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

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Abstract

Background: Muscle wasting, prevalent in maintenance 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 patients on HD underwent US and CT scans on the same day, postdialysis session. QMT for rectus femoris (RF) and vastus intermedius (VI) muscles was taken at the midpoint (MID) and two-thirds (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. (*JPEN J Parenter Enteral Nutr.* 2020;00:1–5)

Keywords

CT scan; hemodialysis; quadriceps; rectus femoris; ultrasound; 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, a gold-standard method for assessment, not only poses radiation risk but also is costly 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

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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 and increasing frailty and hospitalization duration.[2]

Anthropometry measures and bioimpedance analysis are noninvasive approaches to identify the presence of muscle wasting in maintenance 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 patients with chronic kidney disease (CKD).[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 participants and diseased populations.[4-6] Recently, US was applied to determine CSA of muscle in nondialysis CKD patients, with either MRI[7] or CT[8] as comparators. Both studies reported correlation only for rectus femoris (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 Participants

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

Anatomical Landmarks

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

Table 1. Patient Characteristics.

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

BMI, body mass index; F, female; M, male.

Study Protocol

All scans were performed 4–5 hours postdialysis. Patients first underwent the US scan while lying in a supine position on the CT table, with both knees extended but relaxed and with toes pointed toward 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 QMT, namely the RF and vastus intermedius (VI) muscles, was measured by a trained researcher (S.S.), as per standardized protocol[9] for both legs, using portable US equipment (GE Logiq e Digital Portable Color Doppler, GE Healthcare, Wauwatosa, USA). CSA of the RF muscle was measured at the midthigh landmark. Two readings were obtained for each measured site, and the mean value was calculated. The intraobserver reliability of US measurements for all muscle sites was represented by intraclass correlation coefficient (ICC), ranging between 0.98 and 1.00 (Table S1). Similarly, the interobserver reliability of US measurements of this measurer (S.S.) with another measurer (B.H.) falls within ICC of 0.98–0.99 (Table S2).

Computed Tomography Imaging

Noncontrasted CT scan was performed using a multislice CT scanner (Symbia Intevo 16, Siemens Healthcare GmbH, Erlangern, Germany) with the following imaging parameters: 120 kVp, 50 mAs, 10-mm slice thickness, and medium reconstruction kernel. Only 1 image slice (10 mm) was taken per measured site to minimize radiation exposure. The total dose received by each patient was between 0.1 and 0.2 mSv. The CT scans and measurement of QMT and CSA on the CT images were performed by a radiologist (T.T.H.).

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	<.001
VI_{MID}, cm	1.32 ± 0.41	1.22 ± 0.43	0.97	0.93–0.99	<.001
$RF_{2/3}$, cm	1.23 ± 0.33	1.19 ± 0.33	0.94	0.87–0.97	<.001
$VI_{2/3}$, cm	0.92 ± 0.29	1.03 ± 0.29	0.94	0.86–0.97	<.001
RF_{CSA}, cm^2	5.94 ± 2.08	6.27 ± 1.76	0.92	0.83–0.97	<.001

CSA, cross-sectional area; CT, computed tomography; ICC, intraclass correlation coefficient; MID, midpoint; RF, rectus femoris; US, ultrasound; VI, vastus intermedius.

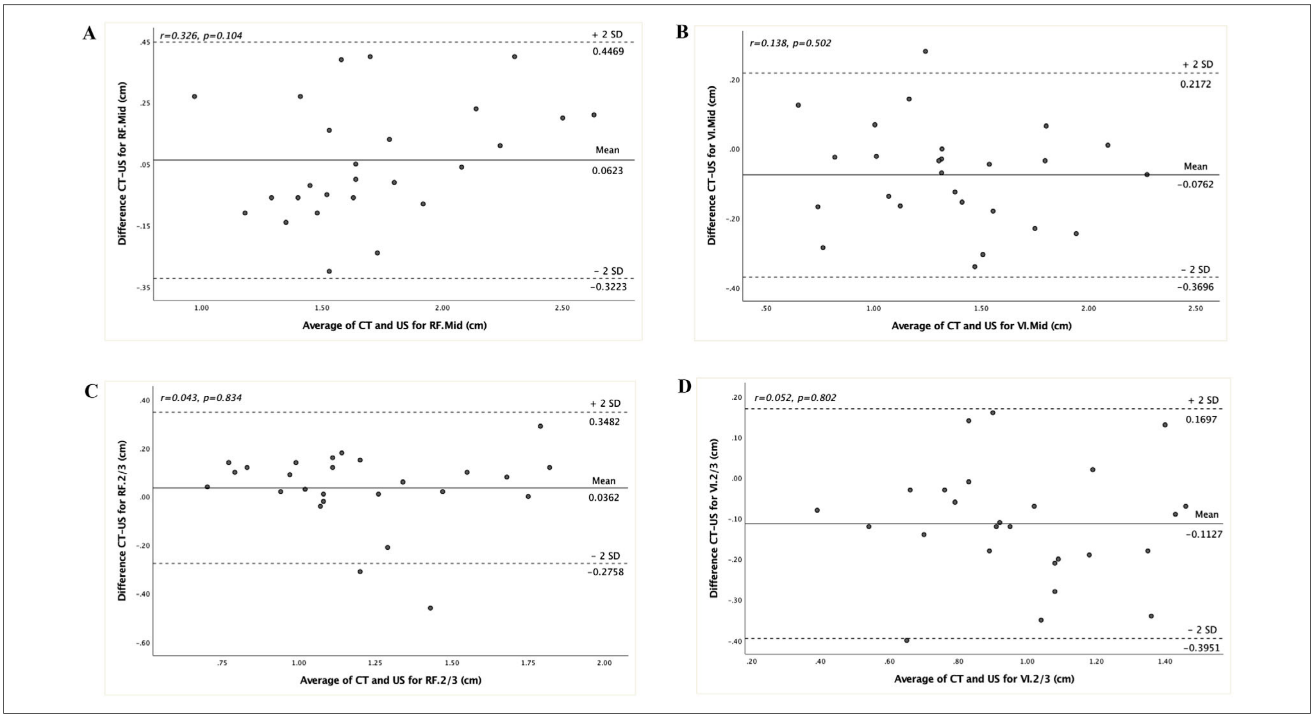

Figure 1. Bland-Altman plot comparing CT and US measurements for muscle thickness measured at (A) RF_{MID} (B) VI_{MID} (C) $RF_{2/3}$, and (D) $VI_{2/3}$. CT, computed tomography; MID, midpoint; RF, rectus femoris; US, ultrasound; VI, vastus intermedius.

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 with the overall average. Data were 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 26.0 (IBM SPSS Statistics Inc, Chicago, IL, USA). Statistical significance was set at $P < .05$ for all evaluated parameters.

Results

An overall description of patient characteristics is shown in 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 $P < .001$).

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, compared with CT, US is a reliable approach in measuring QMT and CSA in HD patients, as indicated by excellent ICC values of 0.92–0.97. Findings are in tandem with those of Thoames et al (2012), which reported an ICC of 0.92 for the thickness of RF muscle in coronary artery disease patients.[5] Noorkoiv et al (2010),

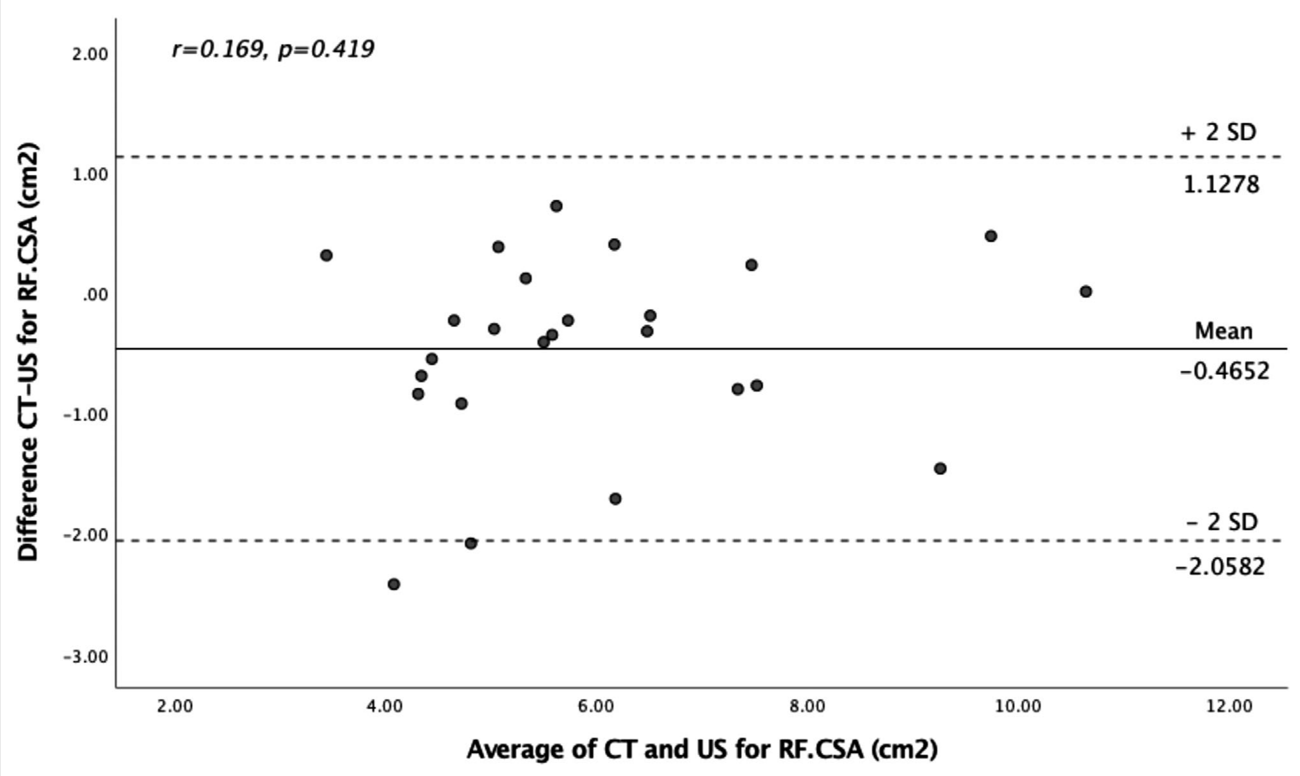

Figure 2. Bland-Altman plot comparing CT and US measurements for CSA of RF muscle. Notes: One outlier was removed for this analysis, as a value for difference between CT and US was above +2 SD. CSA, cross-sectional area; CT, computed tomography; RF, rectus femoris, US, ultrasound.

assessing the CSA of the quadriceps muscles using CT and US methods, found an 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[11,12] but improves significantly in muscle volume with strength training in comparison to other muscles of the quadriceps.[13] Our study also included VI as an additional measurement site, which demonstrated similar findings to the RF muscle. US readings are also not affected by the hydration status of dialysis patients, as shown by a lack of difference between predialysis and postdialysis 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.

Statement of Authorship

T. Karupaiah, S. Sahathevan, B.H. Khor, and C.H. Yeong contributed to conception and design of the research; S. Sahathevan, B.H. Khor, H.M. Ng, G.R. Ong, S.S. Narayanan, A.H.A. Gafor, B.L. Goh, B.C. Bee, Z.A.M. Daud, C.H. Yeong, T.H. Tan, and T. Karupaiah contributed to data acquisition; S. Sahathevan, B.H. Khor, T.H. Tan, A.M.M. Kareem and C.H. Yeong contributed to data interpretation; K. Chinna contributed to data analysis; S. Sahathevan, B.H. Khor, C.H. Yeong, 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.

Supplementary Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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