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Impact of preoperative skeletal muscle quality on postoperative infectious complications and recovery following esophagectomy for esophageal cancer

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Abstract

Background: While this relationship between skeletal muscle mass has been reported following esophagectomy, muscle quality measured by intramuscular adipose infiltration might better reflect physiological reserve. This study explored the potential correlation between preoperative quality of skeletal muscles and development of postoperative infectious complications and recovery process in esophageal cancer treated with esophagectomy. **Methods:** 274 patients undergoing a curative esophagectomy were analysed in a retrospective cohort. Skeletal muscle radiodensity was used to quantify skeletal muscle quality from the pre-operative Computed Tomography (CT) at the third lumbar vertebra. Patients were dichotomised at a sex-specific threshold into low and preserved muscle quality. The main end point was postoperative infectious complications within 30 days while the secondary end point was time to functional recovery. Multivariable logistic and Cox regression analyses were used to determine independent predictors. **Results:** 34.7% of the patients developed infectious complications. Low muscle quality was independently linked with infectious complications (Adjusted Odds Ratio (AOR) 2.63, 95% Confidence Interval (CI) 1.48-4.67), and with pneumonia alone (AOR 2.41, 95% CI 1.31-4.44), and was associated with delayed functional recovery (Adjusted Hazard Ratio (AHR) 0.58, 95% CI 0.43-0.78). Muscle quality was a superior discriminating factor than muscle mass. **Conclusion:** Preoperative muscle quality is an independent predictor of infectious complications and conferred additional prognostic information beyond muscle mass, supporting its use in the pre-operative risk assessment and prehabilitation strategy in patients who undergo esophagectomy.

Keywords: Skeletal muscle quality, Myosteatosis, Esophagectomy, Esophageal cancer, Infectious complications, Sarcopenia, Prehabilitation

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1. Introduction

An accurate prediction of patients at high risk of complications due to their physiology is becoming an important aspect of safe delivery of major cancer surgery. No organ centres this more acutely than in esophageal

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cancer where the surgery is curative, the population of patients is rather frail and nutrition depleted and the time period between diagnosis and surgery provides a real opportunity for optimisation. In this context, objective, reproducible markers, which can be obtained from investigations already done at the time of staging, are particularly important, as these do not increase costs or impose a burden for the purposes of determining who should receive treatment, prehabilitation and the level of peri-operative support.

Although esophagectomy is the backbone of curative treatment of locally advanced esophageal cancers, it is one of the most physiologically challenging procedures in gastrointestinal surgery and has a high rate of postoperative morbidity ([Low et al., 2019](#)). In high volume centres, even if infectious complication rate is low, a significant number of patients will develop infectious complications, most commonly pneumonia, anastomotic leak with mediastinal sepsis and surgical-site infection, which are the major reasons for prolonged intensive-care stay, delayed time to first oral intake or perioperative death ([Kassis et al., 2013](#)). These complications also impact on the time to and receipt of adjuvant therapy so prevention also has implications for oncological outcome in addition to immediate recovery.

Pulmonary complications will play a special role after oesophagectomy among these events. The operation provides abdominal access in addition to thoracic access and, often, single-lung ventilation and renders the mechanism of coughing and ability to effectively cough and handle pneumatics of breathing and pulmonary secretions less functional. Potential patients with respiratory muscle dysfunction, therefore, are poorly equipped to make up increased ventilatory demands during the postoperative period and post-operative pneumonia is still one of the most frequent and serious complications in surgery. All therefore preoperative markers of muscle compartment function are directly relevant to the complication of greatest interest in this population.

Preoperative markers reflecting a patient's physiological reserve and his or her ability to withstand surgical insult have therefore become of interest. Body composition, in particular the skeletal muscle compartment, has proven to be an emerging field because it can objectively be quantified from computed tomography imaging already performed for cancer staging ([Prado et al., 2008](#)). Many of the initial studies have concentrated on skeletal muscle mass, and a reduction in muscle mass (termed sarcopenia) has been linked to complications for various types of cancer surgeries ([Elliott et al., 2017](#)). But muscle mass is merely the amount of tissue and is not indicative of functional state.

However, the quality of skeletal muscle was proposed as an more informative collapse of the state of the muscle compartment and this quality is radiologically captured by the degree of intramuscular adipose infiltration and intermuscular adipose infiltration and represented by skeletal muscle radiodensity ([Aubrey et al., 2014](#)). This fatty infiltration of muscle (myosteatosis) is linked to insulin resistance and decreased mitochondrial function, and could be a more accurate representation of the metabolic derangement of the cancer-bearing state than a simple measurement of cross-sectional area ([Correa-de-Araujo et al., 2020](#)). Preservation in bulk does not necessarily go with the preservation of function – a muscle with a lot of fat in it will not work as well as one without fat – meaning two patients with the same muscle quantities can have very different amounts of physiological reserve.

This distinction has special significance for the current times with neoadjuvant therapy. Preoperative chemotherapy and chemoradiotherapy are beneficial for improving the oncologic outcomes but also induce catabolic stress and have been demonstrated to contribute to LOS and degradation of skeletal muscle in the time period before esophagectomy ([Järvinen et al., 2018](#)). The muscle subsequently available at the time of surgery is therefore not only a reflection of the tumour and its metabolic impact but also of the preceding treatment and a measurement, which mirrored the state of the muscle function would include these aspects more fully than a static quantity assessment would. With the ability to monitor the trajectory of radiodensity on serial imaging, it also has the theoretical ability to monitor muscle health across the neoadjuvant period ([Yip et al., 2014](#)).

Until now, the evidence specific to muscle quality and outcomes in the esophagectomy setting has been scant and, when available, has predominantly focused on overall long-term survivorship as opposed to early postoperative infectious morbidity, which is the most predominant factor during the first few weeks of the postoperative course ([Nishigori et al., 2018](#)). Recovery as an outcome of its own has not yet been studied in great detail, although it is important for patients and for the use of healthcare resources and direct comparisons

of muscle quality against muscle mass within the same cohort are rare (Boer *et al.*, 2016). This raises a pivotal question: can the quality of skeletal muscle a patient has coming to esophagectomy predict for infective complications and rate of recovery on its own, and better than muscle mass?

The present study was undertaken with the aim of filling this gap. The goals of this study were to evaluate the independent association of preoperative skeletal muscle quality derived from routine staging Computed Tomography (CT) with postoperative infectious complications following esophagectomy for esophageal cancer, to investigate the correlation of skeletal muscle quality with the rate of functional recovery, and to compare the ability of skeletal muscle quality with that of traditional skeletal muscle mass to predict postoperative infectious complication development.

2. Materials and methods

2.1. Study design and setting

This was a retrospective observational cohort study at a tertiary referral center for upper-gastrointestinal malignancy. Patients who had an esophagectomy for a confirmed esophageal cancer were identified from a prospectively created surgical database and underwent consecutive resection over a specific time interval. The study was designed and reported using the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement for cohort studies (von Elm *et al.*, 2007). The protocol was reviewed and approved by the institutional review board that determined that informed consent for each subject was not required because the data were anonymised and used retrospectively. All procedures conformed to the principles of the Declaration of Helsinki.

2.2. Participants and eligibility criteria

Eligible patients were those 18 years or older with oesophageal squamous cell cancer or adenocarcinoma who had undergone a curative intent oesophagectomy with gastric conduit reconstruction. Exclusion criteria included emergency surgery, palliative or non-curative surgery, salvage surgery following definitive chemoradiotherapy, no evaluable pre-op Computed Tomography (CT) scan within 8-wk of surgery, prior surgery affecting major muscles of the abdomen or chest and missing clinical/outcomes data. These criteria were implemented to ensure that muscle measurements were representative of the muscle before surgery and that the group of patients was as similar as possible with respect to the intent to cure.

2.3. Assessment of skeletal muscle quality and mass

Body composition measurements were performed using a single axial CT scan at the third lumbar vertebra (L3), which has been shown to be the accepted reference for a correlation with global SM. According to predefined Hounsfield Unit (HU) thresholds for skeletal muscles, the paraspinal, psoas and abdominal wall skeletal muscles were segmented and two parameters were obtained for each patient. Lower radiodensity in Hounsfield Unit (HU) of the skeletal muscles means more fatty infiltration, which represents poor muscle quality. Skeletal muscle mass was measured and expressed as skeletal muscle index that is, total muscle cross sectional area divided by the square of patients' height.

All measurements were made by a trained blinded investigator and radiologist and a random sample was re-measured for reproducibility. Low and preserved muscle-quality groups were formed via sex-specific thresholds for skeletal muscle radiodensity that were set using receiver operating characteristic analysis in the cohort; low mass was determined by the well-established thresholds for skeletal muscle index. To avoid systematic measurement error due to the use of intravenous contrast, all measurements were performed on a single and identical phased series and – to maximize reliability of comparison – all measurements were taken for the same vertebral landmark in all patients.

2.4. Surgical procedure, perioperative care, and outcomes

Proximal or distal gastrotomy was performed to free the gastric conduit or specimen for esophagectomy, which was performed by expert thoracic and upper-gastrointestinal (UGI) surgeons using open, minimally invasive (MIS), or hybrid surgery, with gastric conduit reconstruction; Anastomosis was fashioned in the chest or neck based on tumour location and surgeon preference. All patients had a standardised enhanced-

recovery pathway and a uniform antimicrobial and thromboembolic prophylaxis, structured respiratory physiotherapy, early mobilisation and a planned enteral/oral feeding pathway.

The primary outcome was any postoperative infectious complication within 30 days, which included pneumonia, anastomotic leak with infection, surgical-site infection and any other culture-substantial infectious complication, defined according to standard criteria and severity rated by using the Clavien–Dindo classification ([Dindo *et al.*, 2004](#)). Diagnosis of pneumonia was made by taking into account compatible clinical, radiological and laboratory findings. The secondary outcome was time to functional recovery defined as the duration of time elapsed from surgery to when the patient was able to consume oral or enteral nutrition without support, move around subsequently to surgery without support, and could manage pain with oral analgesics and required no intravenous support. Two clinicians independent of the operating team adjudicated outcomes without knowledge of the body-composition measurements and any disagreements were decided by consensus.

2.5. Statistical analysis

Continuous variables are expressed as mean with standard deviation or median with interquartile range and compared using independent-samples t-test or Mann–Whitney U-test, and categorical variables as frequencies and percentages and compared using the chi-square test or Fisher exact test. Multivariable logistic regression analysis (adjusted odds ratios with 95% confidence intervals) was used to assess the independent association between muscle quality and infectious complications, and multivariable Cox proportional-hazards regression analysis (hazard ratios with 95% confidence intervals) was used to assess the independent association between muscle quality and time to functional recovery. Discriminative ability was compared between muscle quality and muscle mass using area under the receiver operating characteristic curve and model calibration was conducted by applying test of Hosmer–Lemeshow goodness-of-fit. Statistically significant p-values, set at <0.05 , were determined using a two-sided value.

3. Results

3.1. Patient characteristics

A total of 274 patients were considered to be eligible and were included in the analysis. The mean age was 64.2 years, and 72.3% were male. Sixty-one percent (61.7%) of tumours were treated with minimally invasive or hybrid approach, 33.9% were treated with invariant surgery, and 66.1% of the patients underwent neoadjuvant therapy; histopathological results were squamous cell carcinoma in 58.4% and adenocarcinoma in the remaining cases. Based on the sex-specific radiodensity threshold, 114 patients (41.6%) had a low level of skeletal muscle quality. The low quality group had a higher BMI and higher age than the other group reflecting the known association of fatty infiltration of muscle with weight gain and aging (Table 1).

3.2. Infectious complications

Overall, 274 patients developed infectious complications, an incidence of 34.7%, following the surgery. The most common was pneumonia, then anastomotic leak/ infection, or surgical-site infection. Bigger proportion of patients in the low muscle-quality group had an infectious complication (nearly 50%) than in the preserved quality intervention group (about 25%). The effects were all in the same direction for each individual category of infection, with the highest absolute effects occurring for pneumonia. Infectious complications by muscle-quality group are presented in Table 2 and graphically in Figure 1.

3.3. Multivariable analysis of infectious complications

Low skeletal muscle quality was independently associated with any infectious complication, with an adjusted ODDS ratio(OR) of 2.63 (95% CI : 1.48–4.67, P-value: 0.001) when adjusted for age, BMI, ASA physical status, tumour stage, neoadjuvant therapy, approach of surgery and skeletal muscle mass. This association was similar for pneumonia, alone (adjusted OR 2.41, 95% CI 1.31–4.44, $p = 0.005$). In particular, it was found that low skeletal muscle mass was associated with disease in the univariable analysis but became non-significant when muscle quality was added, indicating that muscle quality provided information over and above the quantity of muscle. Of the clinical covariates, advanced physical status remained significantly associated with infectious complications (Table 3).

Table 1: Baseline characteristics by skeletal muscle-quality group

Characteristic	Preserved quality (n = 160)	Low quality (n = 114)	p-value
Age, years, mean (SD)	62.1 (8.9)	67.1 (9.4)	< 0.001
Male sex, n (%)	114 (71.3)	84 (73.7)	0.664
Body mass index, kg/m ² , mean (SD)	23.4 (3.2)	25.8 (4.1)	< 0.001
Current smoker, n (%)	48 (30.0)	41 (36.0)	0.300
ASA III-IV, n (%)	39 (24.4)	44 (38.6)	0.012
Squamous cell carcinoma, n (%)	96 (60.0)	64 (56.1)	0.518
Neoadjuvant therapy, n (%)	108 (67.5)	73 (64.0)	0.545
Minimally invasive/hybrid, n (%)	102 (63.8)	67 (58.8)	0.397
Cervical anastomosis, n (%)	58 (36.3)	43 (37.7)	0.806
TNM stage III, n (%)	62 (38.8)	49 (43.0)	0.483

Table 2: Unadjusted incidence of infectious complications by muscle-quality group

Complication	Preserved quality (n = 160)	Low quality (n = 114)	p-value
Any infectious complication, n (%)	39 (24.4)	54 (47.4)	< 0.001
Pneumonia, n (%)	25 (15.6)	39 (34.2)	< 0.001
Anastomotic leak with infection, n (%)	15 (9.4)	24 (21.1)	0.006
Surgical-site infection, n (%)	14 (8.9)	21 (18.4)	0.019
Reoperation, n (%)	11 (6.9)	18 (15.8)	0.017
ICU stay > 5 days, n (%)	26 (16.3)	38 (33.3)	0.001

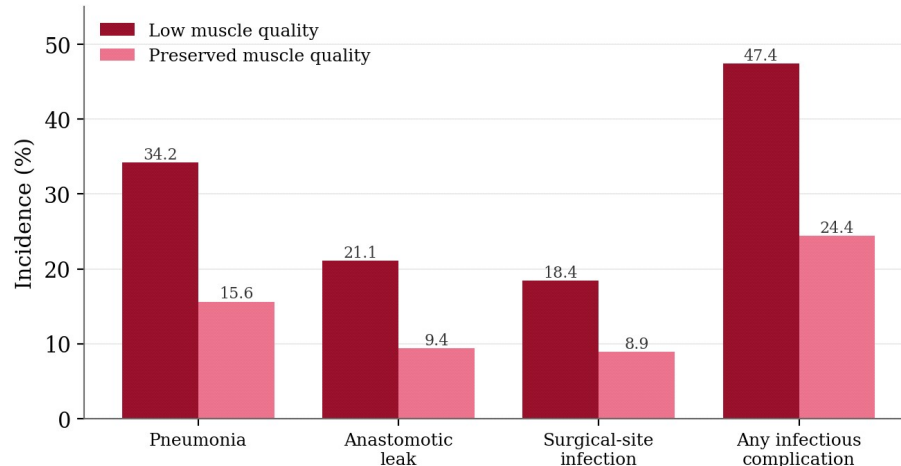
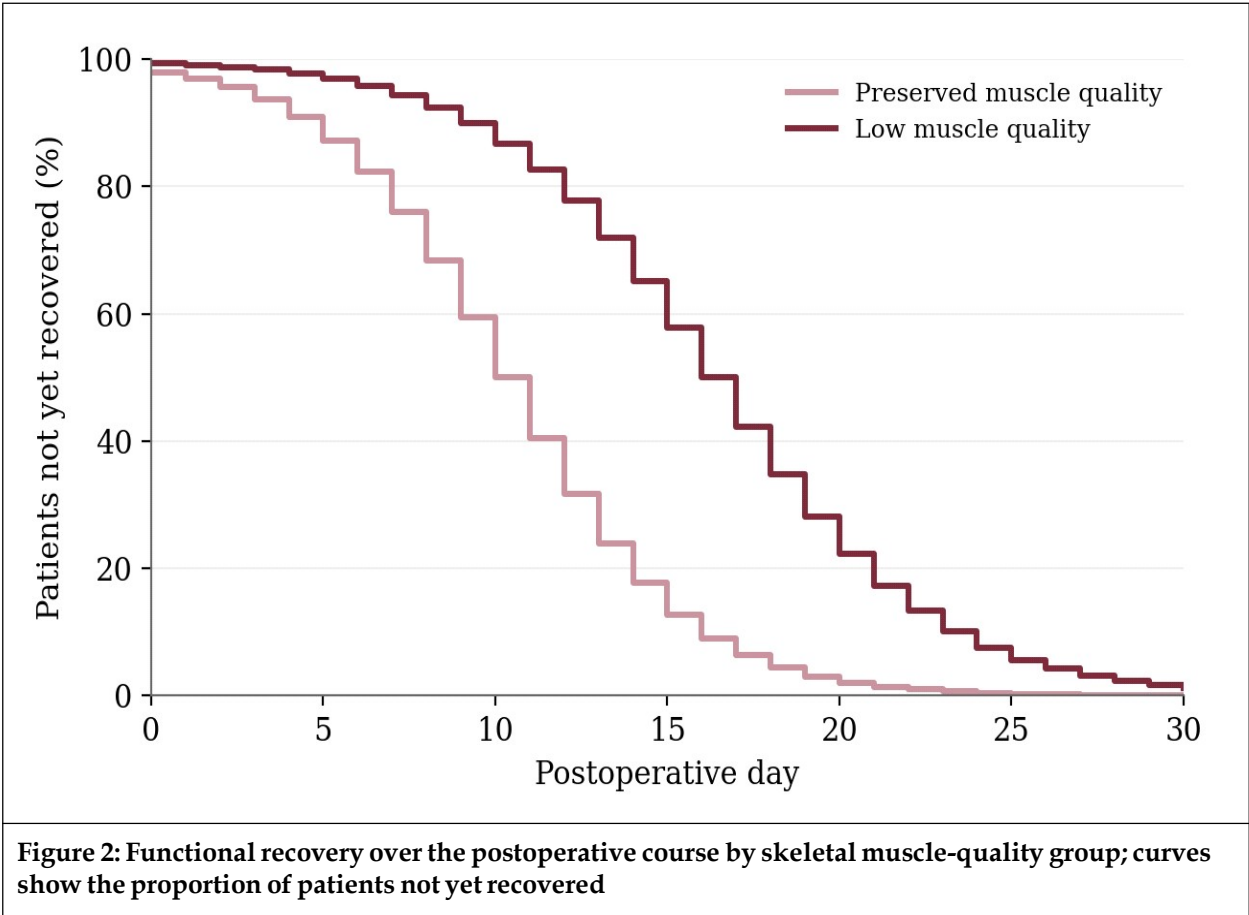
**Figure 1: Incidence of infectious complications according to preoperative skeletal muscle quality**

Table 3: Multivariable logistic regression for any infectious complication			
Variable	Adjusted OR	95% CI	p-value
Low skeletal muscle quality	2.63	1.48–4.67	0.001
Low skeletal muscle mass	1.34	0.74–2.43	0.334
ASA III–IV	1.88	1.05–3.37	0.034
Neoadjuvant therapy	1.29	0.72–2.31	0.393
Open approach	1.61	0.92–2.82	0.096
TNM stage III	1.37	0.78–2.41	0.271
Age (per year)	1.02	0.99–1.05	0.183

3.4. Functional recovery

Rehabilitation outcomes of functional recovery varied significantly in both groups. The low muscle-quality group had a longer time until functional recovery compared with the preserved-quality group, which separated from the first postoperative week onward. Low skeletal muscle quality was independently associated with delayed recovery with an adjusted hazard ratio for reaching functional recovery of 0.58 (95% confidence interval 0.43–0.78, $p < 0.001$), meaning that at any given time those with low skeletal muscle quality recovered at about half the rate of those with preserved skeletal muscle quality. This was reflected in secondary recovery measures as well, with both the low quality group having stayed longer in intensive-care and the low quality group having a longer total hospital length of stay, probably due to the low quality group having more infective events overall (Figure 2).



3.5. Comparative discriminative ability

Comparing the two body-composition parameters, the area under the ROC curve was 0.71 for skeletal muscle quality and 0.62 for skeletal muscle mass for the prediction of infectious complications. A combination of the two parameters resulted in only a slight gain over muscle quality alone, suggesting that the predictive signal was shared mostly with muscle quality. The multivariable model with the addition of muscle quality and the adding of clinical covariates had satisfactory calibration on the Hosmer-Lemeshow test, with no significant deviation between the observed and expected event probabilities (Table 4).

Parameter	AUC	95% CI	Sensitivity/Specificity
Skeletal muscle quality	0.71	0.65–0.77	66%/69%
Skeletal muscle mass	0.62	0.55–0.69	58%/61%
Quality + mass combined	0.72	0.66–0.78	67%/70%

3.6. Subgroup analysis

There was consistency between the association between low muscle quality and infectious complications across clinically relevant groups. No statistically significant interaction was present for any comparison, and the effect remained over each of the following groups of patients: squamous cell carcinoma, adenocarcinoma, neoadjuvant treatment, and no neoadjuvant treatment, and any surgical approach. The consistency of this finding indicates that the muscle quality prognostic value does not only exist in a specific pathological or treatment population of the esophagectomy population (Table 5).

Subgroup	Adjusted OR	95% CI	p (interaction)
Squamous cell carcinoma	2.71	1.29–5.69	0.74
Adenocarcinoma	2.52	1.14–5.57	
Neoadjuvant therapy	2.58	1.24–5.37	0.81
No neoadjuvant therapy	2.74	1.20–6.25	
Minimally invasive/hybrid	2.44	1.18–5.05	0.66
Open approach	2.89	1.30–6.43	

4. Discussion

Preoperative skeletal muscle quality predicted postoperative infectious complications and functional recovery after esophagectomy in this population of esophageal cancer patients treated with curative intent. Having low muscle quality more than doubled the adjusted odds of having an infectious complication and the odds of having pneumonia in particular, and was also associated with much slower functional recovery. Importantly, muscle quality remained as predictor after adjusting for muscle mass which was found to be independently irrelevant, pointing to the fact that the state of the muscle provides more information than just the amount.

4.1. Interpretation and biological rationale

These findings are biologically coherent. Radiodensity measures fatty infiltration of the skeletal muscle and is used as a sign of poor muscle metabolism which has been associated with insulin resistance, mitochondrial dysfunction and chronic low grade inflammation ([Goodpaster et al., 2000](#)). With respect to esophagectomy, the

reserve of the respiratory muscles is a critical determinant of respiratory function: diminished muscle quality is a plausible explanation for decreased clearance of secretions and adequate ventilation in this patient population after a major thoracoabdominal surgical procedure, which may lead to pneumonia, the most commonly reported post-surgical infectious complication in these patients (Ida *et al.*, 2015). It is possible that the consequent systemic inflammatory and metabolic derangement that is seen with myosteatorsis also negatively affects wound and anastomotic healing with a corresponding decrease in the inflammatory response to bacterial challenge, which could explain the overall increased number of infective events in the low-quality group (Argilés *et al.*, 2014).

The finding of a greater importance for muscle quality compared to muscle mass supports the current knowledge of these parameters representing different biological phenomena. While radiodensity provides information at the level of tissue quality – or composition, and thus functional ability – muscle mass reflects the volume of tissue present. An individual can retain their muscle mass but gain intramuscular fat, which will not be identified by measures of mass, but will be by a measure of quality (Martin *et al.*, 2013). This difference is relevant, as it suggests that muscle area may be insufficient to evaluate risk in a large proportion of patients.

Also there seems to be a logical immunological component to the linkage. Intramuscular adipose tissue is metabolically active and secretes pro-inflammatory mediators and myosteatorsis has been associated with chronic inflammatory component which is shared by the syndrome of cancer cachexia (Baracos *et al.*, 2018). This state may disrupt the well-organised and integrated immune response needed to limit the bacterial challenge always present in large thoracoabdominal operations, leading to the clinical expression of an infection. Muscle quality, in this sense, was not simply a marker of physical fitness, but a reflection of a general level of metabolic and inflammatory health of the patient, which could underlie its cross-cutting predictive value; from pulmonary infection to anastomotic and wound infection.

4.2. Comparison with existing literature

The current findings are in favour of and contribute to the rising number of studies pertaining to the body composition evaluation in upper-gastrointestinal cancer surgery. Previous research found that low muscle mass is associated with poor outcomes following the surgery of esophagogastrrectomy, but the authors were interested in muscle mass and poor outcomes had not yet been fully investigated when it comes to muscle quality, and literature regarding muscle quality had been limited mostly to long-term survival (Paireder *et al.*, 2017). Through analysis of both short-term infectious morbidity and recovery as well as comparison of quality versus mass within the same cohort, this study aims to elucidate that it is the quality of the muscle that is the more meaningful parameter in the evaluation of the initial postoperative course. The pneumonia-related complication results have corroborated with the muscle quality and the known association between the body-composition depletion and the respiratory complications following thoracic surgery (Deng *et al.*, 2019).

Interestingly, muscle radiodensity has been associated with poor surgical outcomes in esophageal resection as well as other types of cancer surgery such as colonic resection or hepatobiliary resection, where low muscle radiodensity is associated with higher morbidity and mortality and independent of muscle mass (Xiao *et al.*, 2020). This is even more remarkable that the present study shows this to be the case in esophagectomy, a surgical procedure with a very high incidence of pulmonary complications, which reinforces the idea that muscle quality is a study parameter with broad applicability and not a “specialty” marking the weakness of one organ. These findings were concurrent with similarly divergent literature on muscle mass in esophageal cancer, in that some series did not identify muscle mass as an independent prognostic parameter (Grotenhuis *et al.*, 2016); one reason for this heterogeneity in the literature could be the difference between quantity and quality as outlined in the methods section above, which may have been assessed in separate series.

Rates of infectious complication in this series were in keeping with those reported for modern-day esophagectomy series, which indicates the representativeness of the population analyzed (Fearon *et al.*, 2011). The clustering of events in the low quality group, despite similar tumour stage and approach to surgery in all groups, suggests that the clustering is related to the physiological reserve of the patients, rather than to differences in the complexity of surgery or size of the disease load.

4.3. Clinical implications

The main advantage of skeletal muscle quality as a risk marker is that it can be extracted with no extra cost from the single-slice analysis of the staging computed tomography conducted in all patients who undergo computed tomography, during which scans are already taken from the chest in every direction. Identifying patients with poor muscle quality could enhance the use of prehabilitation in patients undergoing surgery, including targeted exercise-based prehabilitation (West *et al.*, 2015) and/or intensified respiratory physiotherapy and nutrition management to address the identified deficits that poor muscle quality represents, which have been shown to help reduce pulmonary complications following major surgery (Minnella *et al.*, 2018). Postoperatively, recognition of elevated risk also helps to alert the surgeon to the need for especially close monitoring and might guide the patient in what to expect as far as the time course of postoperative recovery.

Implementation would be achievable at little extra cost, spawning from existing pathways. The measurement is performed on available images used for staging, does not require x-rays and will not be an additional cost, and can be incorporated into the multidisciplinary review where treatment is to be planned so that a flag for poor muscle quality is available to the surgical team and anaesthetist prior to the decision on a patient's suitability for treatment and prehabilitation. As automated segmentation tools become increasingly available they remove the significant practical barrier of time needed for manual analysis, and enable routine reporting of muscle quality even in centres with a hefty workload. The cost and impact of a single morbidity due to postoperative pneumonia is far greater than the effort required to compute this marker, therefore this serves to further bolster the argument for using this marker following availability of prospective validation.

4.4. Strengths and limitations

Prioritizing the use of objective, reproducible, body-composition measurement performed under blinding conditions within a single well-characterized cohort, use of a joint muscle-quality end point, and use of a joint muscle-mass end point were the strengths of this study. This fact about the explicit pushing of muscle quantity into the model reinforces the notion that the muscle quality is independent and not a re-stating of muscle quantity. These conclusions are tempered by several limitations. The retrospective, single centre design is associated with selection bias, residual confounding and the relationships presented cannot be interpreted as causal. The radiodensity threshold for low muscle quality was identified in this cohort and would likely lead to over-optimistic estimates of muscle quality performance; it needs to be validated in an independent population and then generalised to other populations. In addition, body composition was measured only once, preoperatively, and failed to account for change over the neoadjuvant interval; this neoadjuvant interval change may have prognostic significance. Although functionality is clearly defined using predetermined criteria, there is some element of subjectivity, and while such a single institution design with a uniform path of management can increase the internal validity, it may not be applicable to other centers with different patient populations and surgical technique.

4.5. Future directions

These results suggest a number of avenues for further research. Further studies across different centres and with external validation would be useful to validate the predictive value of muscle quality and establish cut-offs in general population, preferably automated reduction of segmentation variance to overcome observer variability and make it feasible to perform at scale. Longitudinally assessing patients throughout the neoadjuvant period will suggest if progression of muscle quality contributes to a single measurement done preoperatively. Most important will be interventional trials of exercise-based and nutritional prehabilitation specifically targeting individuals who are identified as having low muscle quality to investigate whether this modifiable diagnostic tool can be rendered into a tool that can be used to reduce risk.

5. Conclusions

Skeletal muscle quality preoperatively is an independent predictor of postoperative infectious complications and functional recovery after oesophagectomy for oesophageal cancer as well as skeletal muscle mass. Muscle quality is easily measured and able to be targeted using prehabilitation and is a useful measure of a potentially modifiable aspect of physiological reserve that could be incorporated into pre-op risk assessment from routine

staging imaging at no additional cost. Further prospective, externally validated studies and in the future invasive trials to increase the quality of muscles before surgery should be performed to confirm these results, as well as to determine if pre-operative optimisation can improve the infectious morbidity rates and shorten the length of time of recovery.

Ethics approval and consent to participate

The study was approved by the Institutional Review Board, which waived individual informed consent for the retrospective analysis of anonymised data.

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Conflicts of interest

The authors declare no conflict of interest.

Data availability

The datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

Author contributions

All authors contributed to the conception and design of the study, data acquisition, analysis and interpretation, drafting and critical revision of the manuscript, and approved the final version for submission.

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