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CHEST IMAGING
ORIGINAL ARTICLE

The association of silicosis severity with pectoralis major muscle and subcutaneous fat volumes and the pulmonary artery/aorta ratio evaluated by CT

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PURPOSE
Silicosis is an incurable occupational disease that sometimes rapidly progresses with fatal outcomes. We aimed to evaluate the association between disease severity and the change in the pectoralis major muscle volume (PMV), subcutaneous fat volume (SFV), and the pulmonary artery/aorta (P/Ao) ratio in patients with silicosis using computed tomography (CT).

METHODS
The study included 41 male silicosis patients and 41 control group subjects with available chest CT images. Using dedicated software, we measured PMV and SFV from the axial CT images. We calculated the P/Ao ratio and obtained body mass index (BMI) and forced expiratory volume/forced vital capacity (FEV1/FVC) results from hospital records. We used the chest X-ray profusion score according to the International Labor Organization (ILO) classification to evaluate the severity of the silicosis.

RESULTS
The mean age was 33.5±4.4 and 34.7±4.7 years in the silicotic and control groups, respectively. The mean BMI, PMV, SFV, and P/Ao values significantly differed between the study and control groups ($p = 0.0009$, $p < 0.0001$, $p < 0.0001$, and $p = 0.0029$, respectively). According to the ILO classification, there were 12 silicosis patients in category 1, 13 in category 2, and 16 in category 3. A significant difference was found between disease categories in terms of PMV, SFV, P/Ao, BMI, and FEV1/FVC values ($p = 0.0425$, $p = 0.0341$, $p = 0.0002$, $p = 0.0492$, and $p = 0.0004$, respectively).

CONCLUSION
Disease severity had a stronger association with decreased PMV and SFV and increased P/Ao ratios than BMI in patients with silicosis caused by denim sandblasting. Thus, CT evaluation might be a useful indicator of disease severity.

Silicosis is an occupational pulmonary disease caused by the inhalation of free silica crystals and characterized by pulmonary fibrosis, which leads to radiographic and pathological abnormalities. Despite being an old disease, it is still life-threatening due to its incurable nature (1, 2). Although the incidence of occupational pulmonary diseases has fallen in many countries, occupational exposure continues to cause a heavy burden of illness in parts of the world undergoing rapid economic development and population growth, and those with a large, unregistered and unregulated workforce (3). The clinical diagnosis of silicosis is based on clinical history and compatible chest X-ray findings, which mainly show abnormalities in the advanced stage (4). The International Classification of Radiographs of Pneumoconioses of the International Labor Organization (ILO) is a powerful tool used throughout the world to improve workers' health surveillance, conduct epidemiological research, and compare statistical data (5). Computed tomography (CT) (6, 7) and magnetic resonance imaging (MRI) (8–10) are also used in the differential diagnosis and follow-up of pulmonary diseases, such as silicosis.

Respiratory symptoms, such as coughing and shortness of breath are prominent in silicosis, and pulmonary function test is used in clinical follow-up. Patients also exhibit symptoms that are uncharacteristic of silicosis such as muscle weakness and weight loss (11); however, their effect on morbidity and mortality of silicosis remains unclear. Although body mass index (BMI) is usually used to monitor weight loss, it is a measure associated with the total amount of body fat and does not provide specific information about body composition. The

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pathological loss of skeletal muscle mass is not always accompanied by a comparable loss of adipose tissue (12). Skeletal muscle mass and glucose consumption are crucial for immune function; therefore, reduced skeletal muscle may result in increased physiological disturbances, mortality, and morbidity (13, 14). The prevention of skeletal muscle loss is an essential objective in reducing mortality and morbidity in chronic obstructive pulmonary disease (COPD) (15). Recognizing and preventing or reversing muscle loss may help improve quality of life and extend lifespan in silicosis, which has no effective cure yet. The ratio of the pulmonary artery diameter to the aortic diameter (P/Ao) measured by CT can be used to evaluate pulmonary hypertension (16). P/Ao >1 is a reliable predictor of pulmonary hypertension, and therefore directly indicates a worse clinical outcome (17). An increased P/Ao ratio may also be a potential indicator of the onset of pulmonary hypertension and mortality in silicosis patients. However, the literature contains no relevant data in silicosis patients.

This study aimed to evaluate the association between the severity of silicosis caused by denim sandblasting and the change in the pectoralis major muscle volume (PMV), subcutaneous fat volume (SFV), and P/Ao ratio using CT. We also investigated whether these changes represented the severity of the disease.

Methods

Study population

The data of 108 patients that presented to the pulmonary medicine outpatient clinic of our hospital and were diagnosed with silicosis between 2007 and 2011 were retrospectively analyzed. Forty-four patients with thorax CT, ILO classification, BMI, and forced expiratory volume -one second (FEV1)/forced vital capacity (FVC) data were included in the study. Patients with chronic diseases that could affect body muscle and fat tissue were excluded (one muscular dystrophy case and two patients with diabetes). The remaining 41 patients with silicosis were included in the study group. All patients in the study group were male. Forty-one age-matched male patients who underwent thoracic CT for trauma and had no pathology on thorax CT and no history of chronic disease that would affect muscle and fat volume were included in the control group. The ethics committee of our institution approved the study.

Main points

- Chest CT can provide information regarding the loss of muscle and adipose tissue in addition to lung parenchymal damage in chronic lung diseases such as silicosis.
- An increased P/Ao ratio may be a predictor of the onset of pulmonary hypertension and mortality in silicosis.
- The decrease in muscle mass and subcutaneous adipose tissue in silicosis patients may be a better indicator of change in body composition. Thus, these parameters can be used instead of BMI in selected patients.

Thorax CT protocol

CT examinations were performed using a second-generation Somatom Definition Flash 256-slice dual-source multidetector CT scanner (Siemens Healthcare). The CT scans were performed in supine position in all cases, with arms raised on both sides of the head, without any contrast material. In some cases, additional contrast-enhanced CT was obtained due to suspicion of malignancy and pulmonary embolism. Contrast-enhanced images were used in the control group. The tube potency was 120 kV, and tube current was 150 mAs. All lung parenchymal areas from the apex of the lung to the basal were visualized during expiration with a section thickness of 5 mm.

Image analysis and measurements

All CT images were analyzed on high-resolution monitors using a picture archiving and communication system (SyngoVia console, software version 2.0; Siemens Medical Solutions). PMV and SFV were measured using a 3D volume measurement workstation (Myrian Pro, Intrasense). The quantitative evaluation of the pectoralis major muscle can be performed from the third thoracic vertebra (T3) level (18) or the aortic arch level (19). However, we obtained PMV approximately 3 cm along the vertical y-axis of the inferior from the level of the fourth thoracic costovertebral junction. To measure the volume of the pectoralis major muscle, the fourth thoracic costovertebral joint (CVJ) was used as the starting point in axial CT slices. At this level, the muscle reached the point of attachment to the shoulder girdle and was entirely within the imaging frame. In addition, this level was the best to distinguish between the pectoralis major and minor muscles. The muscles were marked using a predefined attenuation range of -50 to 90 HU.

For SFV, the lower thoracic/upper abdominal subcutaneous adipose tissue was marked along a 3 cm vertical line starting at the level of the 12th CVJ in the thoracic region (20), and its volume was calculated in cm^3. The subcutaneous fat tissue was marked using a predefined attenuation range of -40 to -175 HU.

The pulmonary conus and ascending aorta diameters were measured approximately 1 cm distal from the valvular level. The P/Ao ratio was obtained. Fig. 1 presents the axial CT images or three-dimensional images of PMV and SFV measurements, and P/Ao calculation in the silicotic and control groups.

The chest X-rays of the silicosis patients were categorized according to the ILO classification (profusion scores) obtained from a follow-up study (21). The ILO values of our patients varied between 4 and 12. In terms of disease severity, the patients were evaluated in three categories: Category 1, ILO 4–6; category 2, ILO 7–9; and category 3, ILO 10–12.

Statistical analysis

The statistical analysis was performed by using MedCalc (version 12). Normality of distribution was evaluated by the D'Agostino-Pearson test. The demographic data were compared between the two groups using the Student t test for age. The PMV, SFV, and P/Ao values were compared between the two groups using the Mann-U Whitney test. BMI values were compared with the Student t test. Patients were grouped according to the disease severity based on ILO classification and compared in terms of PMV, SFV, P/Ao, BMI, and FEV1/FVC, using the Kruskal-Wallis test. Dunn-Bonferroni post hoc test was performed after Kruskal Wallis tests.

Results

The study included 41 male silicosis patients and 41 male controls. The mean age was 33.46±4.44 and 34.65±4.73 years in the silicotic and control groups, respectively. The mean BMI, PMV, SFV, and P/Ao values differed significantly between the study and control groups ($p = 0.0009$, $p < 0.0001$, $p < 0.0001$, and $p = 0.0029$, respectively). The data of the study and control groups are presented in Table 1 and Fig. 2.

According to the ILO radiological classification, there were 12 patients in category 1, 13 in category 2, and 16 in cate-

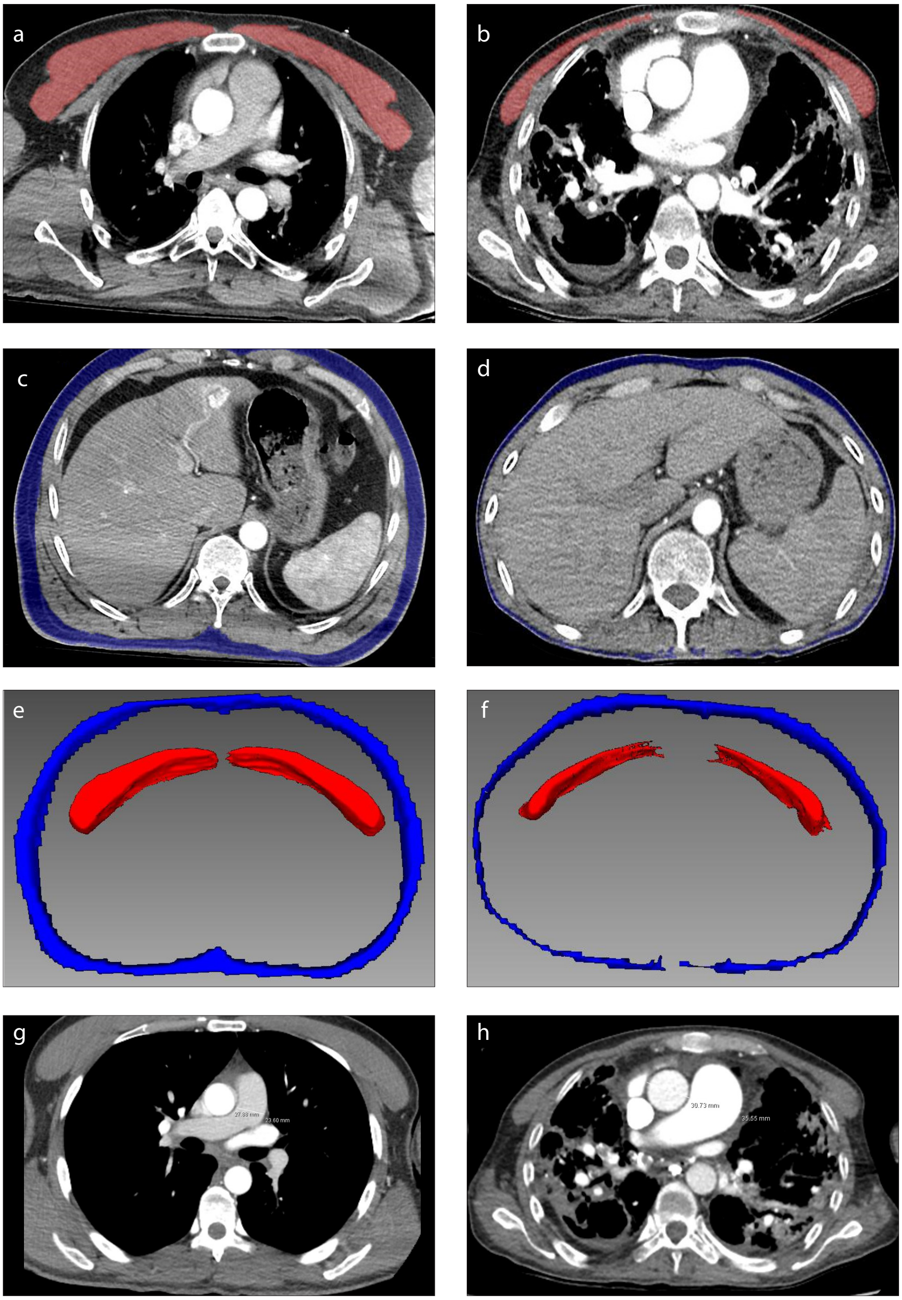

Figure 1. a–h. Axial CT at the level of the fourth costovertebral joint shows the pectoralis major volume (PMV) in the control **(a)** and patient **(b)** groups. Axial CT at level of the 12th costovertebral joint shows the subcutaneous fat volume (SFV) in the control **(c)** and patient **(d)** groups. Three-dimensional images show PMV and SFV in the control **(e)** and patient **(f)** groups. The pulmonary artery and aorta measurements from the axial CT images in the control **(g)** and patient **(h)** groups.

gory 3. A significant difference was found between disease categories in terms of PMV, SFV, P/Ao, BMI, and FEV1/FVC values (p = 0.0425, p = 0.0341, p = 0.0002, p = 0.0492, and p = 0.0004, respectively). Post hoc analysis showed that BMI, PMV, SFV, P/Ao and FEV1/FVC parameters were significantly different in ILO category 3 patients whereas there was no significant difference between ILO category 1 and 2 patients. The data of the study group categorized according to the ILO classification are presented in Table 2.

Discussion

The literature includes studies in which CT muscle measurements were used to analyze the relationship between the changes in muscle volume and disease mortality and morbidity in patients with COPD and cancer (19, 22, 23). However, our literature search yielded no similar studies conducted with silicosis patients. In a study to predict mortality in lung cancer patients participating in the National Lung Screening Trial, muscle area and subcutaneous fat attenuation were measured using chest CT, and it was reported that the deceased patients showed more significant reduction in muscle area compared with the survivors (18). Similarly, in our study, the recent death of a patient with a very low PMV and SFV supports the correlation between reduced muscle-adipose tissue and mortality in silicosis. This suggests that different mechanisms, in addition to respiratory failure, may be useful in predicting mortality in diseases with primary pulmonary involvement, such as silicosis. It has been shown that reduced pectoralis muscle area, which is a new CT-based anthropometric measurement, is correlated with COPD presence and advanced Global Initiative for Chronic Obstructive Lung Disease stage, and may be a more significant indicator of disease severity than BMI (19). We also observed that the profusion score, an indicator of disease severity, had a stronger association with reduced PMV than BMI in our silicosis patients.

Our CT measurements revealed that the patients with silicosis caused by denim sandblasting had significantly reduced PMV and SFV values but a significantly increased P/Ao ratio compared with the controls. These changes were more prominent in advanced stage 3 patients, who had higher ILO scores than the other categories.

Although some publications have demonstrated significant subcutaneous adipose tissue loss in COPD and cancer, suggesting that this might serve as an indicator of disease severity (18), others found no association with the length of stay in the intensive care unit in patients with respiratory failure (24). In our study, we observed a significant reduction in SFV associated with advanced disease stage in silicosis patients when compared with the controls. In silicosis patients, the reduction in muscle mass and subcutaneous adipose tissue may be a better indicator of the changing body composition and can be used instead of BMI.

In a study on idiopathic pulmonary fibrosis, it was shown that patients with P/Ao >1 according to chest CT were three times more likely to die or require a lung transplant (25). We also determined that the P/Ao ratio was significantly higher in silicosis patients compared with the control group

Table 1. Comparison of CT measurements and baseline characteristics between the study and control groups						
	Age	Gender, n (%)	BMI	PMV	SFV	P/Ao
Study group (n=41)	33.46±4.44	M, 41 (100)	24.08±3.89	104.52±16.15	141.89±77.90	0.89±0.10
Control group (n=41)	34.65±4.73	M, 41 (100)	26.50±2.78	148.86±26.12	257.76±117.40	0.82±0.07
p	0.2484		0.0009	< 0.0001	< 0.0001	0.0029

BMI, body mass index; PMV, pectoralis muscle volume; SFV, subcutaneous fat volume; P/Ao, pulmonary artery/aorta.

Table 2. Patient data categorized according to the ILO subgroups						
	n	BMI	PMV	SFV	P/Ao	FEV1/FVC
Category 1	12	25.25±3.10	109.87±15.77	187.41±97.48	0.82±0.04	77.66±3.74
Category 2	13	25.33±2.82	110.53±12.34	161.07±60.96	0.84±0.05	77.84±7.24
Category 3	16	22.18±4.54*	95.62±15.90*	92.15±40.32*	0.98±0.11*	60.87±13.52*
p		0.0492	0.0425	0.0341	0.0002	0.0004

ILO, International Labor Organization; BMI, body mass index; PMV, pectoralis muscle volume; SFV, subcutaneous fat volume; P/Ao, pulmonary artery/aorta; FEV1, forced expiratory volume -one second; FVC, forced vital capacity.
*Significant difference according to post-hoc analysis

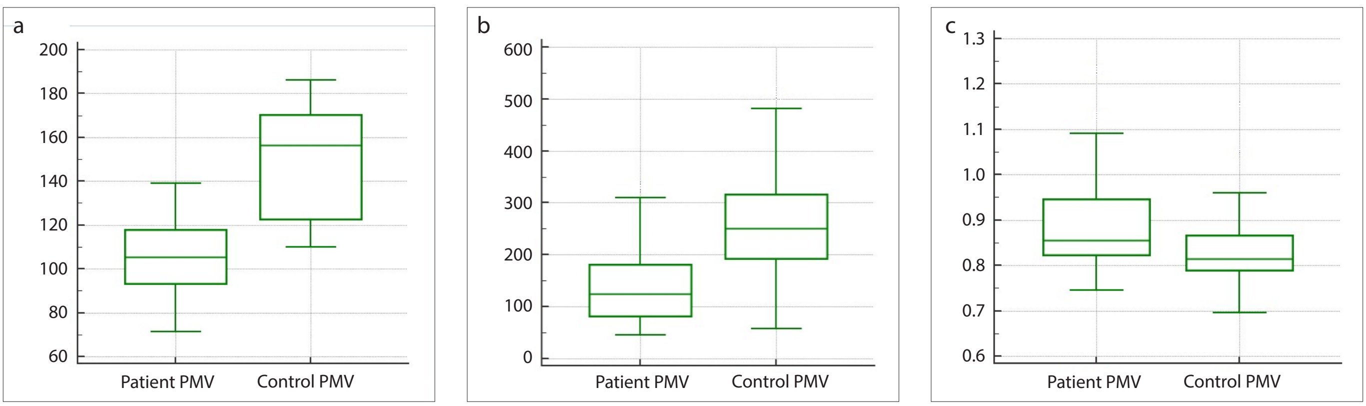

Figure 2. a–c. Box plot **(a)** shows muscle volume measurements in the patient and control groups; box plot **(b)** shows SFV measurements in the patient and control groups; box plot **(c)** shows P/Ao ratio calculation in the patient and control groups.

and that this increase was correlated with the measures of disease severity (profusion and pulmonary function test). Considering the increased risk of pulmonary hypertension in silicosis patients, increased P/Ao ratios may be a predictor of pulmonary hypertension onset and mortality.

Our study had several limitations. First, the results do not represent all silicosis patients because our sample included a specific age group and only cases caused by sandblasting, in whom the acute/subacute clinical picture is more severe. Second, accurate results may not be obtained in silicosis patients with chronic diseases that can affect PMV and SFV, such as diabetes mellitus, muscle dystrophy, and tuberculosis. Therefore, these parameters are more appropriate for use in selected silicosis patients. Although the death of a patient with very low PMV and SFV values suggests that the decrease in muscle and fat tissue in silicosis might be a useful indicator of mortality, more comprehensive studies are needed for statistical evaluation. Third, considering the association between silicosis and increased cardiometabolic risk (26), it would have been better to include abdominal visceral adipose tissue measurements. However, our thorax CT protocol did not allow such measurements in most cases. Lastly, since we could not use gated CT images, the P/Ao ratio may have differed according to the cardiac phase from which the CT images obtained.

In conclusion, we consider that the changes in PMV and SFV provide more valuable data than BMI for the evaluation of body composition in silicosis. In addition, the detection of findings other than lung parenchyma (decreased PMV and SFV and increased P/Ao ratio) with a different view of CT evaluation can help predict morbidity and mortality in these patients.

Conflict of interest disclosure

The authors declared no conflicts of interest.

References

1. Akgün M, Ergan B. Silicosis in Turkey: is it an endless nightmare or is there still hope? Turk Thorac J 2018; 19:89–93. [Crossref]
2. Akgun M, Araz O, Akkurt I, et al. An epidemic of silicosis among former denim sandblasters. Eur Respir J 2008; 32:1295–1303. [Crossref]
3. Cullinan P, Muñoz X, Suojalehto H, et al. Occupational lung diseases: from old and novel exposures to effective preventive strategies. Lancet Respir Med 2017; 5:445–455. [Crossref]
4. Pollard KM. Silica, silicosis, and autoimmunity. Front Immunol 2016; 7:97. [Crossref]
5. Guidelines for the Use of the ILO International Classification of Radiographs of Pneumoconioses. Revised edition, 2011. ILO Occupational Safety and Health Series No. 22. Geneva, Switzerland; International Labour Office; 2011.
6. Alper F, Akgun M, Onbas O, Araz O. CT findings in silicosis due to denim sandblasting. Eur Radiol 2008; 18:2739–2744. [Crossref]

7. Vestbo J, Anderson W, Coxson HO, et al. ECLIPSE Investigators. Evaluation of COPD longitudinally to identify predictive surrogate end-points (ECLIPSE). Eur Respir J 2008; 31:869–873. [Crossref]
8. Alper F, Kurt AT, Aydin Y, Ozgokce M, Akgun M. The role of dynamic magnetic resonance imaging in the evaluation of pulmonary nodules and masses. Med Princ Pract 2013; 22:80–86. [Crossref]
9. Karaman A, Araz O, Alper F, et al. The role of DCE-MRI in the evaluation of progressive massive fibrosis and centrilobular nodules in cases of silicosis due to denim sandblasting. Acta Medica Mediterranea 2015; 31:31–37.
10. Karaman A, Araz O, Durur-Subasi, et al. Added value of DCE-MRI in the management of cystic-cavitary lung lesions. Respirology 2016; 21:739–745. [Crossref]
11. Cowie RL, Murray J, Becklake MR. Pneumoconioses. In: Mason RJ, Murray JF, Broaddus VC, Nadel JA, eds. Murray & Nadel's Textbook of Respiratory Medicine. 4th ed. Saunders, Philadelphia, 2005; 1748–1782.
12. Fearon K, Strasser F, Anker SD, et al. Definition and classification of cancer cachexia: an international consensus. Lancet Oncol 2011; 12:489–495. [Crossref]
13. Brandt C, Pedersen BK. The role of exercise-induced myokines in muscle homeostasis and the defense against chronic diseases. J Biomed Biotechnol 2010; 2010:520258. [Crossref]
14. Lightfoot A, McArdle A, Griffiths RD. Muscle in defense. Crit Care Med 2009; 37:384–390. [Crossref]
15. Schols AM. Nutritional rehabilitation from pulmonary cachexia to sarcoPD. Eur Respir J 2009; 33:949–950. [Crossref]
16. Wells JM, Washko GR, Han MK, et al. Pulmonary arterial enlargement and acute exacerbations of COPD. N Engl J Med 2012; 367:913–921. [Crossref]
17. Mahammedi A, Oshmyansky A, Hassoun PM, et al. Pulmonary artery measurements in pulmonary hypertension: the role of computed tomography. J Thorac Imaging 2013; 28:96–103. [Crossref]
18. Digumarthy SR, De Man R, Canellas R, Otrakji A, Wang G, Kalra MK. Multifactorial analysis of mortality in screening detected lung cancer. J Oncol 2018; 7:2018. [Crossref]
19. McDonald MLN, Diaz AA, Ross JC, et al. Quantitative computed tomography measures of pectoralis muscle area and disease severity in chronic obstructive pulmonary disease. a cross-sectional study. Ann Am Thorac Soc 2014; 11:326–334. [Crossref]
20. Cho YH, Do KH, Chae EJ, et al. Association of chest CT-based quantitative measures of muscle and fat with post-lung transplant survival and morbidity: a single institutional retrospective cohort study in Korean population. Korean J Radiol 2019; 20:522–530. [Crossref]
21. Akgun M, Araz O, Ucar EY, et al. Silicosis appears inevitable among former denim sandblasters: a 4-year follow-up study. Chest 2015; 148:647–654. [Crossref]
22. Fintelmann FJ, Troschel FM, Mario J, et al. Thoracic skeletal muscle is associated with adverse outcomes after lobectomy for lung cancer. Ann Thorac Surg 2018; 105:1507–1515. [Crossref]
23. Kinsey CM, Estepar RSJ, Velden J, Cole BF, Christiani DC, Washko GR. Lower pectoralis muscle area is associated with a worse overall survival in non- small cell lung cancer. Cancer Epidemiol Biomarkers Prev 2017; 26:38–43. [Crossref]
24. Jaitovich A, Khan MHS, Itty R, et al. ICU admission muscle and fat mass, survival, and disability at discharge. Chest J 2019; 155:322–330. [Crossref]
25. Shin S, King CS, Puri N, et al. Pulmonary artery size as a predictor of outcomes in idiopathic pulmonary fibrosis. Eur Respir J 2016; 47:1445–1451. [Crossref]
26. Liu Y, Rong Y, Steenland K, et al. Long-term exposure to crystalline silica and risk of heart disease mortality. Epidemiology 2014; 25:689–696. [Crossref]
27. Pracon R, Kruk M, Demkow M. Qualitative characterization of adipose tissue by MDCT. JACC Cardiovasc Imaging 2014; 7:106. [Crossref]