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Hand-held dynamometry to safely measure muscle strength in patients in intensive care

Segurança da mensuração da força muscular com Dinamômetro Hand-Held em pacientes na Terapia Intensiva

Balbino Rivail Ventura Nepomuceno Júnior[1,2,3]
https ://orcid.org/0000-0002-7274-9593
Kamilla Ribeiro Bastos dos Santos[2]
https ://orcid.org/0000-0003-0760-1856
Jailson de Souza Santos Júnior[2]
https ://orcid.org/0000-0002-5207-3952
Deisimar Fernandes de Almeida[2]
https ://orcid.org/0009-0001-5496-1654
Roberto Moreno de Barros[3]
https ://orcid.org/0009-0007-8645-1847
Mansueto Gomes Neto[1]
https ://orcid.org/0000-0002-0717-9694

1 Universidade Federal da Bahia. Postgraduate Program in Interactive Processes of Organs and Systems. Salvador, BA. Brazil.
2 Gestão em Reabilitação Hospitalar LTDA. Salvador, BA. Brazil.
3 Gestão em Fisioterapia Hospitalar LTDA. Salvador, BA. Brazil.

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Corresponding author
Balbino Rivail Ventura Nepomuceno Júnior.
Institute of Health Sciences, Universidade Federal da Bahia – UFBA
Av. Reitor Miguel Calmon, s/n, 40231-300, Canela, Salvador (BA), Brasil.
E-mail: balbino.nepomuceno@gmail.com

Abstract - Intensive care unit-acquired weakness (ICU-AW) has been increasingly studied and associated with prognostic factors of negative outcomes during the hospitalization of critically ill patients. Therefore, it is essential to evaluate the muscle strength of patients in the intensive care unit (ICU) with accurate quantitative tools, such as the hand-held dynamometer (HHD), which directly measures the strength of large muscle groups, providing earlier and more accurate decision making. The objective of the present study was to evaluate the safety of using HHD to measure the strength of large muscle groups in ICU patients, in addition to determining the prevalence of muscle imbalance in these patients, and correlating HHD measures with the Medical Research Council (MRC) scale. A cross-sectional study was conducted, inferring the impact of strength measurement of the main muscle groups using HHD on vital signs, dyspnea, and pain. The occurrence of adverse events during the evaluation was also observed. Safety was assessed using the paired t-test, calculating the prevalence of muscle imbalance in the sample and Pearson's correlation between the strength measurement instruments. The sample consisted of 46 volunteers, and no clinically significant variability was observed for pre- and post-safety variables. A high prevalence of muscle imbalance was found in the sample, and there was a strong correlation between HHD and MRC. Strength measurement using HHD in the ICU is safe and well-tolerated, providing information on the individual condition of large muscle groups and improving the ability to diagnose muscle imbalance in the ICU patients.

Key words: Diagnosis; Intensive care units; Muscle strength; Muscle strength dynamometer; Safety.

Resumo - *A Fraqueza Muscular Adquirida em Unidade de Terapia Intensiva (FMAUTI) é cada vez mais estudada e associada a fatores prognósticos de desfecho negativo durante o internamento dos pacientes críticos. Visto a relevância de tal marcador, se faz fundamental avaliar a força muscular do paciente internado na Unidade de Terapia Intensiva (UTI) com instrumentos quantitativos acurados, como é o caso do Dinamômetro Hand Held (DHH), que afiram diretamente a força de grandes grupos musculares de função, trazendo mais precocidade e precisão à tomada de decisão. O objetivo do presente estudo é verificar a segurança do uso do DHH na avaliação da força de grandes grupos musculares em pacientes internados em UTI, como também levantar a prevalência de desequilíbrio muscular nestes pacientes e correlacionar as medidas do DHH observadas com a Medical Research Council (MRC). Foi realizado um estudo transversal, inferindo o impacto da avaliação de força com DHH dos principais grupos musculares nos sinais vitais, na dispneia e na dor. A ocorrência de evento adverso durante avaliação também foi observada. Para avaliar a segurança, foi utilizado teste T pareado, calculando a taxa de prevalência do desequilíbrio muscular para a amostra, e o Coeficiente de Correlação de Pearson entre os instrumentos de avaliação de força. A amostra foi composta por 46 voluntários, não sendo observada variabilidade clinicamente significante para variáveis pré e pós-avaliação de segurança. Foi encontrada alta prevalência de desequilíbrio muscular na amostra e houve forte correlação entre o DHH e a MRC. A avaliação da força com DHH em UTI é segura e bem tolerada, conferindo informações sobre as condições individuais de grandes grupos musculares e agregando a capacidade de diagnosticar desequilíbrio muscular no atendimento beira-leito em UTI.*

Palavras-chave: *Diagnóstico; Unidade de terapia intensiva; Força muscular; Dinamômetro de força muscular; Segurança.*

INTRODUCTION

Muscle strength is an important marker of physical and functional assessment in intensive care inpatients[1]. In addition, intensive care unit-acquired weakness (ICU-AW) has been increasingly studied and associated with prognostic factors of negative outcomes during hospitalization of critically ill patients[2-5].

The skeletal muscle system is an important energy reservoir, in addition to its role in locomotion and motricity. Recent studies have shown a relationship between the endogenous hormone irisin and immune optimization and the prevention of severe complications of SARS-CoV-2 infection[6-9]. In older adults, sarcopenia is associated with increased dependence on mechanical ventilation and higher mortality rates[10].

Muscle strength is usually monitored with scales, such as the Medical Research Council (MRC) scale for skeletal muscles that classifies muscle performance according to its range of motion and behavior during free movement and against gravity or resistance imposed on the muscle. This tool is widely used in intensive care units (ICUs), although its validity and accuracy are not known[3,11,12]. The hand-grip dynamometer is also popularly used in ICU, and this tool quantifies the palm grip strength (PGS), which correlates to the strength of major muscle groups. It is a validated measure for intensive care, but it has no accuracy in predicting muscle health of distant muscles, such as quadriceps, psoas, deltoid, and biceps brachii[1,5,12]. Therefore, it is essential to assess the safety and applicability of quantitative instruments that directly evaluate the function of large muscle groups, such as the hand-held dynamometer (HHD) in ICU patients.

Therefore, this study aimed to evaluate the safety of using HHD to measure the strength of large muscle groups in ICU patients, in addition to determining the prevalence of muscle imbalance in intensive care inpatients and correlate the measurements of dynamometry with the MRC scale.

METHODS

This is a cross-sectional study on muscle strength measurement safety using HHD in ICU patients. The participants were patients of both sexes, >18 years of age, admitted to the ICU where the research was conducted, with sufficient cognition to coordinate the muscle strength measurement tests, hemodynamically stable or on minimal dose of vasoactive drugs (dopamine or dobutamine <3 mg/kg/min, adrenaline or noradrenaline <0.05 mg/kg/min, vasopressin <0.01 mg/kg/min), those without intracranial hypertension, arterial dissection or active bleeding, and who agreed (and/or their legal guardian agreed) to participate in the research. We excluded patients if they withdrew consent to participate at any time during the research or if they did not have the minimum force to trigger the device pressure cell, which was graduated at 15 N to avoid cell self-triggering by the weight of the limb or fixation of the device, thus minimizing measurement bias[13].

This study was approved by the Ethics Committee (No. 1537948). A sample calculation was performed, estimating a variation of 20% in heart rate (HR) and systolic blood pressure (SBP), with power of 80% and alpha of 5%, totaling 45 volunteers, estimating a sample loss of 5%.

The sociodemographic and functional data were collected from medical records and written informed consent was obtained from the patient or legal

guardian. Of the variables studied, the following are nominal variables: sex, outcome, and dominance. Functional status score for the intensive care unit (FSS-ICU) and the ICU mobility scale (IMS) were categorical variables. Discrete or continuous quantitative variables were age, weight, height, acute physiology and chronic health evaluation, second version (APACHE II), peak muscle strength, mean muscle strength, and sum of peak torque. The safety data were monitored pre and post the measuring procedure using a Dixtal multiparameter monitor, model DX 2020 (Phillips, Amsterdam, Netherlands), and variables such as HR, respiratory rate (RR), SBP, diastolic blood pressure (DBP), and peripheral oxygen saturation (SpO2) were continuously monitored. The pre and post measurement of categorical variables were performed using the visual analog scale (VAS) and Borg scale of perceived exertion (Borg). If adverse events, such as loss of the device, hematoma, malaise, cold sweats, accidental extubation, fatigue, or lipothymia occurred, the event was notified.

Isometric muscle strength measurement was performed using the HHD, Lafayette model 01165 (Lafayette, Sagamore, USA), and an ISP goniometer, for adequate determination of the joint position in the test of each muscle group. The evaluation was performed in the ICU bed in the dorsal decubitus position. The peak force torque obtained in isometric contraction was tested for the function of the main muscles bilaterally. Before the measurement, the patient was oriented, trained, and warmed up for each movement. After performing the isometric contraction for three seconds, the equipment sounded a beep signaling the end of the contraction for each movement. Each muscle was tested three times and the highest measure was considered. Patients were constantly encouraged by the examiner, who said "Go, go, go!".

Before the study, all the measuring instruments were calibrated in order to minimize possible measurement bias. The maximum torque for each muscle group tested was assessed using the HHD positioned with the hands-on segment.

Six large muscle groups were evaluated, same as those used in the MRC scale, adopting the following positioning for measuring the HHD. First, the shoulder abduction – in dorsal decubitus: limb positioned parallel to the trunk, elbow, and wrists 180°, the patient was requested to perform shoulder abduction. Second, the elbow flexors in dorsal decubitus: shoulder in a neutral position, elbow in 90° flexion and wrists in 180°, and forearm supinated. Third, we performed elbow flexion: the wrist extensors – in dorsal decubitus position, forearm supported on the bed, parallel to the body, shoulder positioned with 15° of abduction, elbow in 0° of flexion and wrists 0°, forearm pronated. HHD was supported on the posterior aspect of the carpal bones, with fixation hand supporting the radius and ulna against the bed. Fourth, extend the wrist: hip flexors – in dorsal decubitus, stabilize the pelvis and contralateral lower limb with inelastic tape, hip and knee with 0° of flexion, HHD supported on the anterior face of the thigh, at its distal third (suprapatellar). Fifth, Hip flexion: knee extensors – in dorsal decubitus, stabilized pelvis and contralateral lower limb with inelastic tape, hip and knee with 45° of flexion, supported with the examiner's fixation hand. HHD was supported on the anterior face of the leg, on its distal third. Sixth, knee extension: ankle dorsiflexors – in dorsal decubitus, stabilized pelvis and contralateral lower limb with inelastic tape, hip and knee with 0° of flexion, HHD supported on the dorsal face of the foot, on its distal third. The ankle fixation hand prevented hip flexion (by synergism). Finally, hip flexion was requested[13-19].

The MRC scale was used to measure the same muscle groups in the same positions with free or resisted movement, categorizing the best performance as 0 (no visible contraction), 1 (visible contraction without movement of the segment), 2 (active movement with the elimination of gravity), 3 (active movement against gravity), 4 (active movement against gravity and resistance), and 5 (normal strength)[11].

The SPSS 28.0 (Statistical Package for the Social Sciences) software for Mac was used for data analysis. Descriptive statistics were used with data presented in tables and graphs. Qualitative data were expressed as absolute and relative frequency, and quantitative data were expressed as mean and standard deviation. The Kolmogorov–Smirnov test was used to test the normality of the distribution of the variables studied. The means of the pre- and post-HHD-use safety variables were compared after the paired t-test to evaluate the safety, considering a $p<0.05$ as statistically significant.

The prevalence of muscle imbalance in ICU patients was calculated by the number of individuals affected at a given moment, divided by the total number of individuals studied in the sample.

The added muscle groups' torque and their mean were correlated with the MRC score using Pearson's correlation coefficient (r). For didactic purposes, to categorize the correlation magnitude, the classification proposed by Mukaka[20] was used. Values of 0.0–0.3 indicated a negligible correlation, 0.3–0.5 a weak correlation, 0.5–0.7 a moderate correlation, 0.7–0.9 indicated a strong correlation, and values >0.9 indicated a very strong correlation.

RESULTS

The study included 46 patients hospitalized in an ICU in the municipality of Catu, Bahia, Brazil, between July 2020 and March 2021. The mean age was 67.6 years, 54.2% were men, with a mean weight of 77.4 kg and mean height of 1.66 meters. As for functionality before hospitalization, the mean IMS was 9.7, corresponding to a mean FSS-ICU of 34.5 at admission. The mean APACHE II was 19.6, with 39.13% of the patients evaluated while under mechanical ventilation (MV), with a mean MV duration at the time of assessment of four days (Table 1).

Table 1. Socio-demographic, clinical and functional data of the sample (n=46).

Variable	f(%)	Mean (SD)
Age, years		67.6(23.7)
Sex, man	26(54.2)	
Weight, kg		77.4(16.5)
Height, cm		166.1 (9.3)
Dominance,right-handed	44 (91.7)	
FSS-ICU, prior		34.5 (1.6)
IMS, admission		9.7 (0.7)
APACHE II		19.6 (5.7)
Artificial airway	18 (39.1)	
Mean MV time		4.2 (1.6)
Outcome, ICU discharge	44 (91.7)	

Note. FSS-ICU: Functional status score for the intensive care unit (0-35); IMS: Intensive care unit mobility scale (0-10); APACHE II: Acute Physiology and chronic health evaluation, second version.

Table 2 shows the muscle strength measurement safety using HHD. The vital signs are normal without any adverse event (Figure 1). Table 3 shows the peak torque of the muscles evaluated bilaterally, observing a high prevalence (30–52%) of muscle imbalance in the six major muscle groups evaluated. The shoulder and hip flexors and dorsiflexors were the muscle groups with the highest prevalence of muscle imbalance in the sample studied.

Table 2. Safety of strength measurement with DHH in ICU patients (n=46).

Variable	Pré -HHD	Pós -HHD	p
	Mean (SD)	Mean (SD)	
HR, in BPM	82.8 (15.2)	83.0 (15.4)	0.86
SBP, in mmHg	133.1 (22.8)	136.3 (21.4)	0.23
DBP, in mmHg	69.6 (14.2)	70.2 (17.4)	0.74
SpO2, in %	96.7 (1.5)	97.0 (1.7)	0.35
RR, in BPM	18.0 (4.5)	18.4 (4.6)	0.55
Borg	0.0 (0.0)	0.1 (0.2)	0.33
VAS	0.2 (0.7)	0.1 (0.6)	0.33

Note. HR: Heart rate; SBP: Systolic blood pressure; DBP: diastolic blood pressure; SpO2: Peripheral oxygen saturation; RR: Respiratory rate; Borg: Borg scale of perceived exertion (0-10); VAS: Visaul analogue scale (0-10).

Table 3. Peak torque measured with the Hand Held Dynamometer, of the main muscle groups and prevalence rate of muscle imbalance between hemids in patients admitted to the ICU (n=46).

Movement	Right hemid	Left hemid	Muscle imbalance
			p
Shoulder abdution	65.3 (34.0)	59.0 (28.0)	52.2%
Elbow flexion	143.9 (76.5)	137.8 (71.5)	30.4%
Wrist flexion	74.9 (43.7)	70.1 (40.0)	47.8%
Hip flexion	98.5 (57.9)	93.3 (60.7)	52.2%
Knee extension	165.5 (103.6)	111.7 (63.3)	43.5%
Dorsiflexion	111.7 (63.3)	111.4 (56.5)	52.2%

Note. Torque peak measured in N.

When the muscle strength classification data collected using the MRC scale were correlated with the peak force-torque measured using the HHD, presented as the sum of the muscle groups or as the peak torque mean of the same muscle groups, a strong correlation was observed in the sum of HHD and MRC (r^2 0.75, p<0.001) and mean of HHD and MRC (r^2 0.74, p<0.001); the correlated mean and the sum of HHD also showed a very strong correlation with r^2 0.99, p<0.001 (Table 4).

Table 4. Correlation between DHH and MRC (n=46).

Score	Mean (SD)	MRC	Sum HHD	Mean of HDD
		53.2 (9.6)	1280.8 (656.3)	108.4 (56.9)
MRC	r2	1.00	0.75	0.74
	P value	-	<0.001	<0.001
Sum HHD	r2	0.75	1.00	0.99
	P value	<0.001	-	<0.001
Mean of HHD	r2	0.74	0.99	1.00
	P value	<0.001	<0.001	-

Note. MRC: Medical Research Council Scale for Skeletal Muscle; HHD sum: sum of the peak torque of the MRC muscles, measured by HHD; Mean of HHD: Mean peak torque of MRC muscles, measured by HHD.

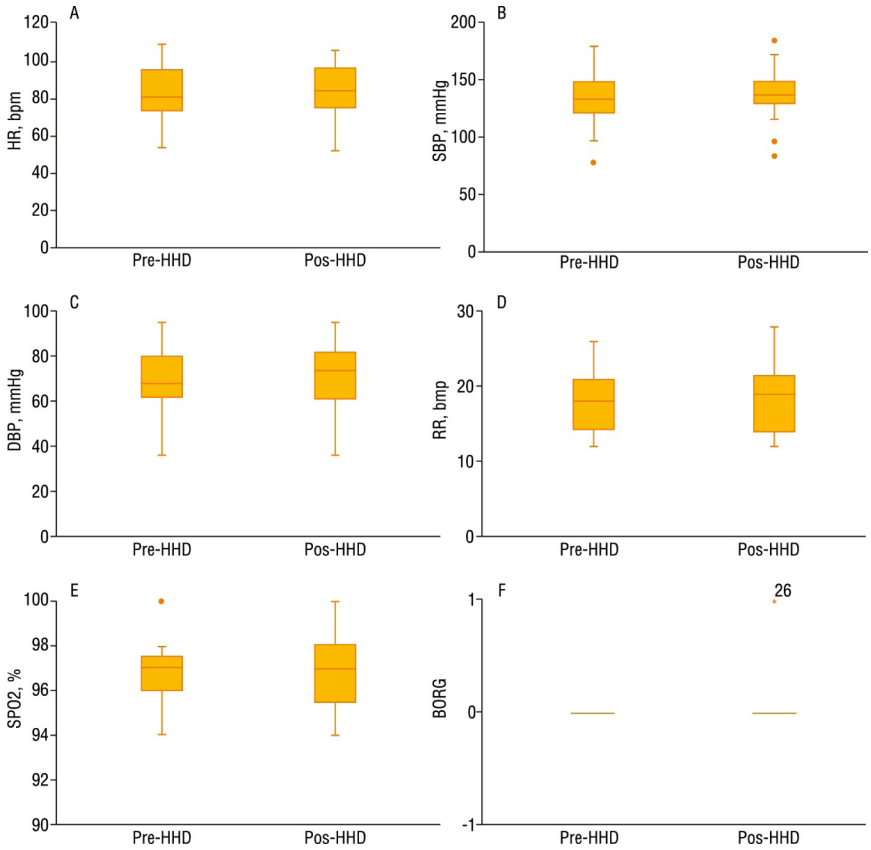

Figure 1. Behavior of safety variables before and after strength measurement with a hand held dynamometer (HHD) in patients hospitalized in intensive care: A- Heart rate (HR); B- Systolic blood pressure (SBP); C- Diastolic blood pressure (DBP); D – Peripheral oxygen saturation (SpO2); E- Respiratory rate (RR); F - Borg's Dyspnea Perception Scale (BORG).

DISCUSSION

To the best of our knowledge, this study is the first to describe the muscle strength measurement safety using HHD in ICU patients. This study found no relevant variation in HR, SBP, DBP, SpO2, RR, or dyspnea measured by Borg or pain measured by VAS. The intervention safety was confirmed by the absence of adverse events during the strength measurement protocol.

Safety is our priority based on the bioethical principle of nonmaleficence; thus, the data found in this study prove that HHD is a safe tool to measure the strength of large muscle groups in critically ill ICU patients evidenced by a good cardiovascular and respiratory tolerance during this assessment. The skeletal muscle system is important since its good general state provides organic energy reserves, and enables transfer and locomotion, and is considered an independent factor for better prognosis of ICU patients. On the other hand, weakness associated with ICU admission is a variable associated with higher mortality, thus, early screening and treatment of loss of strength during hospitalization could change this outcome.

In the European consensus for the definition and diagnosis of sarcopenia, Cruz-Jentoft et al.[1] reinforced the importance of continued screening of muscle strength for early diagnosis of sarcopenia, which is associated with quantitative or qualitative muscle reduction and limitation in the execution of

functions. Multiple etiologies lead to a high incidence of critically ill patients developing ICU-AW. The pathophysiology of severe catabolic diseases, the use of neuromuscular blocking agents, the presence of hydroelectrolytic disorders, the use of some antibiotics, and prolonged immobilization are known factors for the development of ICU-AW. Muscle strength measurement with HHD is a potential low-cost and noninvasive tool to identify variations in strength and assist in the diagnosis of bedside issues.

Our previous studies on HHD[3,21] showed that this strength measurement protocol presents excellent intra-examiner correlation, with an intraclass correlation coefficient (ICC) of 0.89–0.99 for the muscles evaluated, while the inter-examiner measurements also presented excellent correlation with an ICC of 0.81–0.97. When the concurrent validation of HHD with the gold standard method was evaluated, the accuracy was 0.51–0.83 for the six muscle groups tested. When the accuracy in diagnosing muscle imbalance was tested, the HHD showed a sensitivity of 0.90–0.98 and specificity of 0.64–0.89 for the muscles evaluated. Such studies corroborate that the HHD is a reliable and precise tool for the measurement of strength and deficiencies associated with the muscular system[14,18,21].

Muscle imbalance is the difference in muscle strength comparing dominant and non-dominant limbs with a difference >15%, and differences between agonist and antagonist muscle groups[22-25]. Such dysfunction is associated with a higher risk of osteomuscular injury. The present study found a high prevalence of muscle imbalance in ICU patients, with a prevalence of 30.4% for elbow flexors and 52.2% for shoulder abduction, hip flexion, and ankle dorsiflexors.

Kleyweg et al.[11] described the use of MRC in patients with Guillain–Barré syndrome and correlated this marker of strength with palmar grip strength, with a median correlation of 0.91 (0.80–0.99). Hermans et al.[12] measured the agreement between MRC and measurement of PGS with a hand-grip dynamometer in ICU patients. Compared with the sum of all MRC scores, the correlation was 0.95 (0.92-0.97), compared with the sum of the scores of the upper limbs muscles, the correlation was 0.92 (0.87-0.95), and that of the lower limbs was 0.96 (0.92-0.97), showing a particularly good correlation between PGS by hand-grip dynamometer and the MRC score. The present study compared the peak torque of the muscle with the MRC score classification and found a lower correlation of 0.75 for the sum of the muscles and 0.74 for the peak torque mean in the muscles evaluated, with equivalence in the correlation between the sum of HHD and mean HHD with 0.99 correlation. These data confirm that the quantitative and direct measurement of the large muscle groups may have some divergence in relation to the classification of strength by score and indirect estimate of PGS.

This study is the first to evaluate the safety of using dynamometry in critically ill patients in an ICU environment, and its data support future studies to delimit the behavior of the peak torque of patients during hospitalization and the prognostic values for clinical and functional outcomes in follow-up. The HHD is a portable, low-cost device with a test protocol focused on particularities generated by restrictions of hospitalized patients. This study has limitations. First, it did not measure laboratory markers, such as lactate and C-reactive protein, to assess inflammatory response to strength measurement. Second, we did not evaluate PGS with a hand-grip dynamometer. Therefore, new

comparative studies between the measuring instruments should be conducted to further describe peak torque values for the population of patients in the ICU.

CONCLUSION

The present study proved that muscle strength measurement using the HHD in ICU patients is safe and well-tolerated, providing the multidisciplinary team relevant information on the individual condition of large muscle groups, and aiding the diagnosis of muscle imbalance. This method is strongly correlated with the method of strength measurement by classification and can be used in the routine evaluation and monitoring of critically ill patients in the ICU.

Compliance with ethical standards

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Ethical approval

Ethical approval was obtained from the local Human Research Ethics Committee – n° 1.537.948 and the protocol was written in accordance with the standards set by the Declaration of Helsinki.

Conflict of interest statement

The authors have no conflict of interests to declare.

Author Contributions

Conceived and designed the experiments: BRVNJ; MGN. Performed the experiments: BRVNJ; KRBS; JSSJ; DFA; RMB. Analyzed the data: BRVNJ; MGN. Contributed reagents/materials/analysis tools: BRVNJ; MGN. Wrote the paper: BRVNJ; KRBS; JSSJ; DFA; RMB; MGN.

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