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Title page:

Reliability of bedside ultrasound for measurement of quadriceps muscle thickness in critically ill patients with acute kidney injury

Short title:

Ultrasound reliability to assess muscle thickness in acute kidney injury

Authors:

Sabatino Alice[1], Regolisti Giuseppe[1], Bozzoli Laura[3], Fani Filippo[1], Antoniotti Riccardo[1], Maggiore Umberto[2], Fiaccadori Enrico[1]

Institutions:

1. Acute and Chronic Renal Failure Unit, Department of Clinical and Experimental Medicine, University of Parma - Parma (Italy)
2. Kidney Transplant Unit, Parma Hospital, Parma (Italy)
3. Nephrology and Dialysis, Lucca, (Italy)

Corresponding Author:

Enrico Fiaccadori, MD, PhD
Unità di Fisiopatologia dell'Insufficienza Renale Acuta e Cronica
Dipartimento di Medicina Cinica e Sperimentale
Università degli Studi di Parma, Via Gramsci 14, 43100 Parma – Italy
enrico.fiaccadori@unipr.it

Abstract

Main problem: In patients with Acute Kidney Injury nutritional variables that assess nutritional status, and more specifically lean body mass (LBM), at the individual level are lacking. In this clinical setting, ultrasound (US) of the quadriceps femoris could represent a widely available, non-invasive, affordable, and reliable tool to evaluate skeletal muscle, a clinical surrogate of LBM.

Methods: We performed a cross-sectional observational study in adult critically ill patients with KDIGO stage 3 AKI on dialysis. Quadriceps rectus femoris and vastus intermedius thickness were measured by two assessors. Intra- and interobserver reliability was evaluated using the intraclass coefficient correlation (ICC). The same US measures were obtained before and after dialysis.

Results: We enrolled 34 patients, 22 (65%) were male and the mean APACHE II score was 22.7 (± 5.6). In the intraobserver reliability study, assessor 1 performed 288 paired measurements and assessor 2 performed 430 paired measurements in 34 patients, with an ICC equal to 0.99 and 1.00, respectively. There were 238 paired measurements (34 patients) in the interobserver reliability study, with an ICC = 0.92. No difference was found in the measurements obtained before and after dialysis (11.5 (4.2) vs 11.4 (4.1) mm, P = 0.2498), independently from acute body weight changes due to fluid removal.

Conclusion: In patients with AKI, US of quadriceps femoris could represent a simple, accurate, and non-invasive method to evaluate quantitative changes in skeletal muscle.

Introduction

Loss of skeletal muscle, the largest store of Lean Body Mass (LBM) is an early effect of critical illness, due to immobilization, catabolism and protein-energy deficit, and is correlated with mortality (1). Techniques based on radioactive potassium species (2), Dual X-ray Absorptiometry (DEXA) (3), Computed Tomography (CT) scan (4) and Magnetic Resonance Imaging (MRI) (5) still represent the gold standard for LBM assessment, even though they cannot be routinely used for serial nutritional evaluations in the Intensive Care Unit (ICU).

Ultrasonography (US) is widely available and easily applicable at the bedside to different skeletal muscle groups, even in critically ill patients (6-7). It allows the detection of muscle wasting during ICU stay, (7-8), and seems as accurate as CT or MRI in measuring muscle mass (9-11). In particular, mid-thigh thickness (i.e. thickness of the quadriceps femoris) best correlates with fat-free mass by DEXA (12).

No data are currently available on US measurements in AKI, where total body water is often increased (13), and rapid fluid shifts characterize the course of renal replacement therapy (RRT).

Thus, the primary objective of our study was to investigate the reliability of bedside US in the assessment of quadriceps muscle thickness in critically ill patients with AKI; our secondary objective was to determine whether rapid fluid shifts occurring during RRT may influence US measurements.

Materials and Methods

Following the approval by the Institutional Review Board we conducted a cross-sectional observational study in adult critically ill patients with KDIGO stage 3 AKI on dialysis (14), consecutively admitted to the renal ICU of the Parma University Hospital. Written informed consent was obtained by patients or their close relatives.

Two assessors (a renal dietician and a nephrologist), who had previously received formal training with at least 100 supervised measurements, measured quadriceps rectus femoris (QRF) and vastus intermedius (QVI) thicknesses as described by Tillquist et al. (15) by B-mode US (wall tracking system (Philips HD7xe) equipped with a 7.5 MHz linear array transducer). The transducer was placed perpendicular to the long axis of the thigh with abundant use of contact gel and minimal pressure to avoid compression of the muscle. The position and the orientation of the probe were kept steady without using additional equipment in the ICU. The right and left quadriceps values were assessed in both legs with the patient lying supine with both knees extended but relaxed and toes pointing to the ceiling. In patients undergoing RRT (conventional 4-hour HD or 6-12 hour sustained low-efficiency dialysis [SLED]) US was performed at the start and the end of each session. Both assessors were required to perform two blindly measurements at each muscle point (eight measurements per subject), and the mean was used for further analysis. Maximum thickness of each muscle was measured from the femur to the inner edge of the QVI muscle, or from subcutaneous tissue to the inner edge of the QRF muscle (Figure 1) (15-16).

The Wilcoxon signed-rank test was used to analyze the differences in the measurements between assessors, within the same assessor, or before-after RRT. Intra- and interobserver reliability were assessed by the intraclass correlation coefficient (ICC), with values > 0.75 indicating good to excellent reliability (16), and by the Bland-Altman approach . All values are reported as mean ± SD; $P < 0.05$ was considered significant.

Assuming a minimum ICC value of 0.75 for interobserver reliability, with alpha 0.05 and 80% power, we estimated that we would need to enroll at least 18 subjects (16). We enrolled 34 subjects to ensure that enough quality images were available.

Results

Demographics

Demographic and clinical characteristics of the 34 patients with AKI are reported in Table 1. Most of them were oliguric (24/34, 71%) at ICU admission.

Intra- and Interobserver Reliability

Assessor 1 performed 288 pairs of measurements (ICC value of 0.99, across-site range 0.98 – 0.99) (Table 2A). Assessor 2 performed 430 pairs of measurements (ICC value of 1.00, across-site range 0.97 – 0.99). No difference was found in the within-assessor measurements: [(assessor 1: 11.5 (3.8) *vs* 11.5 (3.8) mm, 95% confidence interval (CI) of the mean difference -0.018 to 0.062, P = 0.42], assessor 2 11.6 (4.9) *vs* 11.6 (4.9) mm, 95% CI of the mean difference -0.068 to 0.047, (P = 0.80)] (Table 2B).

The 2 assessors performed 238 paired measurements (across-site range 56 – 62) (ICC value of 0.92, across-site range 0.88 – 0.93) (Table 3A). Although between-investigator differences in measurements were statistically significant at all sites, the mean absolute value of the difference was approximately 0.4 mm [10.7 (3.4) *vs* 10.3 (3.3) mm, 95% CI of the mean difference 0.28 – 0.54, P < 0.0001] (Table 3B), and was therefore clinically insignificant.

Before-after RRT measurements

Measurements before and after RRT are reported in table 4. Assessor 1 performed 294 measurements in 39 sessions, while assessor 2 performed 306 measurements in 40 sessions. Sustained low-efficiency dialysis (8-12 hour sessions) accounted for 38/70 sessions (54%), intermittent HD (4 hour sessions) accounted for the remaining 32 RRT sessions.

No difference was found in the measurements obtained before and after RRT (Table 4), even when only RRT sessions with negative weight change were considered (median weight change per session -1.5 Kg, range -0.5 to -3.0 Kg) (Table 5).

The absolute interobserver and before-after variability, as expressed by the limits of agreement (±1.96 SD), was 4.1 mm (range 3.1 to 4.8 mm for each site), and 3.0 mm (range 2.3 to 3.8 mm), respectively (Table 6). The distributions of the differences are visualized in Figures 2 and 3.

Discussion

Our data confirm that US assessment of peripheral skeletal muscles has excellent reliability in critically ill patients with KDIGO stage 3 AKI, as previously shown in normal subjects (17).

The mean difference in muscle thickness values between assessors was statistically significant because of the large number of measurements performed by each assessor. However, this difference was approximately 0.4 mm, which is not clinically relevant, suggesting that the technique is reliable even when different operators are involved. Furthermore, no significant difference was detected between pairs of measurements performed by each operator.

There is a strong need for reliable tools to evaluate and monitor nutritional status, particularly LBM, in patients with AKI (18). In this regard, nutritional parameters to be evaluated should be clinically relevant, repeatedly measurable at different time points at the bedside without patient discomfort, not influenced by non-nutritional factors, noninvasive and inexpensive. On these grounds, ultrasound techniques are clearly appealing.

Ultrasound techniques are increasingly used to assess muscle mass and quality, and have been applied in different patient populations (9-11, 17, 19). To our knowledge, this is the first study assessing the reliability of this approach in critically ill patients with AKI on RRT. We could also demonstrate by a large number of measurements that US of the quadriceps femoris muscle is not influenced by rapid fluid shifts, as it had been suggested by a previous study in a small number of critically ill patients with multiple organ failure (20).

Our study has several limitations. Firstly, we could not evaluate muscle cross-sectional area or echogenicity. In fact, our probe length did not allow the evaluation of rectus femoris area, nor was a dedicated software to evaluate muscle echogenicity available. Secondly, we did not compare our measurements with those obtained with a gold standard method; however, a very good correlation with CT and DEXA has been previously demonstrated for US (12, 14).

In conclusion, our data suggest that US could represent an easy, accurate, and noninvasive method to evaluate quantitative changes of skeletal muscle in patients with AKI. Ultrasonography can be easily used at the bedside and, with appropriate training, it can also be performed by non-specialists.

Disclosure

Alice Sabatino is the recipient of a young investigator research grant by the Italian Society of Parenteral and Enteral Nutrition (SINPE, Società Italiana di Nutrizione Parenterale ed Enterale) for the project ”Valutazione nutrizionale nell’insufficienza renale mediante ecografia del muscolo quadricipite femorale” (Nutritional assessment of patients with chronic kidney disease and acute kidney injury through ultrasound of the quadriceps femoris muscle)”.

References

1. Puthucheary ZA, Rawal J, McPhail M et al. Acute skeletal muscle wasting in critical illness. JAMA. 2013; 310: 1591-1600.

2. Murphy AJ, Ellis KJ, Kurpad AV, Preston T, Slater C. Total body potassium revisited. Eur J Clin Nutr. 2014; 68: 153-154

3. Albanese CV, Diessel E, Genant HK. Clinical applications of body composition measurements using DXA. J Clin Densitom. 2003; 6: 75-85.

4. Weijs PJ, Looijaard WG, Dekker IM, Stapel SN, Girbes AR, Oudemans-van Straaten HM, Beishuizen A. Low skeletal muscle area is a risk factor for mortality in mechanically ventilated critically ill patients. Crit Care. 2014; 18: R12

5. Al-Gindan YY, Hankey CR, Leslie W, Govan L, Lean ME. Predicting muscle mass from anthropometry using magnetic resonance imaging as reference: a systematic review. Nutr Rev. 2014; 72: 113-126

6. Connolly B, MacBean V, Crowley C et al. Ultrasound for the assessment of peripheral skeletal muscle architecture in critical illness: a systematic review. Crit Care Med. 2015; 43: 897-905

7. Reid CL, Campbell IT, Little RA. Muscle wasting and energy balance in critical illness. Clin Nutr. 2004; 23: 273-280

8. Segers J, Hermans G, Charususin N et al. Assessment of quadriceps muscle mass with ultrasound in critically ill patients: intra- and inter-observer agreement and sensitivity. Intensive Care Med. 2015; 41: 562-563.

9. Thomaes T, Thomis M, Onkelinx S, Coudyzer W, Cornelissen V, Vanhees L. Reliability and validity of the ultrasound technique to measure the rectus femoris muscle diameter in older CAD-patients. BMC Med Imaging. 2012; 12: 7

10. Seymour JM, Ward K, Sidhu PS et al. Ultrasound measurement of rectus femoris cross-sectional area and the relationship with quadriceps strength in COPD. Thorax. 2009; 64: 418-423

11. Arbeille P, Kerbeci P, Capri A, Dannaud C, Trappe SW, Trappe TA. Quantification of muscle volume by echography: comparison with MRI data on subjects in long-term bed rest. Ultrasound Med Biol. 2009; 35: 1092-1097

12. Menon MK, Houchen L, Harrison L, Singh SJ, Morgan MD, Steiner MC. Ultrasound assessment of the lower limb muscle mass in response to resistance training in COPD. Respir Res. 2012; 13: 119-128

13. Ikizler TA, Sezer MT, Flakoll PJ et al; PICARD Study Group. Urea space and total body water measurements by stable isotopes in patients with acute renal failure. Kidney Int. 2004; 65: 725-732

14. KDIGO AKI Working Group. KDIGO clinical practice guideline for acute kidney injury. Kidney Int Suppl. 2012; 17: 1–138.

15. Tillquist M, Kutsogiannis DJ, Wischmeyer PE et al. Bedside ultrasound is a practical and reliable measurement tool for assessing quadriceps muscle layer thickness. JPEN J Parenter Enteral Nutr. 2014; 38: 886-890.

16. Sarwal A, Parry SM, Berry MJ et al. Interobserver Reliability of Quantitative Muscle Sonographic Analysis in the Critically Ill Population. J Ultrasound Med. 2015; 34: 1191-1200

17. Parry SM, El-Ansary D, Cartwright MS et al. Ultrasonography in the intensive care setting can be used to detect changes in the quality and quantity of muscle and is related to muscle strength and function. J Crit Care. 2015; 30: 1151.e9-1151.e14

18. Fiaccadori E, Regolisti G, Maggiore U. Specialized nutrition al support interventions in critically ill patients in renal replacement therapy. Curr Opin Clin Nutr Metab Care. 2013; 16: 217 – 224

19. Ema R, Wakahara T, Mogi Y et al. In vivo measurement of human rectus femoris architecture by ultrasonography: validity and applicability. Clin Physiol Funct Imaging. 2013; 33: 267-273

20. Campbell IT, Watt T, Withers D et al. Muscle thickness, measured with ultrasound, may be an indicator of lean tissue wasting in multiple organ failure in the presence of edema. Am J Clin Nutr. 1995; 62: 533-539

Table 1. Demographics and clinical characteristics of patients with AKI at ICU admission.

Parameters	Subjects (n = 34)
Age	75 (12)
Male sex (%)	22 (65)
APACHE II	22.7 (5.6)
-Oliguria	24 (71)
	11 (32)
-Sepsis	
BMI at ICU admission (mean ± sd)	29.2 (6.4)
Weigth at ICU admission, Kg (mean ± sd)	80.3 (14.8)

BMI, body mass index; ICU, intensive care unit; RRT, renal replacement therapy; SD, standard deviation.

Table 2A. Intraobserver reliability

		Nº measurements	Between subject variance	Within subject variance	ICC
	QRFT 1/2	72	9.229	0.1496	0.98
	QVIT 1/2	72	14.20	0.1382	0.99
Assessor 1	**QRFT 2/3**	72	7.91	0.1096	0.99
	QVIT 2/3	72	9.26	0.0836	0.99
	Total	288	14.33	0.1225	0.99
	QRFT 1/2	108	19.32	0.5872	0.97
	QVIT 1/2	108	30.94	0.3535	0.99
Assessor 2	**QRFT 2/3**	108	10.11	0.3106	0.97
	QVIT 2/3	106	22.67	0.2073	0.99
	Total	430	23.70	0.3654	1.00

ICC, intraclass correlation coefficient; QRFT, quadriceps rectus femoris thickness; QVIT, quadriceps vastus intermedius thickness.

Table 2B. Differences within assessors measurements.

		Nº measurements	Measurement 1	Measurement 2	P
Assessor 1	**QRFT 1/2**	72	14.83 (3.04)	14.81 (1.14)	0.5155
	QVIT 1/2	72	11.12 (3.77)	11.12 (3.69)	0.4039
	QRFT 2/3	72	11.03 (2.81)	11.00 (2.76)	0.3291
	QVIT 2/3	72	9.13 (3.04)	9.09 (2.96)	0.2949
	Total	288	11.53 (3.79)	11.51 (3.76)	0.4208
Assessor 2	**QRFT 1/2**	108	14.16 (4.40)	14.25 (4.32)	0.2378
	QVIT 1/2	108	12.12 (5.56)	12.13 (5.63)	0.6869
	QRFT 2/3	108	10.16 (3.18)	10.15 (3.03)	0.7645
	QVIT 2/3	106	9.76 (4.76)	9.71 (4.71)	0.4100
	Total	430	11.56 (4.87)	11.57 (4.85)	0.7983

QRFT, quadriceps rectus femoris thickness; QVIT, quadriceps vastus intermedius thickness.

Mean (SD), values in mm.

Table 3A. Interobserver reliability

	Nº measurements	Between subject variance	Within subject variance	ICC
QRFT 1/2	56	9.4	1.3	0.88
QVIT 1/2	62	12.7	1.5	0.89
QRFT 2/3	56	6.0	0.8	0.88
QVIT 2/3	62	8.8	0.6	0.93
Total	238	11.7	1.1	0.92

ICC, intraclass correlation coefficient; QRFT, quadriceps rectus femoris thickness; QVIT, quadriceps vastus intermedius thickness.

Table 3B. Differences between assessors measurements

	Nº measurements	Assessor 1	Assessor 2	P
QRFT 1/2	56	13.3 (3.1)	13.1 (3.01)	0.0361
QVIT 1/2	64	10.7 (3.6)	10.3 (3.4)	0.0150
QRFT 2/3	56	9.6 (2.5)	9.3 (2.2)	0.005
QVIT 2/3	62	9.2 (2.9)	8.7 (2.8)	< 0.0001
Total	238	10.7 (3.4)	10.3 (3.3)	< 0.0001

QRFT, quadriceps rectus femoris thickness; QVIT, quadriceps vastus intermedius thickness. Mean (SD), values in mm.

Table 4. Measurements before and after RRT

		Nº Measurements	Before	After	P
Assessor 1	QRFT 1/2	72	15.2 (3.5)	14.9 (3.6)	0.1165
	QVIT 1/2	74	12.0 (4.2)	11.9 (4.0)	0.1827
	QRFT 2/3	72	11.5 (2.9)	11.3 (2.7)	0.0660
	QVIT 2/3	74	9.0 (2.3)	9.0 (2.1)	0.2390
	Total	294	11.9 (4.0)	11.7 (3.8)	0.2530
Assessor 2	QRFT 1/2	75	13.6 (4.2)	13.5 (4.0)	0.4985
	QVIT 1/2	79	11.5 (5.1)	11.5 (5.0)	0.3200
	QRFT 2/3	75	9.8 (2.9)	9.8 (2.9)	0.1264
	QVIT 2/3	77	9.5 (4.3)	9.4 (4.1)	0.2348
	Total	306	11.1 (4.5)	11.0 (4.4)	0.6309
Total	QRFT 1/2	147	14.4 (3.9)	14.2 (3.9)	0.3015
	QVIT 1/2	153	11.7 (4.7)	11.7 (4.5)	0.7918
	QRFT 2/3	147	10.6 (3.0)	10.5 (2.9)	0.1733
	QVIT 2/3	153	9.2 (3.4)	9.2 (3.3)	0.7564
	Total	600	11.5 (4.2)	11.4 (4.1)	0.2498

QRFT, quadriceps rectus femoris thickness; QVIT, quadriceps vastus intermedius thickness; RRT, renal replacement therapy. Mean (SD), data in mm.

Table 5. Measurements before and after RRT only patients with negative weight change.

	№ Measurements	Before	After	P
Assessor 1	231	11.7 (4.0)	11.6 (3.9)	0.0967
Assessor 2	258	11.5 (4.6)	11.4 (4.5)	0.2544

Mean (SD), values in mm.

Table 6. Interobserver and before- after RRT variability as expressed by the limits of agreement.

Parameter		Bland-Altman: 2*1.96*SD
Interobserver variability (mm)	**QRFT 1/2**	3.0
	QVIT 1/2	2.9
	QRFT 2/3	3.8
	QVIT 2/3	2.3
	Total	2.8
Before *versus* after RRT variability (mm)	**QRFT 1/2**	4.1
	QVIT 1/2	4.5
	QRFT 2/3	4.8
	QVIT 2/3	3.6
	Total	3.1

QRFT, quadriceps rectus femoris thickness; QVIT, quadriceps vastus intermedius thickness; RRT, renal replacement therapy; SD, standard deviation.

Figure 1. Assessment of quadriceps femoris thickness using ultrasound. Thickness of each muscle is measured from the femur to the inner edge of the vastus intermedius (VI) muscle, or from subcutaneous tissue to the inner edge of the rectus femoris (RF) muscle.

Figure 2. Bland-Altman plots for agreement between assessors. The x-axis shows the mean of two measurements performed by each assessor. The y-axis shows the difference between means of these values for each assessor. The horizontal lines parallel to the x-axis represent the mean difference and limits of agreement for that muscle parameter

Figure 3. Bland-Altman plots for agreement between measurements performed before and after RRT. The x-axis shows the mean of two values. The y-axis shows the difference between means of these values. The horizontal lines parallel to the x-axis represent the mean difference and limits of agreement for that muscle parameter.