A novel computed tomography method to detect normal from abnormal psoas muscle: a pilot feasibility study

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Abstract

Background Sarcopenia is a syndrome characterized by progressive loss of skeletal muscle which can be detected by computed tomography (CT) by estimating total psoas muscle cross-sectional area (CSA). Relying on total psoas CSA alone takes into account abnormal muscle and intramuscular fat, both of which may be increased in sarcopenic obesity. We developed a novel CT-method to identify the proportion of normal to abnormal psoas muscle at the third lumbar (L3) level. The primary objective of our pilot study was to measure inter-observer agreement between measuring total psoas CSA and proportion of normal and abnormal psoas muscle using a novel CT-method. We hypothesized total psoas CSA and proportion of normal and abnormal psoas muscle would be reliably quantifiable.

Methods CT abdomen images were obtained for 20 adults. Two radiologists independently identified and traced the L3 psoas muscle circumference to estimate CSA. Hounsfield units were applied to the tracing to identify proportion of normal muscle, abnormal muscle, and fat. Inter-observer agreement was assessed using Pearson’s correlation coefficient.

Results Of the 20 patients, 13 were male and six were obese. Mean age was 66 years. Correlation coefficient was excellent for total psoas CSA ($r=0.93$, $p$-value<0.00001) and proportion of normal psoas muscle ($r=0.94$, $p$-value<0.0001). Correlation was excellent between BMI and abnormal muscle ($r=0.67$, $p$-value=0.001). Correlation was poor between total psoas CSA and body mass index (BMI) ($r=0.369$, $p$-value=0.108) and negative between proportion of normal muscle and BMI ($r=-0.50$, $p$-value=0.025).

Conclusions Our study findings demonstrate that total psoas CSA and proportion of normal and abnormal psoas can be reliably quantified. Our CT-method may be superior to total psoas CSA in identifying sarcopenic obesity, the results of which can be used to explore clinical outcomes.

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Introduction

Obesity is a worldwide public health problem. In the United States, obesity prevalence has doubled between years 1980-2004 [1,2]. The obese individual is at increased risk for ischemic heart disease, diabetes, cancer, and all-cause mortality [3]. Body mass index (BMI) alone does not discern all phenotypes of obesity, including sarcopenic obesity. Sarcopenia is a syndrome characterized by progressive loss of skeletal muscle mass and function and can be seen in older adults, malnourishment, malignancy, prolonged physical inactivity, and critical illness [4,5]. Sarcopenic obesity may better correlate to outcomes than BMI [6]. In fact, the presence of sarcopenia has been shown to be a marker for poor outcomes in the elderly and cancer patients [7,8].

Sarcopenia can be identified using computed tomography (CT) by estimating total psoas muscle cross-sectional area (CSA) [9]. Current CT methods identify total psoas muscle CSA using Hounsfield units (HU) in the range of -29 to +150. The Hounsfield scale is a quantitative scale for describing radiodensity, which characterizes the amount of x-ray radiation absorbed by each element in tissue [10]. Relying on a HU range between -29 to +150 to estimate total psoas CSA takes
into account abnormal muscle. Due to increased adiposity and intramuscular fat deposition, the potential for abnormal muscle may be greater in obese individuals, as compared to non-obese. Therefore, identifying the proportion of normal and abnormal muscle may be more important for risk stratifying sarcopenic obesity. Using a Hounsfield scale which quantifies normal and abnormal muscle, we developed a novel CT-method to identify normal muscle, abnormal muscle, and intramuscular fat within the psoas muscle. The objective of this pilot study is to measure the agreement between total psoas muscle CSA and proportion of normal and abnormal muscle based on inter-observer agreement for both measurements. We hypothesize that the total psoas muscle CSA and proportion of normal and abnormal muscle will be reliably and reproducibly quantifiable and may define different populations in obese and non-obese patients.

**Methods**

This was an Institutional Review Board (IRB) approved retrospective pilot study. Using our Picture and Archive and Communication System (PACS), we randomly selected 20 adult patients >18 years old who had CT abdomen performed at Froedtert hospital over a two-month duration between December 1, 2015 and January 31, 2016. We excluded patients with trauma involving the psoas muscle, retroperitoneal pathology infiltrating into the psoas muscle, and/or lumbar spinal instrumentation causing radiographic artefacts, all of which limit accurate muscle measurements.

The primary objective is to measure inter-observer agreement for total psoas muscle CSA and proportion of normal psoas muscle using a CT-method. Secondary objectives are to (a) correlate total psoas CSA to BMI, (b) correlate proportion of normal psoas muscle and BMI, (c) correlate proportion of abnormal muscle and BMI and (d) correlate total normal psoas muscle CSA in obese versus non-obese patients. Obesity is defined as a BMI > 30 kg/m² [11].

**Process for Psoas Muscle Measurements**

De-identified CT abdomen images were uploaded onto a 3D radiology workstation (General Electric Medical Systems: Milwaukee, Wisconsin). Using coronal CT abdomen sections, two radiologists (with 12 years combined post-graduate experience) independently identified the L3 right and left psoas muscles. Each radiologist independently traced the right and left L3 psoas muscle circumference to estimate total psoas muscle CSA, which includes normal muscle, abnormal muscle, and fat. Total psoas muscle CSA was calculated by adding the right and left psoas CSA and dividing by the patient’s body surface area (BSA). The BSA was calculated using the Mosteller method [12]. Quantification of HU to the traced CSA was used to determine the proportion of normal muscle, abnormal muscle, and fat (Figure 1).

**Figures 1a-c:** Two cohort patients’ third lumbar right psoas muscle measurements are shown. Patient 1 is obese (BMI 35 kg/m²) and patient 2 is non-obese (BMI 28 kg/m²). [1a] Third lumbar psoas muscle tracing shows patient 1 and 2 have similar (and normal range) total psoas muscle area (772 mm² and 728 mm²) [1b] When HU are applied to psoas muscle, there is greater proportion of normal muscle (grey) in patient 2, as compared to patient 1 (95.6% versus 70.6%). [1c] Histogram with percentages for corresponding attenuation ranges. HU=Hounsfield units

HU attenuation values of greater than 29 were deemed normal muscle [13, 14]. Fat attenuation signal was -190 to -29 HU. Abnormal muscle signals were between -29 to +29 HU [14].

**Process for Determining Calculations Based on Measurements**

Total psoas muscle CSA was calculated by dividing the sum of right and left CSA by BSA ([left CSA + right CSA in mm²] / BSA [m²]). Normal psoas muscle content was calculated by multiplying the percentage of muscle defined by HU greater than +29 with CSA for both right and left psoas muscles [% normal muscle x total psoas CSA in mm²]. Total normal psoas muscle CSA was calculated by dividing the sum of right and left normal psoas CSA by BSA ([left normal CSA + right normal CSA in mm²] / BSA [m³]). Total abnormal psoas muscle and fat content was calculated by multiplying the percentage of abnormal muscle and fat (as determined by HU -190 to +29) with CSA [% abnormal muscle/fat x CSA in mm²] for both right and left psoas muscles. Absolute abnormal psoas muscle area was calculated by multiplying percentage of abnormal muscle (as determined by -29 to +29 HU) by total psoas CSA.
was used to determine differences between two independent means. Inter-observer agreement was reported using Pearson correlation coefficient. Significance was set at a p-value < 0.05 (two-tailed).

Results

Demographic

Of the 20 patients, 13 were male. Mean age was 66 years (SD±17). Median BMI was 23 kg/m² (IQR 21-31). Six patients were obese.

Primary Objective

Correlation coefficient was excellent for calculated total psoas CSA (r=0.93, p-value <0.00001) (Figure 2) for all patients. Correlation coefficient was excellent between radiologists for proportion of normal psoas muscle (r=0.94, p-value <0.00001) (Figure 3). The coefficient of variation is 6% and the limit of agreement between radiologists is 68 mm² for normal psoas muscle.

Secondary Objectives

There was positive correlation between BMI and abnormal muscle (r=0.67, p-value=0.001) (Figure 4). There was no correlation between total psoas CSA and BMI (r=0.369, p-value=0.108) (Figure 5). There was moderate negative correlation between the proportion of normal psoas muscle and BMI (r=-0.50, p-value=0.025) (Figure 6).

Figure 2 Correlation between radiologist 1 and radiologist 2 for measuring total psoas muscle CSA (r=0.93, p-value <0.00001). CSA=cross-sectional area

Figure 3 Correlation between radiologist 1 and radiologist 2 for detecting the percentage of normal psoas muscle (r=0.94, p-value <0.00001)

Figure 4 Positive correlation between BMI and abnormal psoas muscle (absolute area in mm²) (r=0.67, p-value=0.001). BMI=body mass index

Figure 5 Correlation between BMI and total psoas CSA. BMI=body mass index, CSA=cross-sectional rea, TPA=total psoas cross-sectional area (r=0.369, p-value=0.108)

Statistical Analysis

We calculated 19 patients would be required to achieve correlation coefficient (r) of 0.60 with alpha level of 0.05 and 80% power. All statistical analyses were done using Microsoft Excel 2010 (Microsoft Corporation, Redmond Washington). Descriptive statistics were reported as means with standard deviation (SD) and median with interquartile range (IQR). Student’s t-test

Among the six obese patients, there was poor correlation between total psoas CSA and total normal psoas CSA (r=0.70, p-value=0.121) (Table 1). Among the 14 non-obese patients, there was excellent correlation between total psoas CSA and total normal psoas CSA (r=0.92, p-value<0.0001). Our study was not powered for secondary objectives, thus these data need to be confirmed with additional investigations.

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Furthermore, than and including total mm²/m² BMI obesity 901 676 1132 586 muscle study identify of CT one and six sarcopenia, identifying cancer of phenotypes in our used, a method, to be accurate, and our method can be used to accurately identify normal and abnormal psoas muscle in obese individuals to evaluate outcomes such as physical functioning and the impact of interventions such as nutrition and exercise optimization. Commercially available CT based programs to estimate lean body mass are limited to highly specialized settings, are costly, and require specialized training [9]. The benefits of our method include wide applicability, less expense, and minimal training.

We acknowledge several study limitations. First, this was a retrospective pilot study to evaluate for inter-observer agreement and the results need to be replicated in a larger powered cohort. Second, we acknowledge psoas muscle alone may not represent total body muscle. The purpose of our study was to measure inter-observer agreement between measuring total psoas CSA and proportion of normal and abnormal psoas; however, our study also demonstrated differences between normal and abnormal psoas muscle, particularly in the obese. A follow-up study to determine whether psoas muscle composition using our method correlates with other muscle groups is needed. Third, the significance of identifying normal muscle using our CT-method is unclear and further studies are warranted to evaluate clinical outcomes. Fourth, our study did not enrol individuals with a BMI of greater than 40 kg/m². This may limit external generalizability; however, our method for identifying the L3 psoas muscle and applying Hounsfield units would be unchanged in this population and increasing obesity may only reduce attenuation on the order of 3-6 HU [13]. Fifth, our study did not assess the impact of intravenous contrast on total psoas CSA and normal muscle measurements. Contrast-enhanced CT examinations may affect bone attenuation; however, its effect on muscle attenuation is not known and was untested in this study [20].

In conclusion, our study suggests total psoas muscle CSA and proportion of normal psoas can be accurately identified. Our method may be a surrogate marker for identifying abnormal muscle and may have substantial impact on identifying and risk-stratifying sarcopenic obesity, the results of which can be used to explore clinical outcomes.
Table 2 The mean total psoas CSA, mean total normal psoas CSA, and differences amongst obese and non-obese individuals CSA= cross-sectional area, SD= standard deviation. \( p\)-value<0.05

<table>
<thead>
<tr>
<th></th>
<th>Total Psoas CSA, mean mm(^2)/m(^2) (±SD)</th>
<th>Total Normal Psoas CSA, mean mm(^2)/m(^2) (±SD)</th>
<th>Difference between total CSA and normal muscle CSA, mm(^2)/m(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-obese (n=14)</td>
<td>771 (±99)</td>
<td>591 (±99)</td>
<td>175 (±199)</td>
</tr>
<tr>
<td>Obese (n=6)</td>
<td>865 (±153)</td>
<td>498 (±153)</td>
<td>367 (±153)</td>
</tr>
<tr>
<td>Difference</td>
<td>-94</td>
<td>91</td>
<td>-184 (95% CI –6 to –303)</td>
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Conflicts of Interest

All authors (JP, DB, and KS) have no conflicts of interest.

Statement on Human and Animal Rights

This study was approved by the Medical College of Wisconsin’s institutional review board and meets all standards for ethical conduct in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

Statement on Ethical Guidelines

Jayshil J. Patel (corresponding author) certifies that all work is original, has not been submitted elsewhere for publication, certifies authors listed (JP, DB, KS) on the manuscript have approved its submission and publication as to Journal of Cachexia, Sarcopenia and Muscle Clinical Reports, and certifies each author has made an independent material contribution to the work submitted for publication. The authors certify that they comply with the ethical guidelines for authorship and publishing of the Journal of Cachexia, Sarcopenia and Muscle - Clinical Reports (von Haehling S, Ebner N, Morley JE, Coats AJS, Anker SD. Ethical guidelines for authorship and publishing in the Journal of Cachexia, Sarcopenia and Muscle - Clinical Reports. J Cachexia Sarcopenia Muscle Clinical Reports 2016; 1:e28:1-2.)

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