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# Effect of Radiologically Evaluated Sarcopenia on Survival in Advanced Pancreatic Cancer

## Metastatik Pankreas Kanserinde Radyolojik Olarak Değerlendirilen Sarkopeninin Sağkalıma Etkisi

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## Abstract

**Objective:** Pancreatic cancer is one of the deadliest cancers. The 5-year survival rate in advanced pancreatic cancer is 2%. The presence of sarcopenia in advanced pancreatic cancer is associated with negative outcomes. Although there are many measurements for the diagnosis of sarcopenia, there is still no standard method. In our study, the effect of radiological measurement of sarcopenia on the results of pancreatic cancer was investigated.

**Methods:** Seventy-four patients were retrospectively evaluated. Demographic data and laboratory and imaging parameters of the patients were recorded and analyzed using the SPSS 25 program.

**Results:** The mean age was 64.4 years, and the mean body mass index (BMI) was 25.5 kg/m$^2$. 58.1% of the patients were male. mOS was 9.3±2.4 months in patients with sarcopenia detected with Psoas muscle density (PMD) Hounsfield unit avarage calculation, and 16.1 16.1±1.5 months in those without (*p=0.002). mOS was 5.6±1.6 months in patients with sarcopenia detected with PMI and 16.1 16.1±1.5 months in those without (*p<0.0001). Age, gender, BMI, hemoglobin, CA19-9, and albumin levels did not affect overall survival.

**Conclusion:** Overall survival is significantly lower in patients with radiologically detected sarcopenia with PMD and PMI. The use of PMI and PMD is an effective method for radiological evaluation of sarcopenia.

**Keywords:** Sarcopenia, radiological measurements, pancreatic cancer

## Öz

**Amaç:** Pankreas kanseri en ölümcül kanserlerden biridir. Metastatik pankreas kanserinde 5 yıllık sağkalım %2'dir. Metastatik pankreas kanserinde sarkopeninin varlığı olumsuz sonuçlarla ilişkilidir. Sarkopeni tanısına yönelik birçok ölçüm olmasına rağmen halen standart bir yöntem bulunmamaktadır. Çalışmamızda sarkopeninin radyolojik ölçümünün pankreas kanseri sonuçlarına etkisi araştırıldı.

**Yöntem:** Yetmiş dört hasta retrospektif olarak değerlendirildi. Hastaların demografik verileri, laboratuvar ve görüntüleme parametreleri kayıt altına alınarak SPSS 25 programına analiz edildi.

**Bulgular:** Ortalama yaş 64,4, ortalama vücut kitle indeksi (BMI) 25,5 kg/m$^2$ idi. Hastaların %58,1'i erkekti. Psoas kas dansitesi (PMD) Hounsfield ünitesi ortalama hesaplaması ile tespit edilen sarkopeni hastalarında mOS 9,3±2,4 ay, olmayanlarda ise 16,1±1,5 ay idi (*p=0,002). Psoas kas indeksi (PMI) ile sarkopenisi saptanan hastalarda mOS 5,6±1,6 ay, saptanmayanlarda ise 16,1±1,5 aydı (*p<0,0001). Yaş, cinsiyet, BMI, hemoglobin, CA19-9 ve albümin düzeyleri genel sağkalımı etkilemedi.

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## Öz

**Sonuç:** PMD ve PMI ile radyolojik olarak sarkopenisi saptanan metastatik pankreas kanseri hastalarında genel sağkalım anlamlı olarak daha düşüktür. PMI ve PMD'nin kullanımı sarkopeninin radyolojik değerlendirmesinde etkili bir yöntemdir.


**Anahtar Kelimeler:** Sarkopeni, radyolojik ölçümler, pankreas kanseri

## Introduction

Pancreatic cancer is one of the most common cancers, with a 5-year survival rate of less than 5%[1]. Most patients are unresectable, and the results are worse in this patient group. The stage of the disease, area of involvement, presence of additional diseases, and performance status determine the probability of resectability[2]. Sarcopenia is defined as a decrease in muscle mass and consequent decrease in measurable muscle strength. According to ESPEN, values below -2 standard deviations as measured by healthy young adults are defined as cachexia[3]. Decreased muscle density and muscle area are associated with decreased overall survival in many cancers. The relationship between sarcopenia and pancreatic cancer has been known for a long-time. In recent years, the number of studies on the negative effects of sarcopenia on survival outcomes in pancreatic cancer has been increasing[4]. In various studies, sarcopenia in pancreatic cancer has been shown to be between 20% and 65%[5-7]. This wide range may be due to the heterogeneity of the patient group and the differences in sarcopenia measurement techniques. Malnutrition and sarcopenia are common in pancreatic cancer due to localization of the disease, obstruction, inadequate oral intake, failure to meet the increased metabolic rate due to malignancy, and malabsorption due to exocrine hormonal failure[8]. Decreased performance due to sarcopenia adversely affects both post-surgical complications and chemotherapy-related outcomes[9]. Due to the differences in defining sarcopenia, there were also differences in measurement techniques[10,11]. Various measurements can be made with anthropometry, bioelectrical impedance, dual X-ray absorptiometry (DEXA), computed tomography (CT), and magnetic resonance imaging (MRI) in the evaluation of sarcopenia. To eliminate the subjectivity of measurement techniques, it is becoming increasingly common to evaluate using imaging methods[12]. There are many studies evaluating sarcopenia by measuring muscle with conventional imaging methods used in the diagnosis, staging, and follow-up of pancreatic cancer[13]. Sarcopenia assessments with CT and MRI are more sensitive than DEXA[14]. It has been shown that muscle measurement from L3 vertebrae correlates much better with whole body muscle mass, and measurements from L4-5 vertebrae can be an alternative to L3 measurement[15]. Besides which technique is used for measurement, it should also be considered whether it is evaluated according to height, weight, and body mass index.

In our study, the data of patients with advanced pancreatic cancer diagnosed in our clinic in the last five years were retrospectively analyzed. In addition to descriptive data such as age, gender, and performance status at the time of diagnosis, the effects of laboratory parameters and muscle measurements determined by CT imaging on progression-free survival (PFS) and overall survival (OS) were examined.

## Materials and Methods

### Measurements

Muscle measurements were calculated as follows: Psoas muscle index (PMI) and Psoas muscle density (PMD) hounsfield unit average calculation (HUAC) was used to evaluate cachexia. PMI: (Right psoas muscle area + left psoas muscle area)/height height. Right hounsfield unit (RHUC): (RHUC x right psoas muscle area)/total psoas muscle area. LHUC: (left hounsfield unit x left psoas muscle area)/ total psoas muscle area. PMD HUAC: RHUC +LHUC/2. Low skeletal muscle mass was defined as the lowest quartile in male and female patients separately in categorical analyses. The PMI cutoffs to define low skeletal muscle mass were 2,4 $cm^2/m^2$ in females and 3.3 $cm^2/m^2$ in males, and for Psoas Muscle Dansity, HUAC was 21.53 HU in females and 27,08 HU in males.

Manisa Celal Bayar University Ethics Committee date: 21.03.2022, decision no: 251 approval was received. The procedures followed were in accordance with the ethical standards of the Manisa Celal Bayar University Ethics Committee and with the Helsinki Declaration of 1975, as revised in 2013.

### Statistical Analysis

Overall survival (OS) and progression-free survival (PFS) analyzes were calculated using the Kaplan-Meier method,

and differences between curves were estimated using Log-Rank tests. The effect of low skeletal muscle mass on PFS and OS was evaluated using univariate and multivariate logistic regression analyses. Quantitative variables are expressed as medians. Variables are compared using the two-tailed Student's t-test or the Kruskal-Wallis test, whichever is appropriate. Categorical data were expressed as percentages (numbers) and compared using the $\chi^2$ test or Fisher's Exact test, as appropriate. P-values <0.05 were considered statistically significant. All statistical analyses were performed using SPSS 25 software.

## Results

In our study, 87 patients diagnosed with advanced pancreatic cancer in our hospital between 2016 and 2021 were included in the study. Seventy-four patients whose data were fully accessible were included in the study. Thirteen patients were excluded from the study because of reasons such as change of institution for treatment, inability to access chemotherapy regimens, and undetectable PFS and OS data.

Mean age at diagnosis was 64.4 (31-82), mean weight was 70 kg (45-110), and mean BMI was 25.5 (15.6-40.4). 58.1% (n=43) of the patients were male. Pancreatic head tumor was the primary focus in 74.3% (55) of the patients, whereas 25.7% (19) had pancreatic body or tail tumor. Twenty-three percent (15) of the patients were ECOG-0, 62.2% (46) ECOG-1, 17.5% (13) ECOG-2. There were no ECOG-3 and ECOG-4 patients. 75.7% (56) of the patients were receiving oral nutritional support (ONS). While 36.5% (27) of the patients were using the first or even FOLFIRINOX regimen, 27% (20) had a single agent gemcitabine and 36.5% (27) had a second chemotherapy agent (cisplatin, carboplatin, nab-paclitaxel) together with gemcitabine. While all of the patients included in the study received first-line chemotherapy, 47.3% (35) of the patients who received the second-line chemotherapy were 25.7% (19) who could receive the third-line treatment. Descriptive statistics are presented in Table 1.

When all patients were evaluated, mPFS was 4.8±0.8 months and mOS was 14.3±1.2 months. PFS was not affected by gender (p=0.96) and being over or under 65 years old (p=0.14). OS was not affected by gender (p=0.50) and being over or under 65 years old (p=0.86).

While mPFS was 5.3 months in those who received ONS, mPFS was 2.4 months in those who did not (*p=0.004). There was no significant difference in mOS between those who received and those who did not receive ONS (p=0.66).

When laboratory data were examined, there was no significant difference in terms of PFS or OS between patients with hemoglobin (≤12 vs. >12) and CA19-9 (≤100 vs. >100). However, PFS and OS were significantly lower in those with albumin levels ≤3.5 g/dL.

While mPFS was 8±3.9 months in patients with BMI <18.5, mPFS was 4.8±0.8 months in patients with BMI ≥18.5 (p=0.54). OS was 13.6±6.4 months in patients with BMI <18.5, and 14.7±1.3 months in patients with BMI ≥18.5 (p=0.31). While mPFS was 2.6±0.4 months in those with PMD HUAC and sarcopenia, it was 5.8±0.5 months in those without (*p=0.009). While the mOS was 9.3±2.4 months in those

**Table 1. Descriptives of advanced pancreatic cancer patients**

| | n | % | | n | % |
|---|---|---|---|---|---|
| **Sex** | | | **ONS** | | |
| Female | 31 | 41.9 | No | 18 | 24.3 |
| Male | 43 | 58.1 | Yes | 56 | 75.7 |
| Total | 74 | 100.0 | Total | 74 | 100.0 |
| **Age** | | | **Second line** | | |
| <65 | 29 | 39.2 | No | 39 | 52.7 |
| >65 | 45 | 60.8 | Yes | 35 | 47.3 |
| Total | 74 | 100.0 | Total | 74 | 100.0 |
| **ECOG** | | | **BMI** | | |
| 0 | 15 | 20.3 | <18 | 5 | 6.8 |
| 1 | 46 | 62.2 | >18 | 69 | 93.2 |
| 2 | 13 | 17.5 | | | |
| Total | 74 | 100.0 | Total | 74 | 100.0 |
| **T** | | | **PMI** | | |
| 2 | 40 | 54.1 | Low | 18 | 24.3 |
| 3 | 31 | 41.9 | High | 56 | 75.7 |
| 4 | 3 | 4.1 | Total | 74 | 100.0 |
| Total | 74 | 100.0 | | | |
| **n** | | | **PMD HUAC** | | |
| 0 | 12 | 16.2 | Low | 19 | 25.7 |
| 1 | 27 | 36.5 | High | 55 | 74.3 |
| 2 | 35 | 47.3 | Total | 74 | 100.0 |
| Total | 74 | 100.0 | | | |
| **Localization** | | | **1st-line regimen** | | |
| Head | 55 | 74.3 | Gemcitabine | 20 | 27.0 |
| Tail | 19 | 25.7 | Gem-others | 27 | 36.5 |
| Total | 74 | 100.0 | Folfirinox | 27 | 36.5 |
| | | | Total | 74 | 100.0 |

ONS: Oral nutritional support, BMI: Body mass index, PMI: Psoas muscle index

with sarcopenia with PMD HUAC, it was 16.1±1.5 months in those without (*p=0.002). While mPFS was 2.6±0.4 months in those with PMI and sarcopenia, it was 5.5±0.4 months in those without (*p=0.006). While mOS was 5.6±1.6 months in those with PMI and sarcopenia, it was 16.1±1.5 months in those without (*p<0.0001). While mPFS was 5.8±0.4 months in patients who received FOLFIRINOX as first-line therapy, mPFS was 4.0±0.8 months in patients who did not receive FOLFIRINOX (p=0.85), mOS in patients who received FOLFIRINOX as first-line therapy was 16.1±10 months, mOS was 13.9±3.5 months (p=0.61) in those who did not receive FOLFIRINOX. The PFS and OS data determined depending on the variables are presented in Table 2.

Affecting OS because of univariate analysis: ECOG status, second- line chemotherapy, PMD HUAC, PMI, NLR and albumin values were evaluated by multivariate analysis and the results are presented in Table 3.

**Table 2. PFS and OS data depending on the variables**

| Variables | n/% | mPFS | p-value | mOS | p-value |
|---|---|---|---|---|---|
| **ECOG** | | | | | |
| 0 | 15/20.3 | 5.9 | 0.004 | 26.5 | 0.009 |
| 1 | 46/62.2 | 5.5 | | 13.6 | |
| 2 | 13/17.5 | 2.4 | | 3.9 | |
| **Age** | | | | | |
| <65 | 29/39.2 | 6.5 | 0.14 | 15.1 | 0.86 |
| ≥65 | 45/60.8 | 3.6 | | 13.9 | |
| **Sex** | | | | | |
| Female | 31/41.9 | 5.1 | 0.96 | 13.9 | 0.50 |
| Male | 43/58.1 | 4.8 | | 15.1 | |
| **Localisation** | | | | | |
| Head | 55/74.3 | 4.8 | 0.88 | 14.3 | 0.56 |
| Tail | 19/25.7 | 5.3 | | 13.9 | |
| **ONS** | | | | | |
| No | 18/24.3 | 2.4 | 0.004 | 15.1 | 0.66 |
| Yes | 56/75.7 | 5.3 | | 14.3 | |
| **2nd line** | | | | | |
| No | 39/51.4 | | | 7.2 | 0.007 |
| Yes | 35/48.6 | | | 16.1 | |
| **BMI** | | | | | |
| <18 | 5/6.8 | 8 | 0.54 | 13.6 | 0.31 |
| ≥18 | 69/93.2 | 4.8 | | 14.7 | |
| **PMI** | | | | | |
| Low | 18/24.3 | 2.6 | 0.006 | 5.6 | <0.001 |
| High | 56/75.7 | 5.4 | | 16.1 | |
| **PMD HUAC** | | | | | |
| Low | 19/25.7 | 2.6 | 0.009 | 9.3 | 0.002 |
| High | 55/74.3 | 5.8 | | 16.1 | |
| **Folfirinox** | | | | | |
| No | 47/63.5 | 4.0 | 0.85 | 13.9 | 0.61 |
| Yes | 27/36.5 | 5.8 | | 15.1 | |
| **HGB** | | | | | |
| ≤12 | 27/36.5 | 4.0 | 0.16 | 12.8 | 0.41 |
| >12 | 47/63.5 | 5.5 | | 15.4 | |
| **CA19-9** | | | | | |
| ≤100 | 32/43.2 | 5.8 | 0.76 | 15.4 | 0.22 |
| >100 | 42/56.8 | 3.3 | | 14 | |
| **Albumin** | | | | | |
| ≤3.5 | 9/12.2 | 2.3 | 0.027 | 9.0 | 0.026 |
| >3.5 | 65/87.8 | 5.5 | | 15.1 | |
| **NLR** | | | | | |
| ≤3 | 44/59.5 | 5.8 | 0.98 | 16.1 | 0.019 |
| >3 | 30/40.5 | 2.9 | | 9.0 | |

ONS: Oral nutritional support, BMI: Body mass index, OS: Overall survival, PMI: Psoas muscle index

## Discussion

In our study, it was shown that the overall survival results were worse in patients with advanced stage pancreatic cancer who were found to have cachexia because of CT evaluation at the time of diagnosis. Other factors affecting mOS in the multivariate analysis were ECOG performance and the patient's ability to receive second-line therapy.

It should also be considered that the optimal treatment of sarcopenia is still unknown. Follow-up of patients with appropriate ONS before their condition worsens may affect survival outcomes. There is an increased catabolic process and fragility in sarcopenic patients[16]. In our study, it was seen that mPFS was detected better in ONS patients. It can be recommended to evaluate cachexia and sarcopenia in terms of diagnosis and to start ONS as early as possible in those who need it. While some studies have shown that the presence of sarcopenia is associated with worse overall survival, there are studies that do not support this data[7,17-20].

Many anti-inflammatory and proanabolic products have been tried to reverse sarcopenia, but many of them have not been shown to have a positive effect on the results. Although the results are contradictory, the use of polyunsaturated fatty acids has positive effects in patients receiving chemotherapy[21]. In addition, some studies have supported the role of megestrol acetate and medroxyprogesterone acetate in preventing the progression of sarcopenia[22,23]. However, because of the increased frequency of thromboembolic

**Table 3. Univariate-multivariate analyses of overall survival**

| | Univariate analysis | | | Multivariate analysis | | |
|---|---|---|---|---|---|---|
| **Variables** | **HR** | **(95% CI)** | **p-value** | **HR** | **(95% CI)** | **p-value** |
| ECOG | 1.95 | (1.26-3.0) | 0.009 | 2.69 | (1.58-4.56) | <0.001 |
| 2nd line | 0.47 | (0.27-0.82) | 0.008 | 0.32 | (0.17-0.62) | 0.001 |
| PMI | 0.33 | (0.18-0.61) | 0.026 | 0.48 | (0.25-0.95) | 0.034 |
| PMD HUAC | 0.40 | (0.21-0.73) | 0.003 | 0.40 | (0.19-0.70) | 0.008 |
| Alb ≤3.5/>3.5 | 0.42 | (0.20-0.90) | 0.026 | 0.90 | (0.38-2.12) | 0.81 |
| NLR ≤3/>3 | 1.95 | (1.11-3.40) | 0.019 | 1.46 | (0.78-2.74) | 0.24 |

CI: Confidence interval, PMI: Psoas muscle index, HR: Hazard ratio, Alb: Albumin

events in pancreatic cancer, these molecules can be used by considering the potential benefit-harm balance.

The presence of sarcopenia also affects the performance status of the patient. In patients with low performance scores, the preferred chemotherapy regimen may change. In addition, chemotherapy is more toxic in sarcopenic patients, which negatively affects survival outcomes[24].

There are studies showing that there are more serious complications with chemotherapy in patients with sarcopenia[24,25]. In our study, there was no difference in terms of mPFS or mOS between patients with BMI <18.5 and patients with >18.5 because of BMI evaluation. Cachexia can also be seen in patients who are in the obesity or normal group according to BMI. Therefore, BMI is considered insufficient in the evaluation of sarcopenia[26,27]. CT, PET-CT, and MRI can be used in the diagnosis and follow-up of cancer. While manual measurements may lead to subjective results in the evaluation of cachexia and sarcopenia, more objective results can be determined by CT. However, in CT measurements, the problem is that the standard values differ between nationalities. For this reason, it is recommended that countries determine their own sarcopenia values and studies are conduct studies in this direction[12,28,29]. It should be considered that both chemotherapy response and overall survival will be worse in patients with sarcopenia detected at the time of diagnosis. Disease management should be shaped according to this situation.

When the literature is evaluated, it is seen that there is more than one method in the evaluation of sarcopenia with imaging methods. PMD, HUAC, and PMI are two of these methods. Sarcopenia detected with PMD, HUAC, and PMI is an independent poor prognostic factor in pancreatic cancer. Other prognostic factors affecting mOS in our study were the patient's ECOG performance and ability to receive second-line chemotherapy. Having received second-line chemotherapy is also an indirect indicator of good performance status. There is no standard consensus regarding the assessment of sarcopenia. It is suggested that each nation determines an index according to their own data. The reason why we preferred PMD HUAC and PMI in our study is the effort to identify patients who are in the lowest quartile compared with our population, instead of using a standard value.

### Study Limitations

The limitations of our study are the small number of patients and the retrospective nature of our study. The results may have been affected by individual differences in chemotherapy preference and difficulties in accessing nabpaclitaxel in our country. The fact that chemotherapy complications were not evaluated in our study is one of the limitations of our study. Complications were excluded from the evaluation because there were insufficient complication data in the file information.

## Conclusion

The evaluation of sarcopenia in the imaging control performed during the staging of metastatic pancreatic cancer provides information both in terms of prognosis and gives an idea about the intensity of the treatment modality to be applied and the complications that may occur. In addition, in patients with sarcopenia at the time of diagnosis, ONS can be initiated at an early stage and contribute to the improvement of the results.

### Ethics

**Ethics Committee Approval:** Manisa Celal Bayar University Ethics Committee date: 21.03.2022, decision no: 251 approval was received. The procedures followed were in accordance with the ethical standards of the Manisa Celal Bayar University Ethics Committee and with the Helsinki Declaration of 1975, as revised in 2013.

**Informed Consent:** In our study, which was conducted as a retrospective patient file scan, a patient consent form was obtained.

### Authorship Contributions

Surgical and Medical Practices: A.Ö., S.A., Concept: A.Ö., Design: A.Ö., S.A., Data Collection or Processing: A.Ö., S.A., Analysis or Interpretation: A.Ö., Literature Search: A.Ö., S.A., Writing: A.Ö.

**Conflict of Interest:** No conflict of interest was declared by the authors.

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## References

1. Wolfgang CL, Herman JM, Laheru DA, et al. Recent progress in pancreatic cancer. CA Cancer J Clin 2013;63:318-48.
2. Huang L, Jansen L, Balavarca Y, et al. Resection of pancreatic cancer in Europe and USA: an international large-scale study highlighting large variations. Gut 2019;68:130-9.
3. Cederholm T, Barazzoni R, Austin P, et al. ESPEN guidelines on definitions and terminology of clinical nutrition. Clin Nutr 2017;36:49-64.
4. Zalite IO, Zykus R, Gonzalez MF, et al. Influence of cachexia and sarcopenia on survival in pancreatic ductal adenocarcinoma: a systematic review. Pancreatology 2015;15:19-24.
5. Hendifar AE, Chang JI, Huang BZ, Tuli R, Wu BU. Cachexia, and not obesity, prior to pancreatic cancer diagnosis worsens survival and is negated by chemotherapy. J Gastrointest Oncol 2018;9:17-23.
6. Choi Y, Oh DY, Kim TY, et al. Skeletal muscle depletion predicts the prognosis of patients with advanced pancreatic cancer undergoing palliative chemotherapy, independent of body mass index. PLoS One 2015;10:e0139749.
7. Rollins KE, Tewari N, Ackner A, et al. The impact of sarcopenia and myosteatosis on outcomes of unresectable pancreatic cancer or distal cholangiocarcinoma. Clin Nutr 2016;35:1103-9.
8. Kordes M, Larsson L, Engstrand L, Löhr J. Pancreatic cancer cachexia: Three dimensions of a complex syndrome. Br J Cancer 2021;124:1623-36.
9. Gruber ES, Jomrich G, Tamandl D, Gnant M, Schindl M, Sahora K. Sarcopenia and sarcopenic obesity are independent adverse prognostic factors in resectable pancreatic ductal adenocarcinoma. PLoS One 2019;14:e0215915.
10. Bundred J, Kamarajah SK, Roberts KJ. Body composition assessment and sarcopenia in patients with pancreatic cancer: a systematic review and meta-analysis. HPB (Oxford) 2019;21:1603-12.
11. Cooper C, Fielding R, Visser M, et al. Tools in the assessment of sarcopenia. Calcif Tissue Int 2013;93:201-10.
12. Derstine BA, Holcombe SA, Ross BE, Wang NC, Su GL, Wang SC. Skeletal muscle cutoff values for sarcopenia diagnosis using T10 to L5 measurements in a healthy US population. Sci Rep 2018;8:11369.
13. Wu CH, Chang MC, Lyadov VK, et al. Comparing Western and Eastern criteria for sarcopenia and their association with survival in patients with pancreatic cancer. Clin Nutr 2019;38:862-9.
14. Boutin RD, Yao L, Canter RJ, Lenchik L. Sarcopenia: current concepts and imaging implications. AJR Am J Roentgenol 2015;205:W255-66.
15. Vangelov B, Bauer J, Kotevski D, Smee RI. The use of alternate vertebral levels to L3 in computed tomography scans for skeletal muscle mass evaluation and sarcopenia assessment in patients with cancer: a systematic review. Br J Nutr 2022;127:722-35.
16. Meza-Junco J, Montano-Loza AJ, Baracos VE, et al. Sarcopenia as a prognostic index of nutritional status in concurrent cirrhosis and hepatocellular carcinoma. J Clin Gastroenterol 2013;47:861-70.
17. Kurita Y, Kobayashi N, Tokuhisa M, et al. Sarcopenia is a reliable prognostic factor in patients with advanced pancreatic cancer receiving FOLFIRINOX chemotherapy. Pancreatology 2019;19:127-35.
18. Facciorusso A, Antonino M, Muscatiello N. Sarcopenia represents a negative prognostic factor in pancreatic cancer patients undergoing EUS celiac plexus neurolysis. Endosc Ultrasound 2020;9:238-44.
19. Kays JK, Shahda S, Stanley M, et al. Three cachexia phenotypes and the impact of fat-only loss on survival in FOLFIRINOX therapy for pancreatic cancer. J Cachexia Sarcopenia Muscle 2018;9:673-84.
20. Basile D, Parnofiello A, Vitale MG, et al. The IMPACT study: early loss of skeletal muscle mass in advanced pancreatic cancer patients. J Cachexia Sarcopenia Muscle 2019;10:368-77.
21. de van der Schueren MA, Laviano A, et al. Systematic review and meta-analysis of the evidence for oral nutritional intervention on nutritional and clinical outcomes during chemo (radio) therapy: current evidence and guidance for design of future trials. Ann Oncol 2018;29:1141-53.
22. López AP, i Figuls MR, Cuchi GU, et al. Systematic review of megestrol acetate in the treatment of anorexia-cachexia syndrome. J Pain Symptom Manage 2004;27:360-9.
23. Wen HS, Li X, Cao YZ, et al. Clinical studies on the treatment of cancer cachexia with megestrol acetate plus thalidomide. Chemotherapy 2012;58:461-7.
24. Davis MP, Panikkar R. Sarcopenia associated with chemotherapy and targeted agents for cancer therapy. Ann Palliat Med 2019;8:86-101.
25. Ryan AM, Prado CM, Sullivan ES, Power DG, Daly LE. Effects of weight loss and sarcopenia on response to chemotherapy, quality of life, and survival. Nutrition 2019;67:110539.
26. Kim EY, Kim YS, Park I, Ahn HK, Cho EK, Jeong YM. Prognostic significance of CT-determined sarcopenia in patients with small-cell lung cancer. J Thorac Oncol 2015;10:1795-99.
27. Anjanappa M, Corden M, Green A, et al. Sarcopenia in cancer: Risking more than muscle loss. Tech Innov Patient Support Radiat Oncol 2020;16:50-7.
28. Choudhary S, Wadhawan M, Dhawan S, Ganesan PK, Mittal P, Sahney A, Kumar A. Normative values of skeletal muscle indices for nutritional assessment and implications on definition of sarcopenia in Indian adult population. Indian J Gastroenterol 2022;41:69-76.
29. Tan L, Ji G, Bao T, Fu H, Yang L, Yang M. Diagnosing sarcopenia and myosteatosis based on chest computed tomography images in healthy Chinese adults. Insights Imaging 2021;12:163.