Validity of Ultrasound Imaging in Measuring Quadriceps Muscle Thickness and Cross-Sectional Area in Hemodialysis Patients

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Validity of ultrasound imaging in measuring quadriceps muscle thickness and cross-sectional area in hemodialysis patients

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Conflicts of interest: None declared.

Background: Muscle wasting, prevalent in hemodialysis (HD) patients diagnosed with protein energy wasting, represents an assessment challenge in the outpatient HD setting. Quadriceps muscle thickness (QMT) and cross-sectional area (CSA) assessment by ultrasound (US) is a potential surrogate measure for muscle wasting. We aimed to determine the validity of US to measure QMT and CSA against the gold standard, computed tomography (CT).

Methods: Twenty-six HD patients underwent US and CT scans on the same day, post-dialysis session. QMT for *rectus femoris* (RF) and *vastus intermedius* (VI) muscles was taken at the mid-point and 2/3 of both thighs and CSA of the RF muscle (RF_{CSA}), respectively. Correlation between US and CT measurements was determined by intraclass correlation coefficient (ICC) and Bland-Altman plot.

Results: ICC (95% CI) computed between US and CT was 0.94 (0.87-0.97), 0.97 (0.93-0.99), 0.94 (0.87-0.97), 0.94 (0.86-0.97) and 0.92 (0.83-0.97) for RF_{MID}, VI_{MID}, $RF_{2/3}$ $VI_{2/3}$ and RF_{CSA}, respectively (all $p<0.001$). Bland-Altman analysis indicated no bias in agreement between both methods.

Conclusion: The US imaging offers a valid and quick bedside assessment approach to assess muscle wasting in HD patients.

Keywords: hemodialysis, ultrasound, CT scan, quadriceps, rectus femoris, vastus intermedius

Clinical Relevancy Statement

Muscle wasting, highly prevalent in global hemodialysis (HD) populations, affects patient mobility, quality of life and risk for mortality. Accurate diagnosis of muscle wasting is critical to implement early treatment. Applying repeated computed tomography (CT), a gold standard method, for assessment is costly, poses radiation risk and unsuitable in clinical settings. Ultrasound (US) imaging has been applied and validated for measurement of quadriceps muscle in other diseases but not for HD patients. This study reveals that US is a reliable, highly portable and cost-effective method in assessing muscle wasting in HD patients.

Introduction

Muscle wasting associated with protein energy wasting is highly prevalent in the global dialysis population and is associated with increased mortality [1]. But importantly muscle wasting also affects patient mobility by decreasing strength of the lower limbs, increasing frailty and hospitalization duration [2].

Indirect assessment of muscle wasting via anthropometry measures and bio-impedance analysis are non-invasive approaches to identify presence of muscle wasting in hemodialysis (HD) patients, but both rely on predictive equations to estimate skeletal muscle mass [3]. These methods are further limited by the presence of edema, a common issue in the dialysis population [3]. Quantifying muscle wasting using gold standard methods such as computed tomography (CT) and magnetic resonance imaging (MRI) are expensive, require trained personnel and pose radiation risk specifically in chronic kidney disease patients [2-4].

Ultrasound (US) imaging provides an alternative method for muscle wasting assessment. The validity and reliability of US in measuring quadriceps muscle thickness (QMT) and its cross-sectional area (CSA) against CT has been reported in healthy subjects and diseased populations [4-6]. Recently, US was applied to determine CSA of muscle in non-dialysis CKD patients with either MRI [7] or CT [8] as comparators. Both studies only reported correlation for RF muscle measurements between US and MRI or CT scans. US application in HD patients is reported [9] but without the validity of this measurement. Therefore, we aimed to determine the validity of US in assessing muscle wasting in HD patients in comparison to CT measurements.

METHODS

Study subjects

The study was approved by the Medical Research Ethics Committee of University Kebangsaan Malaysia (FF-2019-034). Twenty-six HD patients were recruited after obtaining written consent.

Anatomical landmarks

Both thighs were landmarked [KT] for the iliospinale® and anterior patella® as per the International Society for the Advancement of Kinanthropometry protocol [10]. Length between the two landmarks was determined using a non-stretch metal tape (Lufkin®, Apex Tool Group, LLC, NC, USA), and the mid-point and 2/3 length landmarked. Both US and CT scans were acquired on the exact same location according to the landmarks.

Study protocol

All scans were performed 4 to 5 hours post-dialysis. Patients first underwent the US scan while lying in a supine position on the CT table with both knees extended but relaxed and toes pointing towards the ceiling. Upon completion of the US scan, the CT scan was performed on the same table. Patient calves were fastened with an elastic band to restrict movement during scans.

Ultrasound imaging

The quadriceps muscle thickness (QMT), namely the *rectus femoris* (RF) and *vastus intermedius* (VI) muscles was measured by a trained researcher [SS] as per standardized protocol [11] for both legs using a portable US equipment (GE Logiq e Digital Portable Color Doppler, GE Healthcare, Wauwatosa, US). CSA of the RF muscle (RF_{CSA}) was measured at the mid-thigh landmark. Two readings were obtained for each measured site, and the mean value calculated. The intra-observer reliability of US measurements for all muscle sites was represented by interclass correlation coefficient (ICC) ranging between 0.98-1.00 (Refer Supplementary material Table S1). Similarly, the inter-observer reliability of US measurements of this measurer [SS] with another measurer [BH] falls within ICC of 0.98-0.99 (Refer Supplementary material Table S2).

CT imaging

Non-contrasted CT scan was performed using a multi-slice CT scanner (Symbia Intevo 16, Siemens Healthcare GmbH, Erlangern, Germany) with the following imaging parameters: 120kVp, 50mAs, 10mm slice thickness and medium reconstruction kernel. Only one image slice (10mm) was taken per measured site to minimise radiation exposure. The total dose received by each patient was between 0.1-0.2mSv. The CT scans and measurement of QMT and CSA on the CT images were performed by a radiologist [TTH].

Statistical Analysis

Variables are presented as mean ± SD or frequency (%). The ICC was calculated to determine the validity of US against CT scan measurements. Bland-Altman plot tested the difference between methods compared to the overall average. Data was checked for homoscedasticity as per the correlation between the difference and average scores. All analyses were computed using the IBM Statistical Package for Social Sciences version 23.0 (IBM SPSS Statistics Inc. Chicago IL. USA). Statistical significance was set at $p<0.05$ for all evaluated parameters.

Results

An overall description of patient characteristics is shown is **Table 1**.

QMT and CSA for the RF and VI muscles presented in **Table 2** indicate high ICC of 0.92-0.97 between methods obtained for all muscle sites (all $p<0.001$).

The Bland-Altman plot representing differences between methods against measurement means for each muscle site is shown in **Figures 1** and **2**. The correlation between the difference and mean scores was not significant for all muscle sites (p>0.05) indicating homoscedasticity.

Discussion

This study showed that US is a reliable approach in measuring QMT and CSA in HD patients compared to CT as indicated by excellent ICC values of 0.92-0.97. Findings are in tandem with Thoames et al. (2012) who reported ICC of 0.92 for the thickness of RF muscle in coronary artery disease patients [5]. Noorkoiv et al. (2010) assessing the CSA of the quadriceps muscle using CT and US method found ICC of 0.95-0.99 in healthy men [4]. Most studies only report for the RF muscle as it appears more sensitive towards muscle wasting [12] but improves significantly in muscle volume with strength training compared to other muscles of the quadriceps [13]. Our study also included VI as an additional measurement site, which demonstrated similar findings to RF muscle. US reading are also not affected by the hydration status of dialysis patients, as shown by lack of difference between pre- and post-dialysis measurements of muscle thickness [9]. This study validated US as an alternative approach to gold standard measurement in the assessment of muscle wasting in HD patients.

Supplementary Material

Supplementary material Table S1 and Table S2 are available online at the end of the article.

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Statement of Authorship

T. Karupaiah, S. Sahathevan, Khor B. H. and Yeong C. H. contributed to conception and design of the research; S. Sahathevan, Khor B. H, Ng H. M, S.S. Narayanan, Gafor A.H.A., Goh B. L., Bee B. C., Zulfitri A.M.D, Yeong C. H., Tan T. H. and T. Karupaiah contributed to data acquisition; S. Sahathevan, Khor B. H., Tan T. H., Kareem, A.M.M. and Yeong C. H. contributed to data interpretation; K. Chinna contributed to data analysis; S. Sahathevan, Khor B. H., Yeong C. H. and T. Karupaiah drafted the manuscript. All authors critically revised the manuscript, agree to be fully accountable for ensuring the integrity and accuracy of the work, and read and approved the final manuscript.

Tables

Table 1. Patient characteristics

Characteristics (n=26)	Mean ± SD or frequency (%)
Gender (M/F)	15/11 (57.6/42.4)
Dialysis vintage (months)	104 ± 77
Age (years)	56.8 ± 9.06
Height (cm)	160.8 ± 9.5
Weight (kg)	66.7 ± 11.9
BMI (kg/m^2)	26.0 ± 5.5

Abbreviations: BMI, body mass index; F, female; M, male

Table 2. Measures of quadriceps muscle

Muscle sites	CT	US	ICC	95% CI	*p*-value
RF_{MID} (cm)	1.74 ± 0.44	1.68 ± 0.38	0.94	0.87-0.97	<0.001
VI_{MID} (cm)	1.32 ± 0.41	1.22 ± 0.43	0.97	0.93-0.99	<0.001
$RF_{2/3}$ (cm)	1.23 ± 0.33	1.19 ± 0.33	0.94	0.87-0.97	<0.001
$VI_{2/3}$ (cm)	0.92 ± 0.29	1.03 ± 0.29	0.94	0.86-0.97	<0.001
RF_{CSA} (cm^2)	5.94 ± 2.08	6.27 ± 1.76	0.92	0.83-0.97	<0.001

Abbreviations: CI, confidence interval; CSA, cross-sectional area; CT, computed tomography; ICC, intraclass correlation coefficient; RF, *rectus femoris*; US, ultrasound; VI, *vastus intermedius*

Figures

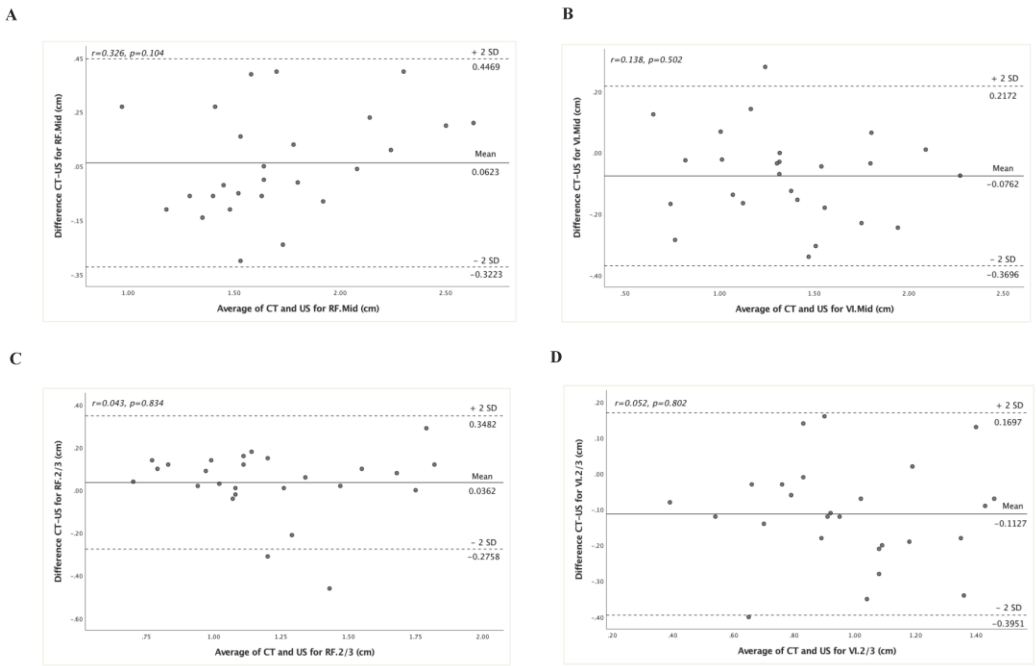

Figure 1

Bland-Altman plot comparing CT and US measurements for muscle thickness measured at (A) RF_{MID} (B) VI_{MID} (C) $RF_{2/3}$ and (D) $VI_{2/3}$

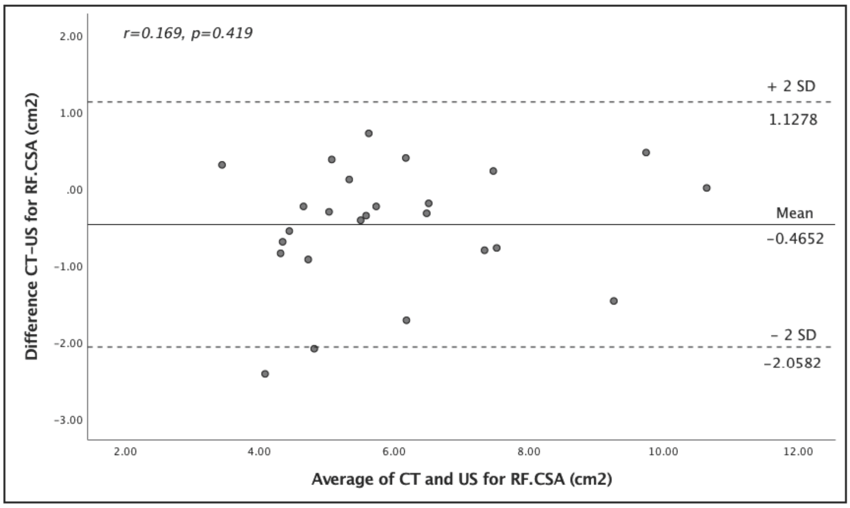

Figure 2

Bland-Altman plot comparing CT and US measurements for cross-sectional area of RF muscle

Notes: One outlier was removed for this analysis as a value for difference between CT and US was above +2 SD