great significance for surgical risk assessment. BMI, a commonly used body weight indicator, was used to assess cancer risk in the study by Chen *et al.* [16]. However, it has limitations when evaluating complex body compositions, such as in patients with sarcopenic obesity [17]. In such cases, BMI may not accurately reflect the underlying risks because it cannot distinguish between fat and muscle mass. Alternative indicators such as psoas muscle area (PMA) and volume (PMV), and total abdominal muscle area (TAMA) [18] provide a more detailed assessment, thus improving risk assessment.

The assessment of body composition involves a variety of techniques, which can be divided into imaging techniques, non-invasive techniques, and functional assessments, each with its own advantages and disadvantages. The choice needs to consider multiple factors comprehensively. Imaging techniques include computed tomography (CT) and magnetic resonance imaging (MRI) [19]. CT is easily accessible and has a low cost. In the study by Bitencourt *et al.*, CT was used to quantify the cross-sectional areas of muscle and fat tissues at the fifth, eighth, and tenth thoracic vertebrae [14]. MRI has good soft-tissue imaging and is radiation-free, but it is expensive and has low availability. Studies have demonstrated the utility of CT and MRI in predicting patients' body composition, highlighting the value of imaging-based body composition analysis [14] [17] [20]. Non-invasive techniques, such as bioelectrical impedance analysis (BIA) and dual-energy X-ray absorptiometry (DXA), are practical imaging alternatives for assessing body composition [21]. BIA is relatively inexpensive, portable, and easy to use, but its accuracy may be affected by hydration status and other factors. DXA has higher accuracy compared to BIA and can assess regional components, but it is expensive and has poor portability. Functional assessments include grip strength tests and walking tests. In the study by Sato *et al.*, it has been confirmed that handgrip strength is a risk factor for postoperative complications in esophageal cancer patients [22].

Each assessment technique has limitations. Integrating multiple techniques and considering multiple factors comprehensively can help to more comprehensively assess body composition and provide a reference for the treatment of esophageal cancer.

3. Association between Body Composition and Pulmonary Complications after Radical Resection of Esophageal Cancer

The occurrence of postoperative pulmonary complications in esophageal cancer patients has always been a key area of focus in clinical research and treatment. These complications can increase the morbidity and mortality of patients, prolong their hospital stay, raise medical costs, and reduce their overall health level.

3.1. Skeletal Muscle and Pulmonary Complications

The prevalence of sarcopenia varies, but it significantly increases in cancer patients. In the research report by Elliott *et al.*, the prevalence in esophageal cancer patients increased significantly from 16% at the time of diagnosis to 31% after neoadjuvant therapy [11]. From the perspectives of molecular biology and immunology, a reduction in muscle mass impairs immune function through multiple mechanisms. On the one hand, muscles are important sites for protein synthesis.

A decrease in muscle mass leads to a reduction in protein synthesis, including the synthesis of immune-related proteins such as immunoglobulins and complements, which in turn reduces the body's immune defense ability. On the other hand, muscle cells are also involved in the regulation of cytokine secretion. In patients with sarcopenia, cytokine production is impaired. For example, there is an imbalance in the secretion of pro-inflammatory cytokines such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α), which affects the activation, proliferation, and differentiation of immune cells, and thus weakens the ability of the immune system to recognize and eliminate pathogens [7] [23].

In terms of the respiratory defense mechanism, a decrease in skeletal muscle mass leads to respiratory muscle weakness. The weakening of the strength of respiratory muscles (such as the diaphragm, intercostal muscles, etc.) reduces the patient's ability to cough and clear respiratory secretions [21]. Under normal circumstances, there is a mucus-ciliary clearance system on the surface of the respiratory mucosa, which expels respiratory secretions out of the body through the movement of cilia to maintain the cleanliness of the respiratory tract. However, respiratory muscle weakness will affect this process, leading to the accumulation of secretions in the respiratory tract, providing a favorable environment for the growth of pathogens such as bacteria and viruses, and increasing the risk of pulmonary infection.

A number of studies have consistently shown that sarcopenia is an independent risk factor for pulmonary infection after esophageal cancer resection [12] [24] [25]. For example, studies have shown that 55% of patients with sarcopenia develop pulmonary complications, compared to 36% of patients without sarcopenia [11]. A low skeletal muscle mass can weaken the function of respiratory muscles, leading to a decline in patients' ability to cough, clear secretions, and maintain a normal breathing pattern, thus increasing the likelihood of delayed extubation, prolonged hospital stay, and the use of mechanical ventilation. In Nagata's study, the psoas muscle index (PI) decreased significantly 6 months after surgery, which was associated with a higher incidence of pneumonia [26]. These findings highlight the crucial role of skeletal muscle mass in the long-term recovery of patients undergoing esophagectomy.

3.2. Fat and Pulmonary Complications

The distribution and content of fat in the human body have a significant impact on the occurrence of pulmonary complications after radical esophagectomy, especially visceral fat. Visceral fat has high metabolic activity, and when it increases abnormally, it can trigger a series of pathophysiological changes. From the perspective of molecular biology, there are a large number of adipocytes in visceral adipose tissue, and these cells secrete a variety of bioactive substances, such as free fatty acids, cytokines, and adipokines. Among them, the release of free fatty acids can activate the inflammatory signaling pathway, such as the nuclear factor-κB (NF-κB) pathway. Free fatty acids bind to receptors on the cell surface, activate downstream signal transduction, and promote the translocation of NF-κB from the cytoplasm to the nucleus, initiating the transcription of a series of inflammation-related genes, leading to an increase in the expression and secretion of pro-inflammatory cytokines such as interleukin-6 (IL-6), tumor necrosis factor-α (TNF-α), and C-reactive protein (CRP), thus triggering a systemic inflammatory response [27].

In terms of immunology, this systemic inflammatory environment can interfere with the normal function of the immune system. The massive release of inflammatory factors can inhibit the proliferation and activation of T lymphocytes and B lymphocytes, reducing the specific immune response of the body. At the same time, inflammation can also affect the phagocytic function of macrophages, reducing their ability to clear pathogens, making patients more susceptible to infection after surgery [27].

In terms of the physiological function of the lungs, the inflammatory response can cause damage to the pulmonary vascular endothelial cells, increase vascular permeability, cause fluid to exude into the alveoli and interstitium, and affect gas exchange. In addition, inflammation can also stimulate the contraction of bronchial smooth muscle, leading to airway stenosis, increasing the resistance to breathing, and further increasing the burden on the lungs. For example, studies have shown that patients with high visceral fat content may experience immune response disorders after surgery and are more likely to develop infections [27].

In contrast, the impact of subcutaneous fat is relatively weaker [14]. An appropriate amount of subcutaneous fat can serve as an energy reserve, providing necessary energy support for the patient's postoperative recovery, helping to maintain the normal metabolic and physiological functions of the body, and playing a buffering and protective role to a certain extent. However, excessive subcutaneous fat will increase the difficulty of surgery and the difficulty of postoperative wound healing, prolong the patient's hospital stay, and indirectly increase the probability of pulmonary complications. Currently, the research results on the relationship between subcutaneous fat and pulmonary complications after radical resection of esophageal cancer are not entirely consistent, and more research is still needed to further clarify its specific mechanism of action and influencing factors.

When evaluating the relationship between fat and pulmonary complications after radical esophagectomy, commonly used fat indicators include visceral fat area (VFA) and the ratio of visceral fat to subcutaneous fat (VSR), etc. VFA is an indicator that directly reflects the degree of visceral fat accumulation. In Sakai's study, it was found that a high V/P ratio is an independent prognostic factor for low overall survival in esophageal cancer patients who undergo surgery ($p = 0.003$) [15]. VSR takes into account the distribution of both visceral fat and subcutaneous fat. When the VSR increases, it means that there is relatively excessive visceral fat. This abnormal fat distribution is closely related to the body's metabolic disorders and inflammatory state, thus increasing the risk of pulmonary complications. Compared with the simple assessment of BMI, indicators such as VFA and VSR can more accurately predict the patient's prognosis. For example, patients with sarcopenic obesity, referring to those with low muscle mass and excessive fat mass, account for a considerable proportion in the patient population. For instance, the preoperative prevalence in some patients with locally advanced cancer reaches 8.2% [18]. For such patients, the BMI may be high, but BMI cannot accurately diagnose this condition.

3.3. Other Components in the Body and Pulmonary Complications

Apart from skeletal muscle and fat, changes in other components of the body composition, such as water and bone, may also potentially influence the occurrence of pulmonary complications after radical esophagectomy. In esophageal cancer patients, due to factors like dysphagia, insufficient intake, and surgical trauma, water metabolism disorders, such as dehydration or water-sodium retention, are prone to occur. Maintaining an appropriate fluid balance with proper water levels is essential for normal cellular metabolism and physiological functions. In the study by Buchholz *et al.*, a higher daily positive postoperative fluid balance had a significant negative impact on the severity of complications, the incidence of pulmonary complications, and anastomotic leakage [28]. In esophageal cancer patients, osteoporosis can reduce the strength and stability of bones, increasing the likelihood of fractures. For patients who have undergone radical esophagectomy, fractures not only exacerbate the patients' suffering and the difficulty of treatment but may also restrict their mobility, causing them to remain bedridden for extended periods. This, in turn, raises the risk of pulmonary complications such as pulmonary infection and atelectasis. However, currently, there are relatively few studies on the relationship between the measurement of components like water and bone in body composition and pulmonary complications after radical esophagectomy. Further in-depth exploration and research are still required to clarify their clinical significance.

4. Clinical Applications of Body Composition in Pre-Operative and Post-Operative Management

4.1. The Role of Body Composition in Pre-Operative Risk Stratification

Risk stratification before radical esophagectomy is crucial for surgical planning and reducing complications. Body composition parameters play an important role in this process. Sarcopenia or sarcopenic obesity is a predictive factor for poor postoperative prognosis. A low skeletal muscle index (SMI), a high visceral fat area (VFA), or an abnormal body mass index is associated with an increased incidence of complications. For example, in the study by Bitencourt *et al.*, patients with normal lean body mass had a higher survival rate than those with low lean body mass, indicating that lean body mass is a relevant prognostic factor [14]. This is because lean body mass includes key tissues such as skeletal muscles, and normal lean body mass means better physical function reserve and metabolic capacity, enabling the body to better cope with surgical trauma and the postoperative recovery process.

In order to perform more accurate preoperative risk stratification, in addition to considering body composition indices alone, they can also be combined with inflammatory biomarkers. Inflammatory indices such as C-reactive protein (CRP) and interleukin-6 (IL-6) can reflect the inflammatory state of the body [29]. When the body is subjected to surgical trauma or there is a potential risk of infection, the inflammatory response will be enhanced, and the levels of these indices will increase. Combining them with body composition indices for comprehensive assessment can provide a more comprehensive understanding of the patient's physical condition. For example, if a patient not only has a low SMI but also elevated CRP and IL-6 levels, it means that he not only has poor physical reserve but may also be in an active inflammatory state, and the risk of adverse events such as pulmonary complications after surgery will increase significantly.

By integrating multiple body composition parameters to generate a risk score, it can provide doctors with a more intuitive basis for risk assessment and assist doctors in formulating surgical plans and postoperative care plans. For high-risk patients, doctors can consider using more conservative or minimally invasive surgical methods to reduce surgical trauma; in terms of postoperative care, strengthen the monitoring and support of respiratory function, such as conducting blood gas analysis more frequently, promptly detecting and handling abnormal respiratory conditions, and also preparing mechanical ventilation equipment in advance so that timely intervention can be carried out when the patient's respiratory function has problems.

4.2. Monitoring Physical Condition and Post-Operative Recovery Process

Continuous monitoring of the body composition of patients with esophageal cancer is crucial for tracking the postoperative recovery situation and promptly detecting potential problems. This can be achieved through various methods such as repeated CT scans, bioelectrical impedance analysis (BIA), and grip strength tests. A decrease in muscle mass and an increase in fat after surgery often indicate a delay in recovery. Taking sarcopenia as an example, it is closely related to postoperative pneumonia and impaired lung function. The study by Nishi *et al*. pointed out that sarcopenia defined according to the modified criteria of the European Working Group on Sarcopenia in Older People (EWGSOP) is an important predictive indicator of postoperative pneumonia [30].

Body composition indices can detect malnutrition, the progression of sarcopenia, or metabolic problems that are easily overlooked in daily assessments. Patients who have undergone esophagectomy usually experience muscle and fat loss before surgery, and monitoring is helpful for timely intervention. Case studies have shown that incorporating body composition monitoring into postoperative care, such as in the enhanced recovery after surgery (ERAS) program, combined with early jejunostomy tube feeding, can improve the prognosis of patients with esophageal cancer [31]. Under the concept of ERAS, provide patients with nutritional support in the early postoperative period, adjust the nutritional formula according to the results of body composition monitoring, ensure a reasonable intake of nutrients such as protein and calories, and promote muscle synthesis and physical recovery.

In the future, emerging technologies can be used to achieve more convenient and efficient body composition monitoring. For example, wearable devices can collect data such as the patient's exercise and body fat changes in real time through sensors and upload them to a medical platform, and doctors can remotely monitor the patient's physical condition; using artificial intelligence algorithms to analyze these data can more accurately predict the patient's recovery trend, promptly detect potential risks, and provide a basis for adjusting the treatment plan.

4.3. Multidisciplinary Intervention Strategies: Integration of Nutrition and Rehabilitation

Carrying out multidisciplinary interventions based on the results of body composition testing is of great significance for optimizing the prognosis of patients with esophageal cancer. Developing personalized nutrition plans for problems such as sarcopenia and obesity, which are imbalances in body composition, is a key link. In a randomized study comparing enteral nutrition (EN) and parenteral nutrition (PN) during neoadjuvant chemotherapy after surgery for patients with esophageal cancer, it was found that compared with PN, EN support significantly slowed down the decrease in SMI [31], which fully highlights the importance of targeted nutritional interventions. For patients with sarcopenia, the intake of foods rich in high-quality protein, such as lean meat, fish, and beans, should be increased, and at the same time, sufficient vitamin D and calcium should be supplemented to promote muscle synthesis and bone health; for obese patients, especially those with visceral obesity, the total calorie intake should be controlled, the intake of high-fat and high-sugar foods should be reduced, the intake of dietary fiber should be increased, and the metabolic condition should be improved.

Exercise rehabilitation is also an important part of multidisciplinary interventions. The exercise rehabilitation plan should be formulated according to the patient's physical condition and surgical situation, including resistance training, aerobic exercise, and inspiratory muscle training. Resistance training, such as using elastic bands for limb strength exercises, can increase muscle strength and mass; aerobic exercises such as brisk walking and Tai Chi can improve cardiopulmonary function; inspiratory muscle training exercises the respiratory muscles through a special inspiratory trainer to enhance respiratory function, which is particularly beneficial for patients with impaired lung function. For patients with a short 6-minute walk distance before surgery, it indicates that their physical function is poor and the risk of postoperative complications is high [25], and they should be given special attention in the rehabilitation plan, and the exercise intensity and time should be gradually increased.

In addition, preoperative smoking cessation, rational use of steroid drugs, and strengthening oral care should not be ignored. The collaboration of a multidisciplinary team (including surgeons, dietitians, rehabilitation therapists, nurses, etc.) is the key to the postoperative recovery of patients. However, currently, challenges such as shortages of medical resources and poor patient compliance are faced during the implementation process. In response to this, hospitals can optimize resource allocation and train professional members of the multidisciplinary team; strengthen health education for patients to improve their understanding and compliance with the treatment plan.

5. Conclusion

5.1. The Crucial Value of Body Composition Assessment after Esophageal Cancer Surgery

Comprehensive assessment of body composition is of great significance for predicting the prognosis of esophageal cancer patients after esophagectomy. Indicators such as skeletal muscle mass, fat distribution, and BMI affect the incidence of postoperative complications [22] [32]. Sarcopenia can increase the risk of pulmonary infection due to weakened respiratory muscle strength and decreased overall recovery ability [11] [33]. Abnormal fat distribution (especially increased visceral fat) can trigger systemic inflammation, affect metabolism and immunity, and delay wound healing [7] [34]. High BMI is associated with obesity, increasing the risks of wound complications and fatigue [35] [36]. Therefore, body composition is a key factor influencing surgery and recovery. Incorporating its assessment into clinical practice can help identify high-risk patients and implement interventions such as preoperative exercise and nutritional support to improve prognosis and patient care.

5.2. Unified Assessment Methods and Standardized Intervention Programs

Body composition plays a crucial role in the postoperative prognosis of esophageal cancer patients. However, current assessment techniques vary widely. Although imaging techniques are accurate, their popularity is limited. The accuracy and usability of non-invasive methods are uneven, and there is a lack of unified standards for functional assessment. This hinders data comparison and guideline development. Therefore, it is urgent to develop standardized assessment guidelines through international cooperation. This requires unifying assessment methods, promoting applicable tools, and conducting training to ensure the accurate application of results. At the same time, intervention programs should be developed according to individual body composition characteristics. For example, nutritional and exercise plans can be customized for patients with sarcopenia, and measures can be taken to reduce inflammation and improve metabolism for those with visceral obesity. Multicenter trials are important for verifying the effectiveness of the programs. Although faced with challenges such as cost and accessibility, cost-effective solutions should still be explored to improve patients' prognosis and quality of life.

5.3. Future Prospects

To fill the current research gaps, future research can be carried out in the following aspects:

- Optimization of assessment technologies: Conduct in-depth research on the application of multimodal imaging technologies (such as the fusion technologies of CT, MRI, PET, etc.) in the assessment of the body composition of patients with esophageal cancer, further improve the accuracy and comprehensiveness of the assessment, and at the same time, strive to reduce costs and enhance clinical accessibility. Explore new non-invasive assessment technologies to reduce the interference of external factors on existing non-invasive methods (such as bioelectrical impedance analysis) and improve accuracy, so as to achieve wider clinical application.
- Precise prediction and personalized treatment: Utilize machine learning and artificial intelligence algorithms to integrate a large amount of data such as patients' body composition and clinical characteristics, and construct more accurate risk prediction models. Predict in advance the risk of adverse prognoses such as postoperative pulmonary complications in patients with esophageal cancer, providing strong support for personalized treatment.
- Research on long-term impacts and quality of life: Conduct large-scale, long-term follow-up studies to deeply explore the impact of changes in body composition on the long-term quality of life of patients with esophageal cancer, covering multiple dimensions such as physical function, psychological state, and social activities. Incorporate patient-reported outcomes (PROs) into the scope of research to comprehensively understand patients' subjective experiences and needs during the treatment process, so as to formulate more targeted rehabilitation and support strategies and improve patients' long-term quality of life.
- Optimization and verification of intervention measures: Further optimize the multidisciplinary intervention measures based on body composition, strengthen the collaboration of multidisciplinary teams including nutrition, rehabilitation, and nursing, and improve the implementation effect of the intervention measures. Through more high-quality randomized controlled trials and multicenter studies, verify the effectiveness and safety of various intervention measures to provide more reliable evidence for clinical practice. At the same time, explore methods to improve patients' compliance with intervention measures to ensure the maximization of the intervention effect.

Continuous research will promote the development of esophageal cancer treatment towards personalization and high-efficiency, improving patients' survival rate and long-term quality of life.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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