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Sarcopenia associates with increased hospitalization rates and reduced survival in patients with chronic pancreatitis

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ABSTRACT

Background: Objectives: Malnutrition is a well-known complication of chronic pancreatitis and alterations in body composition are common in this context. We investigated the prevalence of sarcopenia in patients with chronic pancreatitis, its associated risk factors and health-related outcome.
Methods: This was a prospective cohort study of chronic pancreatitis outpatients. Bioelectric impedance was used to measure body composition, and a handheld dynamometer and the timed-up-and-go test characterized muscle function. Several demographic and disease characteristics, including exocrine pancreatic insufficiency (EPI), were analyzed for their association with sarcopenia. The EORCT QLQ-C30 questionnaire was used to document life quality, and associations between sarcopenia and the number of hospital admissions, the number of in-hospital days and survival over the next 12 months were analyzed.
Results: A total of 182 patients were enrolled in the study. The prevalence of sarcopenia was 17.0% (95% CI; 11.9–23.3) and 74% of sarcopenic patients had a BMI in the normal or overweight range (BMI >18.5 kg/m^2). EPI was an independent risk factor for sarcopenia (OR 3.8 95% CI [1.2–12.5]; $p = 0.03$). Several QLQ-C30 scales and items were associated with sarcopenia including physical functioning ($p < 0.001$) and global health ($p = 0.003$). During follow-up, sarcopenia was associated with an increased risk of hospitalization (OR 2.2 95% CI [0.9–5.0]; $p = 0.07$), increased number of in-hospital days ($p < 0.001$), and reduced survival (HR 6.7 [95% CI; 1.8–25.0]; $p = 0.005$).
Conclusion: Sarcopenia is a common complication of chronic pancreatitis and associates with adverse health-related outcomes. As sarcopenia is not recognized by conventional anthropometric parameters in the majority of patients, systematic nutritional assessment should be prioritized.

Introduction

Chronic pancreatitis (CP) is a fibro-inflammatory syndrome of the pancreas characterized by a persistent pathological response to parenchymal injury or stress [1]. Most patients develop significant impairment of exocrine and endocrine pancreatic functions as the disease evolves and, together with chronic abdominal pain, this negatively affects dietary intake and nutritional processing [2]. Alterations in body composition and metabolic adaption are common in this context and may lead to reduced physical activity and progressive loss of skeletal muscle mass and function (i.e. sarcopenia).

Sarcopenia has for long been recognized as an independent predictor of poor clinical outcome in various settings and diseases. For example, it has been associated with increased in-hospital mortality in acute necrotizing pancreatitis [3] and sarcopenia is present in up to 40% of patients with chronic liver disease on the transplant waiting list, where it has been shown to predict mortality independently of conventional prognostic scores [4,5]. Likewise, sarcopenia is associated with reduced survival in malignant diseases and has been identified as a significant predictor of operative complications following pancreatectomy and other surgical procedures [6–8]. Taken together this emphasizes the clinical importance of sarcopenia, but little is known about this entity in

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the context of CP [9–11] and until today no studies have prospectively investigated how sarcopenia influences outcome in patients with CP.

In a cohort of CP outpatients, we prospectively investigated the prevalence of sarcopenia, its associated risk factors, and health-related outcome. We hypothesized that the presence of sarcopenia was associated with impaired quality of life (Qol) as well as an increased hospitalization burden and reduced survival. The aims of the study were: 1) to determine the prevalence of sarcopenia in CP outpatients; 2) to determine risk factors associated with sarcopenia; 3) to investigate the association between sarcopenia and QoL and 4) to prospectively investigate the association between sarcopenia, hospitalization burden and survival.

Methods

This was a one-year prospective monocentric cohort study of CP outpatients. The study was conducted at Centre for Pancreatic Diseases, Department of Gastroenterology and Hepatology, Aalborg University Hospital, Denmark, which is a tertiary centre specialized in treatment of acute and chronic pancreatitis. All assessments were obtained during routine clinical work-up and consequently the informed consent requirement was waived in agreement with directions from the ethical committee at our institution. Approval for data collection and storage was obtained from the Danish Data Protection Agency, Northern Denmark Region (ID 2008-58-0028).

Patient population

Consecutive patients with clinical suspicion of CP were screened for inclusion. Inclusion criteria were age 18–75 years and a diagnosis of definitive or probable CP according to the M-ANNHEIM classification system [12]. Both patients with definitive and probable CP were included to cover the full disease spectrum of CP [13]. Exclusion criteria were: i) patients not assessable for bioelectrical impedance due to edema, cardiac comorbidity treated with pacemakers or implantable defibrillators, metal implants, abnormal body geometry or unwillingness to fast for the required period prior to assessment of bioelectrical impedance measurement, ii) patients not assessable for muscle strength or function due to neurological or musculoskeletal comorbidities, and iii) patients with a history of active cancer or cirrhosis as these conditions are associated with high rates of sarcopenia.

Demographic and disease characteristics

Information on patients' demographics (gender and age) and disease characteristics including duration and etiology of CP, smoking habits, pain pattern and pain medication as well as the presence of EPI and diabetes were recorded in standardized case report forms based on patient interviews, review of medical records and biochemistry.

Exocrine pancreatic function was characterized by the fecal elastase concentration test or fecal fat collection as deemed appropriate by the referring physician. In case the exocrine pancreatic function had not been investigated prior to study inclusion, the fecal elastase concentration test was used, and the test result was registered when available. Exocrine pancreatic insufficiency (EPI) was defined as a fat excretion (aliphatic carboxylate [C14-C26]) >25 mmol per 24 h or fecal elastase-1 level <200 μg/g [14].

Nutritional assessments

Anthropometrics: Patients were classified using conventional anthropometric parameters (weight, height, and body mass index [BMI]). BMI was calculated as body weight divided by the height squared and stratified according to the world health organization criteria; underweight (BMI <18.5 kg/m^2), normal weight (BMI 18.5–24.9 kg/m^2) and overweight or obese (BMI ≥25.0 kg/m^2).

Bioelectrical impedance: Patients muscle mass was determined by bioelectrical impedance measured using a multi-frequency analyzer BioScan 920-II (Maltron, Essex, UK). A published standardized protocol was followed; patients fasted for 4 h (a limited amount of water was allowed until 2 h before the test), refrained from engaging in physical activity for 8 h, urinated prior to assessment and were instructed to lay down in a supine position at a non-leading examination couch for 10 min before measurement [15]. The patient was positioned with approximately 45° between the legs and 30° between each arm and the torso. Four adhesive electrodes were placed in a tetra polar arrangement on the dorsal surface of the hand, wrist, foot and ankle at the patient's right side. Resistance against an alternating electric current (0.8 mA) was measured to determine the skeletal muscle mass [16]. To account for inter-individual differences in height, a skeletal muscle mass index (SMI) (kg/m^2) was calculated as the skeletal muscle mass divided by the height squared. The SMI was characterized as normal or below normal according to previous published normative values: female patients SMI<6.76 kg/m^2 and male patients SMI<10.76 kg/m^2 [17].

Hand grip strength: Muscle strength was determined by hand grip strength (HGS) measured to the nearest kilogram using a hydraulic hand dynamometer (NC70142, North Coast Medical, Arcata, CA, USA). The dynamometer was held in the second handle position and the patient was instructed to sit on a chair with the shoulder neutrally rotated, holding the elbow bend 90° and the wrist in neutral position. HGS was measured 3 times for each hand; assessments were separated by intervals of approximately 10 s. The highest value for each hand was recorded and the mean value was calculated. The mean HGS was characterized as normal or below normal according to previous published normative values: female patients HGS<20 kPa and male patients HGS<30 kPa [18].

Timed up-and-go test: Muscle function was characterized by the timed up-and-go test (TUG). This test is performed and reported as the time it takes a patient to get up from sitting position on a chair, walk three meters, turn around, walk back to the chair, and sit down. The TUG test result was characterized as normal or below normal according to previous published normative values stratified by the following age groups: <70 Years: TUG<9 s, 70 < 80 Years TUG<10.2 s and TUG ≥80 years TUG<12.7 s [19].

Definition of sarcopenia

Sarcopenia was defined according to the criteria proposed by the European Working Group on Sarcopenia in Older People (EWGSOP) [20]. These are based on the combined assessments of SMI, HGS and TUG with stratification of age- and gender specific cut-off values as specified above. Accordingly, sarcopenia was defined as a SMI below normal in the combination of either HGS or TUG below normal (Fig. 1).

Outcomes

Quality of life: The EORCT QLQ-C30 questionnaire was used to document life quality, physical function, and a number of other health-related parameters [21]. The questionnaire has been validated specifically for assessment of patients with CP and is composed of single-item measures and multi-item scales with scores ranging from 0 to 100 after linear transformation of the raw score [21]. A high score for a functional scale represents a high level

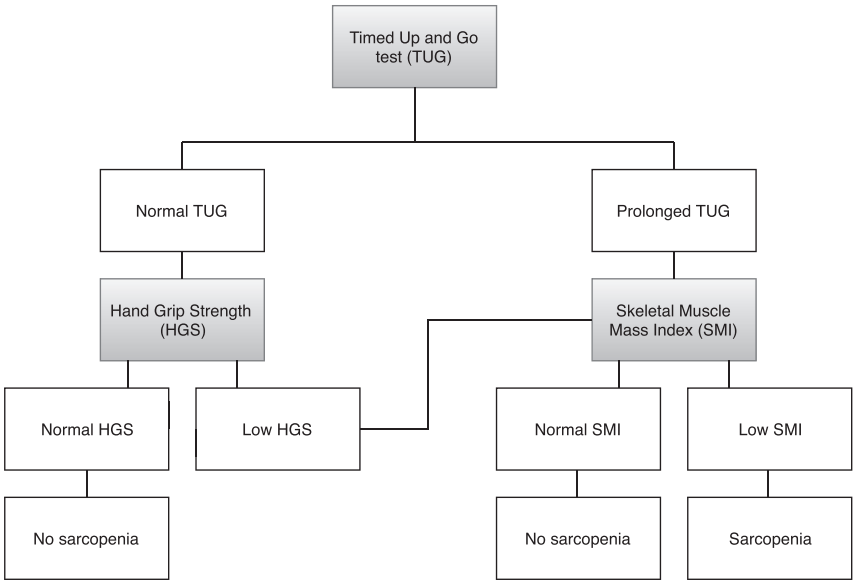

Fig. 1. Algorithm for sarcopenia case finding in patients with chronic pancreatitis.

of functioning, as does a high score for the global health status, while a high score for the symptom items represents a high level of symptomatology.

Hospitalization: The burden of hospitalization was characterized by the number of (re)-admissions to hospital and total length of hospital stay (LOS) within 12 months from inclusion. For patients with a follow-up period <12 months due to death or early study termination, yearly hospital readmission rates and LOS per year were estimated using the individual observation period to account for variations in follow-up times. In addition, pancreatitis-related readmissions and pancreatitis-related LOS was included as an additional endpoint. A hospital stay was considered related to pancreatitis if the admission was due to an episode of acute pancreatitis, exacerbation of abdominal pain caused by pancreatitis, invasive procedures related to the pancreatic gland or infectious complications including the pancreas.

Survival: Survival times and all-cause mortality were calculated with respect to the day of nutritional assessments. Cases were censored at the limit of follow-up or day 365, whichever occurred first. The cause of death was determined based on review of the patients' medical records when death occurred during hospitalization. Three patients died outside the hospital setting during the observation period and the exact cause of death could not be determined in these cases.

Statistical analysis

All data were reported as means ± SD or numbers unless otherwise indicated. Univariate and stepwise multivariate logistic regression with backward elimination was employed for analysis of the association between sarcopenia and demographics and disease characteristics. The associations between sarcopenia and BMI subgroups was analyzed using a Fisher's exact test. Associations between sarcopenia, QoL parameters and hospitalization endpoints were analyzed using logistic regression, Student's *t*-test or Wilcoxon's unpaired rank sum tests as appropriate. Survival curves were constructed using the Kaplan-Meier method and cox proportional hazard regression was used to analyze the association between sarcopenia and survival. A p-value<0.05 was considered statistical significant; in case of multiple comparisons a Bonferroni correction was applied. The software package STATA version 15.1 (StataCorp LP, College Station, Texas, USA) was used for statistical calculations.

Results

Between March 1, 2012 and December 31, 2017, we prospectively screened 274 patients with suspected CP, of whom 182 were included in the study. Reasons for exclusion were: i) patients not fulfilling diagnostic criteria for CP (n = 12), ii) patients not assessable for bioelectrical impedance due to edema, a history of cardiac arrhythmia treated with pacemakers or implantable defibrillators or unwillingness to fast for the required time period (n = 37), iii) patients not assessable for muscle strength or function due to neurological or musculoskeletal comorbidities (n = 39), and iv) patients with an active cancer (n = 1) and liver cirrhosis (n = 3) – Supplementary Fig. 1. The mean age of included patients was 57.4 ± 12.9 years, 69% were men, and 54% had an alcoholic etiology of CP - Table 1.

Prevalence of sarcopenia and association with BMI

Thirty-one of 182 patients had sarcopenia, which corresponds to a prevalence of 17.0% (95% CI; 11.9–23.3). The mean BMI was decreased in patients with sarcopenia compared to their non-sarcopenic counterparts (20.9 ± 4.1 vs. 23.9 ± 4.5 kg/m^2; p < 0.001). A significant association between sarcopenia and BMI subgroups was observed (p = 0.009) – Fig. 2. However, this was not absolute and 23 (74%) of sarcopenic patients had a BMI in the normal or obese range.

Risk factors for sarcopenia

Sarcopenia was significantly associated with opioid treatment (p = 0.002) and EPI (p = 0.01) on univariate analysis. Multivariate analysis confirmed the independence and significance of these associations viz. opioid treatment (OR 2.81 [1.02 to 7.72]; p = 0.045) and EPI (OR 3.80 95% CI [1.16–12.5]; p = 0.03) – Table 2.

Table 1
Demographic and clinical characteristics of the study cohort.

		Complete data, n (%)
Age, Years	57.4 ± 12.9	182 (100)
Gender, n (%)		182 (100)
- Female	56 (31)	
- Male	126 (69)	
BMI, kg/m^2	23.3 ± 4.5	182 (100)
History of recurrent acute pancreatitis, n (%)	86 (47)	161 (88)
Duration of CP, Years	4.8 ± 6.7	176 (97)
Etiological risk-factors, n (%)[a]		177 (97)
- Alcohol	97 (54)	
- Nicotine	138 (78)	
- Nutritional	0 (0)	
- Hereditary	47 (26)	
- Efferent	20 (11)	
- Immunological	1 (1)	
- Miscellaneous	11 (6)	
Pain pattern, n (%)		142 (78)
- No pain	67 (47)	
- Intermittent pain	31 (22)	
- Constant pain	44 (31)	
Opioid treatment, n (%)	42 (30)	141 (77)
EPI, n (%)	93 (54)	173 (95)
Diabetes, n (%)	60 (33)	180 (99)

BMI; body mass index, CP; chronic pancreatitis, EPI; exocrine pancreatic insufficiency.
[a] According to the M-ANNHEIM classification multiple risk factors can be present in the individual patient.

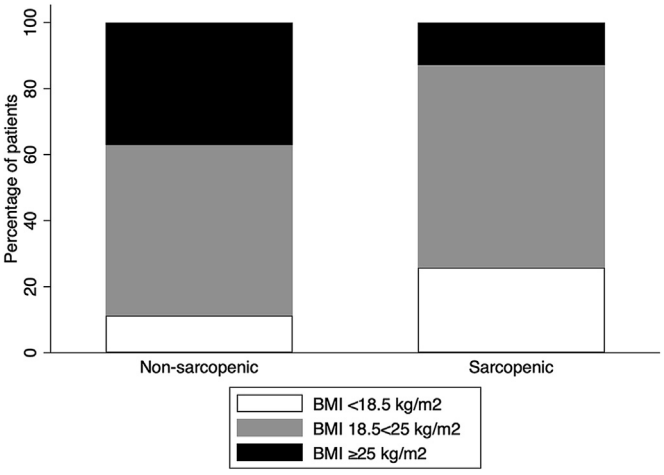

Fig. 2. Distributions of BMI subgroup, by sarcopenia.

Sarcopenia and clinical outcomes

Quality of life: Decreased median (IQR) global health scores were observed in sarcopenic patients compared to their non-sarcopenic counterparts (33.3 [16.7–50.0] vs 50.0 [33.3–66.7]; $p = 0.003$). Likewise decreased physical functioning was observed in sarcopenic patients (40.0 [26.7–46.7] vs 73.3 [53.3–93.3]; $p < 0.001$) as well as decreased role ($p = 0.002$) and emotional functioning ($p = 0.04$). In addition, a higher symptom level for fatigue ($p = 0.003$), pain ($p = 0.005$) and constipation ($p = 0.03$) was observed – Table 3.

Hospitalization: During the one-year follow-up period patients were admitted 1.7 times (95% CI; 1.3–2.1) on average; making up for 317 hospital admissions of which 163 (51%) were directly related to CP. The average LOS was 10.7 days during the follow-up period (95% CI; 7.5–13.8) adding up to 1942 admission days, of which 1124 (58%) were directly related to CP.

Sarcopenia was associated with an increased risk of *hospitalization* during the follow-up period (OR 2.17 95% CI [0.94–5.02];

Table 2
Uni- and multivariate analysis of risk factors associated with sarcopenia in patients with chronic pancreatitis.

	Sarcopenia	No Sarcopenia	Univariate		Multivariate	
			OR (95% CI)	P-value	OR (95% CI)	P-value
Age, years	60.6 ± 11.6	56.8 ± 13.0	1.02 (0.99–1.05)	0.14		
Male sex, n (%)	24 (77)	102 (68)	1.65 (0.66–4.08)	0.28		
Duration of CP, years	4.8 ± 6.8	4.8 ± 6.1	1.00 (0.94–1.06)	1.00		
Alcoholic etiology, n (%)	20 (65)	77 (52)	1.68 (0.75–3.74)	0.21		
Smoking, n (%)[a]	23 (82)	92 (63)	2.65 (0.95–7.38)	0.06		
Pain pattern, n (%)						
- No pain	8 (31)	59 (51)	Reference			
- Intermittent pain	7 (27)	24 (21)	2.15 (0.70–6.59)	0.12		
- Constant pain	11 (42)	33 (28)	2.46 (0.90–6.72)	0.08		
Opioid treatment, n (%)	14 (56)	28 (24)	4.00 (1.63–9.81)	0.002	2.81 (1.02–7.72)	0.045
EPI, n (%)	22 (76)	71 (49)	3.23 (1.30–8.04)	0.01	3.80 (1.16–12.5)	0.03
Diabetes, n (%)	8 (27)	52 (35)	0.69 (0.29–1.64)	0.40		

CP; chronic pancreatitis, EPI; exocrine pancreatic insufficiency.
[a] Current smoking vs. never or former smoking.

Table 3
Median (interquartile range) EORTC QLQ-C30 subscales and items by sarcopenia.

	Sarcopenia	No sarcopenia	P-value[a]
Global health	33.3 (16.7–50.0)	50.0 (33.3–66.7)	0.003
Functional scales			
Physical functioning	40.0 (26.7–46.7)	73.3 (53.3–93.3)	<0.001
Role functioning	16.7 (0–50.0)	66.7 (33.3–100)	0.002
Emotional functioning	54.2 (16.7–66.7)	70.8 (50.0–91.7)	0.04
Cognitive functioning	58.3 (33.3–83.3)	83.3 (50.0–100)	0.35
Social functioning	50.0 (33.3–66.7)	66.7 (50.0–100)	0.06
Symptom scales/items			
Fatigue	77.8 (55.6–100)	55.6 (22.2–66.7)	0.003
Nausea and vomiting	16.7 (0–50.0)	0 (0–33.3)	0.54
Pain	91.7 (50.0–100)	50.0 (16.7–83.3)	0.005
Dyspnoea	33.3 (0–66.7)	0 (0–33.3)	0.44
Insomnia	66.7 (33.3–66.7)	33.3 (0–66.7)	1.00
Appetite loss	66.7 (0–100)	33.3 (0–66.7)	0.30
Constipation	33.3 (0–66.7)	0 (0–33.3)	0.03
Diarrhoea	50.0 (0–66.7)	0 (0–33.3)	0.29
Financial difficulties	0 (0–100)	0 (0–66.7)	1.00

[a] P-values corrected for multiple comparisons using the Bonferroni method are shown.

$p = 0.07$) - Fig. 3 (upper panel). Also, the overall mean LOS in hospitalized patients during the follow-up period was increased in patients with sarcopenia compared to their non-sarcopenic counterparts (23.4 ± 36.4 days vs. 8.1 ± 15.9 days; $p < 0.001$).

Sarcopenia was not associated with an increased risk of *pancreatitis related hospitalization* during the follow-up period (OR 1.42 95% CI [0.64–3.12]; $p = 0.39$) – Fig. 3 (lower panel). Likewise, the mean LOS for pancreatitis related hospitalizations during the follow-up period was comparable in patients with sarcopenia compared to non-sarcopenic patients (9.4 ± 24.6 days vs. 5.5 ± 13.3 days; $p = 0.21$).

Survival: The median follow-up period was 365 days (range 71–366). During the follow-up period 5 patients (16%) in the sarcopenic group died compared to 4 patients (3%) in the non-sarcopenic group (HR 6.69 [95% CI; 1.79–24.9]; $p = 0.005$) – Fig. 4. In the group of sarcopenic patients the causes of dead were liver cirrhosis related complications, sepsis, pancreatic cancer, and undetermined in two patients. The patient dying of liver cirrhosis related complications was diagnosed with cirrhosis after enrollment in the study. In the group of non-sarcopenic patients causes of dead were pancreatic cancer in three patients and undetermined in one patient.

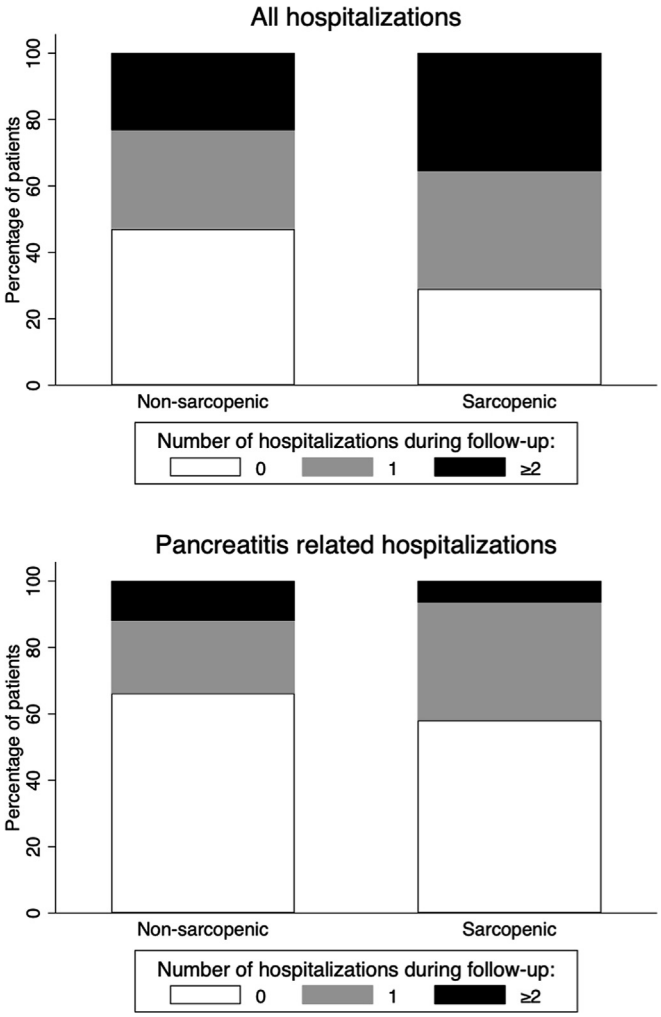

Fig. 3. Overall hospitalization frequencies (top panel) and pancreatitis related hospitalization frequencies (lower panel), by sarcopenia.

Discussion

The prevalence of sarcopenia and its associations to health-related outcomes were investigated in a large cohort of outpatients with chronic pancreatitis. One out of five patients had sarcopenia and the majority of sarcopenic patients had a BMI in the normal or obese range. Sarcopenia was associated with reduced quality of life and physical functioning as well as an increased hospitalization burden and reduced survival. Exocrine pancreatic insufficiency was confirmed as a significant and independent risk factor for sarcopenia. These findings attest to the growing body of evidence supporting sarcopenia as a clinical significant risk factor for adverse outcomes in gastrointestinal and liver diseases.

Prevalence of sarcopenia and association with BMI

The prevalence of sarcopenia was nearly 20% in our population. There are no comparable studies in patients with CP to compare this estimate with. In a pilot study by O'Conner and co-workers, 15 of 29 patients (52%) were characterized as sarcopenic using a computed tomography-based assessment of skeletal muscle mass [22]. This is in contrast to the present study, where a multimodal approach including quantification of muscle mass as well as muscle function was employed in agreement with international

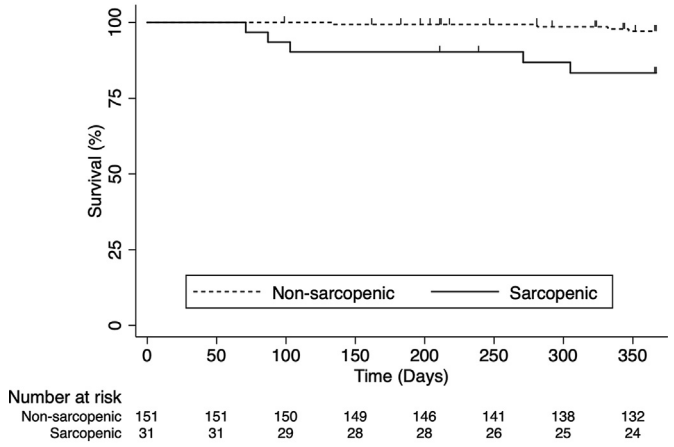

Fig. 4. Medium-term (12-month) survival in chronic pancreatitis patients, by sarcopenia. Vertical markers indicate censored patients.

recommendations [23]. In a Japanese study by Shintakuya and co-workers, sarcopenia was defined as the lower quartile of skeletal muscle mass quantified using computed tomography-based segmentation and, as such, the prevalence of sarcopenia was artificially fixed at 25% in that study [24]. Overall prevalence estimates of sarcopenia vary widely in gastrointestinal and liver diseases ranging from 73% in patients with intestinal failure on home parental nutrition [25], to 30–70% of cirrhotic patients [26] and 30–65% of patients with pancreatic cancer [27].

A significant association between sarcopenia and BMI was observed in the present study. However, this was not absolute as more than two-thirds of sarcopenic had a BMI above the underweight criteria defined by the World Health Organization (BMI<18.5 kg/m^2). Hence, a large proportion of patients would not be recognized as being sarcopenic by conventional anthropometric parameters. This is in agreement with the findings from the aforementioned Irish study, where more than half of sarcopenic patients had a BMI in the overweight or obese range and underlines that conventional anthropometric parameters do not detect sarcopenia in a significant proportion of patients [22].

Risk factors for sarcopenia

Exocrine pancreatic insufficiency was significantly and independently associated with sarcopenia on multivariate analysis. This finding is in agreement with the study by Shintakuya and co-workers, where EPI was also found to be associated with sarcopenia [24]. Many patients, however, lose weight and decrease physical activity early in their disease course and prior to evolution of EPI and, as such, other factors must be of significance [28]. For example, postprandial pain, as seen in many CP patients, may limit food intake and physical activity with ensuing underweight and sarcopenia. Along this line, opioid treatment, a surrogate marker for chronic abdominal pain, was identified as an associated risk factor on univariate analysis in the present study.

Sarcopenia and clinical outcomes

Several QoL scales and items were associated with sarcopenia including reduced physical functioning and global health. These findings are in agreement with previous findings where underweight and malnutrition has been associated with reduced life quality in patients with CP [29].

An increased hospitalization rate was observed in sarcopenic patients, which corresponds to findings from a previous study from our group where low plasma albumin levels, a surrogate marker for a poor nutritional status, was associated with increased hospitalization rates in CP patients [30]. Likewise, a recent study developed and validated a scoring system for prognostication of CP – the Chronic Pancreatitis Prognosis Score (COPPS) [31]. This was based on five parameters, including BMI, and found that a low BMI was associated with increased hospitalization rates [31]. On the other hand, as underlined by the present study, BMI is not an accurate predictor of sarcopenia and the limitations of BMI as a marker of the overall nutritional status is well recognized [32]. While the association between hospitalization rates and sarcopenia has not previously been investigated in CP, our findings are in agreement with observations in patients with chronic liver disease, where gait speed was significantly and independently associated with hospitalization rates in cirrhotic patients evaluated for liver transplant [5].

The increased hospitalization burden observed in sarcopenic patients was mainly associated with an overall increased hospitalization rate. This observation indicates that general complications of sarcopenia rather than pancreatitis related complications accounts for the majority of hospitalizations in these patients. A detailed analysis of the non-pancreatic causes of hospitalization was not undertaken in the present study, but previous studies support this observation. For example, sarcopenia may impair diaphragmatic work due to reduced muscle mass, which may favor pulmonary complications and infection [26]. Likewise, sarcopenic patients are at an increased risk of sepsis and many patients develop frailty, with an increased risk of falls and fractures [26,33].

A reduced survival rate was observed in the sarcopenic subgroup in our study. This finding corroborates findings from previous studies showing increased mortality rates in CP patients [34–36]. In a population-based study by Bang and co-workers, a fivefold increased risk for death was observed in CP patients compared to controls [35]. The increased death rates were associated with increased rates of cancer (particularly pancreatic cancer) and a higher incidence of comorbidities [35]. In the present study, however, pancreatic cancer was not the explanation for the increased death rate in the sarcopenic group as more patients developed pancreatic cancer during the 12-month follow-up period in the non-sarcopenic group (3 patients vs. 1 patient, respectively). The small numbers, however, precludes any detailed analysis of death causes and the finding needs validation in future and larger prospective studies.

Study limitations

Our study has some limitations: First; the monocentric nature of the study may compromise external validity and larger multicenter studies are needed to confirm our findings. Second, the methods used for nutritional assessments are relatively time consuming and not available in all clinics. Hence, future studies should investigate alternative methods for assessment of sarcopenia including computed tomography-based segmentation of muscle mass or even simpler evaluation using two-point cross-sectional imaging parameters [37,38]. Third, the quantification of muscle mass was based on bioelectrical impedance which may be biased by the presence of edema. While this has been a well-established problem in the setting of chronic liver disease, edema and ascites are not commonly seen in stable CP outpatients [39]. In addition, all nutritional assessments were performed by the same investigator (MK) and careful selection of patients prior to evaluation was undertaken to limit bias. Consequently, we do not consider edema to be a significant bias of our assessments. Fourth, patients with CP have increased prevalence's of various comorbidities which may influence the risk of sarcopenia [35]; it is, however, not possible to take all these into consideration and further restriction of the study cohort would have compromise the external validity of our study. Finally, we did report data on non-pancreatitis reasons for hospitalization, this information may provide further insight to the health-related risk associated with sarcopenia and should be included in future studies.

Conclusion

Sarcopenia is a common complication of patients with chronic pancreatitis and it is not recognized by assessment of conventional anthropometric parameters in the majority of patients. As sarcopenia is associated with a worsened clinical outcome, including increased hospitalization rates and reduced survival, systematic evaluation of this common complication should be prioritized.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pan.2019.01.006.

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