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Value of Skeletal Muscle Ultrasonography in The Assessment of Critical Illness Myopathy in Patients with Weaning Failure from Mechanical Ventilation

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Abstract

Background*: In critically ill cases, muscle strength evaluation is often delayed due to impaired attentiveness or consciousness, which may be caused by delirium or sedation.*

Aim*: To evaluate the role of muscle ultrasound (echogenicity, muscle thickness, and length) in the diagnosis of critical disease neuromyopathy compared to nerve conduction studies (NCS).*

Patients and methods*: This prospective research has been performed in the Critical Care Unit of Kasr Al-Ainy Hospital, Cairo University. The present study included fifty critically ill cases that were admitted to the intensive care unit from June 2021 to January 2023 and experienced failure of weaning from mechanical ventilation during their ICU course.*

Results*: Ultrasonography tests on the diaphragm and quadriceps femoris muscles showed that the diaphragm moved an average of 1.99 cm and the quadriceps femoris muscle was 32.78 cm thick. Most of the people who were studied had grade I muscle echogenicity (62%). The mean muscle strength assessment (MRC) scale was 3.66, while the mean APACHE II score was 20.22, and 19 patients died.*

Conclusion*: Bedside ultrasonography may be very beneficial for diagnosing and evaluating cases of intensive care unit acquired weakness (ICUAW) in the ICU. Combining muscle echogenicity and dimensions is useful in the detection of muscle alterations through the course of critical disease and may be utilized as a screening tool.*

Key words: *Critically ill patients, muscle ultrasound, myopathy, echogenicity.*

Introduction

Critical illness myopathy (CIM), critical illness polyneuropathy (CIP), and the overlap, critical illness polyneuromyopathy (CIPNM), are the most prevalent causes of neuromuscular weakness in the ICU and a frequent reason for unsuccessful ventilator weaning. The disease is characterized by flaccid paresis or plegia, that also affects the respiratory muscles. Muscle atrophy is typically observed in conjunction with weakness. CIM is an independent indicator of one-year mortality and has been related to delayed weaning, extended ICU stays, and hospitalizations (1).

Generalized muscle weakness, which includes respiratory muscles lacking deep tendon reflexes and a distal decrease in sensation, is a typical clinical feature of CIP (2). The extended period of mechanical ventilation and weaning failure are the results of respiratory muscle weakness (3). Moreover, Patients with CIP exhibited worse acute morbidity findings, consumed more resources, and exhibited a greater mortality rate compared to those without weakness. The persistent weakness at discharge from the ICU exacerbated late mortality (4).

In critically ill cases, muscle strength evaluation is often delayed due to impaired attentiveness or consciousness, which may be caused by delirium or sedation. This information limited the clinical applicability of volitional muscle strength testing in critically ill cases (5). Diagnosing ICU-AW promptly following the onset of critical disease is crucial for the start of supportive interventions, including early rehabilitation, that might enhance functional outcomes (6). As a result, there is an urgent requirement for non-invasive and easily applicable tools to assess the muscle state of critically ill cases. The diagnostic use of muscle ultrasound for neuromuscular conditions has demonstrated increasing potential (7). It serves as an informative method for evaluating the muscles of cases in ICU. Specifically in ICU, ultrasound is a non-invasive diagnostic tool that is inexpensive and easily accessible. It enhances neurophysiological testing by providing information on morphological alterations of muscles during the early stages of sepsis. Axonal nerve damage causes changes in muscle structure and spontaneous muscle activity in people with CIP, while direct muscle impairment causes these changes in people with CIM (8). It is possible to identify both spontaneous activity and structural alterations utilizing muscle ultraound (9).

The research aimed to assess the muscle ultrasound role (echogenicity, muscle thickness, and length) in the diagnosis of critical disease neuromyopathy compared to NCS.

PATIENTS AND METHODS

This prospective research has been performed in Critical Care Unit of Kasr AL-Ainy Hospital, Cairo University. The present study included fifty critically ill cases that were admitted to the ICU from June 2021 to January 2023 and experienced failure of weaning from mechanical ventilation during their ICU course.

The study was accepted by the critical care medicine department scientific committee and faculty of medicine ethics committee, informed consent has been gathered from all patients or the case's next-of-kin.

Inclusion criteria: Adult cases aged over nineteen of the two genders and patients with difficult or prolonged weaning from mechanical ventilation (failed to sustain spontaneous breathing trial or re-intubated within 48 hours following extubation trial).

Exclusion criteria: Pregnant women or patients with cardiac pacemakers, history of neuromuscular conditions as poly- myopathy, neuropathy, motor neuron illness, acute neurological diseases rather than CINM as Guillain Barré Syndrome, myasthenic crisis, acute spinal cord injury and patients with clinical conditions not permitting to perform EPS as severe burn, post cardiac surgery.

Ultrasound protocol

Ultrasonography has been conducted to included patients who were diagnosed to have weaning failure from mechanical ventilation between days 2 to 5 utilizing a nine to thirteen MHz probe real-time linear array scanner (Siemens Acuson, Erlangen, Germany) with standardized gain and varying depth depended on the overlying soft tissue amount and muscle size. The linear transducer array has been utilized to determine the cross-sectional area of the rectus femoris (RF-CSA) utilizing B-mode ultrasonography. The transducer has been positioned perpendicular to the long axis of the thigh on its superior part, three-fifths of the distance from the anterior superior iliac spine to the superior patellar border. This is the highest point in the thigh where the entire rectus femoris cross-section might be observed in a single field in every participant. The imaging was performed while the case was supine, with the rested leg supported in passive extension. To reduce the distortion of the underlying soft tissue, an excessive amount of contact gel was applied. Before image acquisition, gentle contraction-relaxation maneuvers were used to delineate muscle septa. On a frozen image, a moveable cursor has been used to outline the inner echogenic line of the rectus femoris, and a planimetric method was used to estimate RF-CSA. The RF-CSA has been calculated as the mean of 3 consecutive measurements in a ten percent range (10).

The muscle echogenicity has been evaluated by muscle ultrasound and graded, regarding Heckmatt and colleagues (11). Diaphragmatic ultrasound was performed to obtain two measurements (diaphragmatic thickness fraction and diaphragmatic excursion).

Nerve conduction studies: Using a portable electrophysiologic device (Neuromyan; Medicom Russia) with surface electrodes, routine NCS has been performed.

APACHE score: Illness severity was quantified using the APACHE II model on the 1st day of ICU admission (12).

MRC score

Muscle strength has been assessed utilizing the MRC score calculation between days 2 and 5 after starting mechanical ventilation.

RESULTS

Table (1): Age distribution of the enrolled patients

		Range	*Mean± SD*
Age		*(24 -85) years*	*67.04±10.6*
Sex	***Female***	*40%*	
	Male	*60%*	

Thirty of them were males (60%), and the rest were females (40%). The age varied between 24 and 85 years, with an average of 67 ± 10.6 years (Table 1).

able (2): Laboratory investigations of enrolled patients.

	Minimum	*Maximum*	*Mean*	*Standard Deviation*	*Median*
HB	*7.80*	*14.60*	*9.97*	*1.62*	*9.65*

Creat.	*0.50*	*5.50*	*1.82*	*1.16*	*1.35*
Na	*118.00*	*153.00*	*132.30*	*7.80*	*132.00*
K	*2.80*	*5.20*	*4.21*	*0.54*	*4.20*
Magnesium	*1.30*	*2.70*	*2.01*	*0.31*	*2.10*
Calcium	*6.40*	*9.80*	*8.00*	*0.99*	*7.80*
Phosphorus	*1.80*	*4.80*	*3.08*	*0.71*	*3.10*
CPK	*23.00*	*974.00*	*119.00*	*226.40*	*42.50*
Total protein	*5.40*	*8.20*	*6.55*	*0.65*	*6.50*
Albumin	*2.10*	*4.00*	*3.02*	*0.54*	*3.05*

Laboratory data showed that the mean hemoglobin level was 9.97 ± 1.62, the mean level of albumin was 3.02 ± 0.54, the mean level of creatinine was 1.82 ± 1.16, and the mean potassium (K) level was 4.21 ± 0.54.

Table (3): Ventilatory data of studied population.

		Count	*%*
Primary Cause of MV	*Pneumonia*	*28*	*56.0%*
	pulmonary edema or effusion	*12*	*24.0%*
	COPD or asthma	*7*	*14.0%*
	airway problems or central causes	*3*	*6.0%*
Cause Weaning failure of MV	*Persistent original cause*	*24*	*48.0%*
	Complications of mech. Vent.	*4*	*8.0%*
	Pulmonary causes	*6*	*12.0%*
	Cardiac failure	*11*	*22.0%*
	Neurological causes	*3*	*6.0%*
	Muscle weakness	*2*	*4.0%*
Mode of MV	*volume control*	*33*	*66.0%*
	pressure control	*4*	*8.0%*
	pressure support	*13*	*26.0%*
	other modes	*0*	*0.0%*
Tracheastomy	*Yes*	*10*	*20.0%*

	No		*40*	*80.0%*	
	Minimum	*Maximum*	*Mean*	*SD*	*Median*
P/F ratio	*76.00*	*311.00*	*154.02*	*52.64*	*147.00*
number of extubation failure trials	*0.00*	*3.00*	*0.88*	*0.72*	*1.00*
number of failed SBTs	*1.00*	*5.00*	*2.74*	*1.16*	*3.00*
Duration of MV(days)	*6.00*	*22.00*	*11.24*	*4.43*	*10.00*

28 (56%) of patients developed respiratory failure and experienced invasive mechanical ventilation due to pneumonia, 28 patients (56%) developed failure of weaning of mechanical ventilation due persistent original cause, the majority of patients were ventilated with volume control mode (66%) & 10 patients (20%) had tracheostomy surgery.

Table (4): Sonographic data of enrolled patients.

	Minimum	*Maximum*	*Mean*	*Standard Deviation*	*Median*
Diaphragmatic excursion by US in MV (cm)	*1.60*	*2.50*	*1.99*	*0.23*	*1.90*
Diaphragmatic thickness fraction by US %	*23.00*	*34.00*	*30.08*	*3.06*	*30.00*
Quadriceps femoris thickness (mm)	*25.00*	*41.00*	*32.78*	*3.91*	*33.00*
RF-CSA (cc2)	*3.1*	*5.3*	*4.08*	*0.50*	*4.10*
		Count		*%*	
RF Echogenicity	*Grade 1*	*31*		*62.0%*	
	Grade 2	*10*		*20.0%*	
	Grade 3	*6*		*12.0%*	
	Grade 4	*3*		*6.0%*	

Ultrasonographic evaluation of the diaphragm and quadriceps femoris muscle showed mean diaphragmatic excursion 1.99 cm, mean quadriceps femoris thickness 32.78, and regarding rectus femoris echogenicity the majority of the studied population had grade I muscle echogenicity (62%).

Table (5): Neurophysiological data of enrolled patients.

Site of stimulation	Nerve		Minimum	Maximum	Mean	Median	SD
EMG (duration m sec.)			4.28	2.30	7.10	3.80	1.59
EMG (Amplitude µV)			339.69	69.00	546.00	375.00	161.99
EMG (phases)			2.51	1.00	6.00	2.00	1.60
Wrist	Ulnar nerve	Latency m sec.	3.00	7.40	4.43	4.10	1.27
		Amplitude mV	1.10	7.50	3.21	3.25	1.51
Elbow		Latency m sec	7.10	11.50	9.11	8.90	1.24
		Amplitude mV	0.90	6.70	3.59	3.60	1.43
		Nerve conduction velocity m/sec	38.50	61.50	51.55	51.85	5.84
		F wave	25.00	38.60	31.55	31.25	3.63
Ankle	Tibial nerve	Latency m sec.	5.30	9.30	6.99	6.90	0.97
		Amplitude mV	1.10	4.50	3.05	3.35	1.00
Fossa		Latency m sec.	10.90	19.90	14.08	13.65	1.97
		Amplitude mV	0.10	3.80	2.55	2.80	0.98
		Nerve conduction velocity m/sec.	28.40	53.20	44.39	46.55	6.23
		F wave	41.80	69.69	52.42	51.30	6.61
Ankle	Common peroneal Nerve	Latency m sec.	2.80	5.70	4.24	4.30	0.71
		Amplitude mV	0.30	3.70	2.37	2.55	0.84
Knee		Latency m sec.	8.90	17.30	11.18	10.95	1.77
		Amplitude	0.30	4.10	2.35	2.50	0.93
		Nerve conduction velocity m/sec	33.30	57.30	45.73	46.90	5.20
	Sural nerve	Latency m sec.	2.70	4.70	3.54	3.60	0.51
		Amplitude mV	1.60	9.50	4.69	4.00	2.16
		Nerve conduction velocity m/sec.	38.40	58.30	48.51	48.35	5.74

Regarding the neurophysiological studies, the mean EMG amplitude was 339.6, while the amplitude, latency *and nerve conduction velocity of the studied nerves (14).*

Table (6): Classification of Patients according EPS results.

		Count	%
Critical illness neuropathy CIN	Yes	21	42.0%
	No	29	58.0%
Critical illness myopathy CIM	no myopathy	32	64.0%
	critical illness myopathy	15	30.0%
	other Pathology	3	6.0%
Critical illness neuromyopathy CINM	Yes	10	20.0%
	No	40	80.0%
ICU Acquired Weakness	Yes	26	52.0%
	No	24	48.0%

In this study, 26 patients were diagnosed to have ICU-AW based on their neurophysiological results, of which 21 patients had CIN, 15 patients had CIM and 10 patients had CINM.

Table (7): Outcome and scores of studied patients.

	Mean	SD	Median	Minimum	Maximum
SOFA score	5.04	3.86	6.50	0.00	11.00
APACHE II score	20.22	4.51	19.50	11.00	29.00
MRC scale	3.66	1.15	4.00	1.00	5.00
ICU stay (days)	15.86	5.03	14.50	9.00	27.00
		Count		%	
ICU mortality	Yes	19		38.0%	
	No	31		62.0%	

Mean MRC scale was 3.66, while mean APACHE II score was 20.22, and mortality occurred in 19 patients.

DISCUSSION

Critically ill cases admitted to ICU are at risk of developing severe diffuse weakness, which is referred to as ICUAW (1). It is now recognized that the majority of these people have a complex combination of nerve and muscle pathology, with some exhibiting polyneuropathy and others myopathy (2).

CIP and CIM have a reported prevalence of up to 65% of critically ill cases. Muscle wasting happened early and rapidly throughout the 1st week of critical disease and was more severe in those with multiorgan failure compared to single organ failure (3).

The age varied between 24 and 85 years with a mean of 67 ± 10.6 years, thirty of them were males (60%), and the rest were females (40%). The mean MRC scale was 3.66, while the mean APACHE II score was 20.22, and mortality occurred in 19 patients.

Our results agreed with the outcomes of Fukumoto et al. performed their study on 92 females with an average age of 70.4 ± 6.6 years in 2012 and detected that muscle quality evaluated by echogenicity of skeletal muscle by ultrasound has been associated with muscle strength assessment by the MRC scale independently of age or muscle thickness (13).

Regarding the neurophysiological studies, the mean EMG amplitude was 339.6, while the amplitude, latency, and nerve conduction velocity of the studied nerves

In this study, 26 patients were diagnosed to have ICU-AW based on their neurophysiological results, of which 21 patients had CIN, 15 patients had CIM and 10 patients had CINM.

Laboratory data showed that the mean hemoglobin level was 9.97 ± 1.62, the mean level of albumin was 3.02 ± 0.54, the mean level of creatinine was 1.82 ± 1.16, and the mean potassium (K) level was 4.21 ± 0.54. There were 28 (56%) patients who developed respiratory failure and experienced invasive mechanical ventilation due to pneumonia; 28 patients (56%) developed failure of weaning of mechanical ventilation due to persistent original cause; the majority of patients were ventilated with volume control mode (66%); and 10 patients (20%) had tracheostomy surgery. Ultrasonographic evaluation of the diaphragm and quadriceps femoris muscles showed a mean diaphragmatic excursion of 1.99 cm and a mean quadriceps femoris thickness of 32.78 cm. Regarding rectus femoris echogenicity, the majority of the studied population had grade I muscle echogenicity (62%).

These results came in agreement with a study conducted by Parry et al. in 2015 to report patterns of quadriceps muscle wasting within the 1st ten days of admission and detect the association between muscle ultrasonography and volitional measures. They studied 22 patients ventilated for up to forty-eight hours, and sequential quadriceps ultrasound images have been gathered over the 1st ten days, on awakening and discharge. The study found that there was an increase in echogenicity in the vastus intermedius and rectus femoris by 12.7% and 25.5%, respectively, with a strong relationship among muscle function and echogenicity ($r = 0.82$), concluding that ultrasonography is a useful surrogate measure to identify future muscle impairment (14).

Also, in prospective research that compared cases with sepsis to controls, Grimm et al. assessed muscle echogenicity. The research was performed in 2013 on 28 cases with severe sepsis or septic shock. On the fourth and fourteenth days following the onset of sepsis, muscle ultrasound and NCS were performed. The ultrasound assessment included an evaluation of echogenicity. Additionally, 26 healthy controls were subjected to the identical protocol. The research revealed that 92% of controls exhibited normal mean echogenicity (grades 1–1.25), while 75% of cases exhibited mean echogenicity >1.5, the highest value observed in the control group. The mean muscle echogenicity of controls and patients differed significantly on days four and fourteen (P value < 0.001) (15).

CONCLUSIONS

Bedside ultrasonography may be very beneficial for diagnosing and evaluating cases of ICUAW in intensive care units. Combining muscle echogenicity and dimensions is useful in the detection of muscle alterations through the course of a critical disease and may be utilized as a screening tool.

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