Nutritional evaluation in cirrhosis: Emphasis on the phase angle

Sabrina Alves Fernandes, Angelo Alves de Mattos, Cristiane Valle Tovo, Claudio Augusto Marroni

Abstract

Protein-calorie malnutrition (PCM) is a common condition in cirrhotic patients, leading to a worse prognosis, complications, poor quality of life and lower survival rates. Among ways of assessing nutritional status, there are anthropometric methods such as the evaluation of the triceps skinfold, the arm circumference, the arm muscle circumference and the body mass index, and non-anthropometric methods such as the subjective global assessment, the handgrip strength of non-dominant hand, and the bioelectrical impedance analysis (BIA). PCM is frequently under-diagnosed in clinical settings in patients with cirrhosis due to the limitations of nutritional evaluation methods in this population. BIA is a useful method, but cannot be indicated in patients with abnormal body composition. In these situations, the phase angle (PA) has been used, and can become an important tool in assessing nutritional status in any situation. The PA is superior to anthropometric methods and might be considered as a nutritional indicator in cirrhosis. The early characterization of the nutritional status in patients with cirrhosis means an early nutritional intervention, with a positive impact on patients’ overall prognosis. Among the usually accepted methods for nutritional diagnosis, the PA provides information in a quick and objective manner.

Key words: Malnutrition; Bioelectrical impedance; Phase angle; Sarcopenia; Nutrition

© The Author(s) 2016. Published by Baishideng Publishing Group Inc. All rights reserved.

Core tip: Malnutrition in cirrhotic patients is a common clinical condition, but there is currently no nutritional diagnosis method defined as the gold standard. Presently, the only nutritional indicator compatible with the clinical condition through the Child-Pugh score in cirrhosis is the phase angle (PA). The PA has been
Fernandes SA, de Mattos AA, Tovo CV, Marroni CA. Nutritional evaluation in cirrhosis: Emphasis on the phase angle. World J Hepatol 2016; 8(29): 1205-1211 Available from: URL: http://www.wjgnet.com/1948-5182/full/v8/i29/1205.htm DOI: http://dx.doi.org/10.4254/wjh.v8.i29.1205

INTRODUCTION

Many factors favor the development of protein-calorie malnutrition (PCM) in cirrhosis, a common condition that leads to serious repercussions regarding the general state and clinical course of patients and that presents a worse prognosis, complications, poor quality of life and lower survival rates. However, malnutrition is often underdiagnosed in this situation. It is difficult to evaluate the nutritional status of patients with cirrhosis, as there are particularities due to the clinical condition that make it hard to precisely inform the real nutritional status and its consequent prognosis.

Malnutrition can be directly related to a poor survival rate in patients with cirrhosis, and its improvement is a strong indicator of quality of life, especially for those who are on the waiting list for liver transplantation. Early detection of malnutrition in cirrhotic patients is of great clinical relevance and interferes positively in patient recovery.

The new European Society of Clinical Nutrition and Metabolism (ESPN) consensus, recommends that subjects at risk of malnutrition be identified by validated screening tools, and they advocate two options for the diagnosis of malnutrition: The body mass index (BMI), kg/m² lower than 18.5 to characterize malnutrition, and the combined finding of unintentional weight loss and either reduced BMI or a low fat-free mass index (FFMI), or both. Weight loss could be either greater than 10% of habitual weight regardless of time, or greater than 5% over 3 mo. Low FFMI is characterized as lower than 15 or lower than 17 kg/m² in females or males, respectively. However, many other tools, such as anthropometric and non-anthropometric methods as well as laboratory tests may be used, classifying the degrees of malnutrition as mild, moderate and severe in different ways - although none of these other tools are widely recognized as a gold standard, and thus must be considered together. Various nutritional parameters has been used to assess the nutritional status such as anthropometry parameters [mid arm circumference, triceps skinfold thickness (TSF)], hand grip, serum albumin level, creatinine height index, and total lymphocyte count. Recently electrical bioimpedance has been proposed for body composition analysis of patients with chronic liver disease. In view of paucity of data on prevalence of malnutrition and its relationship with morbidity and mortality in patients with liver cirrhosis as well as the absence of a gold standard method for nutritional evaluation in these patients, we conducted this study to determine the prevalence of malnutrition by various methods and its clinical importance in cirrhotic patients according the severity of disease.

Considering the scarcity of data in the evaluation of malnutrition in patients with liver cirrhosis as well as the absence of a gold standard for nutritional evaluation in these patients, the present review was performed, critically addressing the following points: Malnutrition in cirrhosis; sarcopenia; nutritional assessment in cirrhosis; bioelectrical impedance analysis and the phase angle.

MALNUTRITION IN CIRRHOSIS

Malnutrition is one of the most frequent complications in cirrhotic patients. However, its frequency in cirrhosis is highly variable, and may affect between 20% of the patients with compensated cirrhosis and more than 60% of these patients with severe hepatic dysfunction. Alberino et al. studied 212 hospitalized patients with liver cirrhosis that were followed for 2 years or until death. The severely and moderately malnourished patients had lower survival rates than normal and over nourished patients, and severe depletion of muscle mass and body fat was found to be an independent predictor of survival. This data suggests that malnutrition is an independent predictor of survival in patients with liver cirrhosis. Additionally, a nationwide analysis of the prevalence of PCM in patients with cirrhosis and portal hypertension (PHTN) and its mortality was conducted in the United States. There were 114703 admissions with cirrhosis and PHTN between 1998 and 2005, and the prevalence of PCM was higher among patients with cirrhosis and PHTN compared with general medical inpatients; this prevalence was also associated with higher in-hospital mortality and resource utilization. The authors concluded that PCM may be an indicator of disease severity and should be routinely assessed on admission.

Besides the metabolic changes observed in cirrhosis, there are factors that can contribute to increased malnutrition in this population. Factors such as anorexia and early satiety, triggered by changes in endogenous leptin, mineral deficiencies and reduction in gastric expandability favor a negative energetic balance, with an imbalance between ingestion and energy intake and expenditure, and PCM may develop as a result. The zinc and magnesium deficiencies that may be often seen in the population of patients with cirrhosis contribute to the development of dysgeusia, which aggravates the intake capacity.

The clinical complications that can occur in decompen-sated cirrhosis - such as gastrointestinal bleeding,
hepatic encephalopathy (HE) and ascites - can further accentuate the PCM situation[14], alongside the diet offered to these patients, which is restrictive in most cases. Thus, although for a short period of time, a hypoproteic diet may be eventually implemented, especially in cases of HE grades III and IV[14]. It is worth highlighting that the protein restriction has been banned in HE in order to prevent the worsening of PCM, and a diet with 1 to 1.5 g of protein per kilogram of weight is suggested[4].

The recommended low-sodium diet in the treatment of patients with ascites and peripheral edema makes the food intake even more difficult and significantly decreases the daily calorie intake, thus stimulating PCM. A low-sodium diet with a daily intake of 2 g of salt is recommended[17].

It is known that skeletal muscles contribute in the proper metabolic functioning of macro and micro-nutrients, favoring body homeostasis. In individuals with cirrhosis, there is a significant loss and dysfunction of such musculature, often characterizing sarcopenia[18,19]. This state generates systemic and inflammatory changes associated with the PCM, negatively impacting the patient’s clinical status[20].

The classical study by Merli et al[21] prospectively evaluated a total of 1053 cirrhotic patients to determine whether malnutrition is a risk factor for mortality in cirrhosis. They found that the cumulative survival was lower in patients with a reduction in muscle mass in Child-Pugh classes A and B.

Montano-Loza et al[22] studied 112 cirrhotic patients consecutively evaluated for liver transplantation, and observed that sarcopenia occurred in up to 40% of the patients and was related to the worsening of clinical conditions represented by biochemical and clinical parameters; moreover, by multivariate Cox analysis, the Child-Pugh (HR = 1.85; P = 0.04), the model for end-stage liver disease (MELD) scores (HR = 1.08; P = 0.001) and sarcopenia (HR = 2.21; P = 0.008) were independently associated with mortality. The median survival time for patients with sarcopenia was 19 ± 6 mo, compared with 34 ± 11 mo among non-sarcopenic patients (P = 0.005). Sarcopenia can be considered an indicator of risk of infection in cirrhotic individuals, directly reflecting a decline in immune function, worsening the quality of life and decreasing survival.

**SARCOPENIA**

Malnutrition in cirrhosis is closely related to the development of sarcopenia, which will be one of the most common complications related to survival in this population of patients. Nevertheless, there is a lack of an optimal index for sarcopenia and of a consensus definition for sarcopenia in patients with cirrhosis in whom ascites and edema may interfere with body composition analysis[23].

Sarcopenia is a syndrome characterized by progressive and generalized loss of skeletal muscle mass and strength with a risk of adverse outcomes such as physical disability, poor quality of life and death[24,25]. The European Working Group on Sarcopenia in Older People recommends using the presence of both low muscle mass and low muscle function (strength or performance) for the diagnosis of sarcopenia[26].

Montano-Loza et al[19] evaluated a population of 248 cirrhotic patients enlisted for liver transplantation and identified sarcopenia in 45% of patients; sarcopenia was associated with a longer period of hospitalization and higher risk of bacterial infection after transplantation.

Similarly, Tandon et al[23] evaluated 142 patients with cirrhosis listed for liver transplantation, and found that 41% were sarcopenic. Male gender, the BMI, and Child-Pugh class C cirrhosis (but not the MELD score) were independent predictors of sarcopenia, which was an independent predictor of mortality after adjustments for age and MELD scores. The authors concluded that sarcopenia is associated with increased waiting-list mortality and is poorly predicted by subjective nutritional assessment tools such as BMI and subjective global assessment (SGA). The objective assessment of sarcopenia holds promise for prognostication in this patient population.

**NUTRITIONAL ASSESSMENT IN CIRRHOSIS**

Among the different ways of assessing nutritional status, there are anthropometric methods such as determining the TSF, the arm circumference (AC), the arm muscle circumference (AMC) and the BMI, as well as non-anthropometric methods such as SGA, handgrip strength (HS) of non-dominant hand, the adductor pollicis muscle thickness (APMT) and the phase angle (PA) by bioelectrical impedance analysis (BIA).

Classical anthropometry assesses the measurement of body size and its proportions. The results obtained are compared with the points of reference previously described[27].

Cirrhotic individuals present significant changes regarding body weight by hydric retention, making BMI an inadequate method for nutritional diagnosis[28]. Such distortion was observed in the study performed by Gottschall et al[29], in which 61.8% of patients were classified as overweight, while other techniques, such as SGA or HS, found malnutrition in 38% and 85.7% in the same population of patients, respectively.

The TSF measurement indirectly estimates fat mass by measuring the thickness of two layers of skin and the adjacent subcutaneous fat. This is a good assessment method, although some studies have found a low prevalence of malnutrition in cirrhosis when comparing this method to others[30-32].

Abbott et al[31] and Alberino et al[36] described, in their studies, that 54% of the evaluated cirrhotic patients were malnourished when utilizing AC and AMC, supporting the findings of Merli et al[21], which suggest...
AMC as an accurate indicator of malnutrition in patients in the early stages of cirrhosis. On the other hand, a study performed in our center by Fernandes et al[34] showed that AC and AMC are not sensible parameters for the nutritional diagnosis.

As a general rule, the anthropometric parameters may be affected when there is hydric retention; the results are observer-dependent and can be conflicting, becoming inadequate in the nutritional assessment of patients with cirrhosis.

When considering the non-anthropometric methods, SGA is a method of interest that uses easily reproducible parameters such as the clinical history and physical conditions of the individual, focusing on the nutritional aspects and offering a score that provides the nutritional diagnosis[35]. However, this method shows limitations, especially when the patient has some difficulty to understand or even HE, as patients will not report their nutritional history adequately[36].

Figueiredo et al[37] observed that SGA has a sensitivity of only 22% in cirrhotic individuals and underestimates their nutritional status in 57%, while overestimating it in 6%[38]. On the other side, Ritter and Gazzola[38] established SGA as a good option for the nutritional assessment of patients with liver disease.

Although some authors[36,39,40] have suggested that SGA might be useful to assess the nutritional status evolution of cirrhotic patients who are liver transplant candidates, these studies have detected malnutrition in only 25% of cases with this method.

The HS assessment through dynamometry refers to the measurement of muscle strength and of pressure distribution[41], classifying the nutritional status of individuals by gender and age. In dynamometry, there is the assumption that in PCM there is a decrease in muscle mass, hindering one’s functional capacity[42]. Studies with cirrhotic patients have shown the superiority of HS assessment when compared to SGA in diagnosing malnutrition; HS is considered a low-cost and simple method that is not influenced by the presence of hydric retention[42]. Curiously, in different studies, HS - while proving to be a good method in assessing nutritional risk - does not present a correlation between malnutrition and the staging of liver disease through the Child-Pugh score, although it is considered that liver disease patients, when classified as Child-Pugh C, are malnourished per se[41].

The APMT has been suggested as a promising marker of muscle mass[43,44]. The adductor pollicis muscle is the only muscle that allows direct thickness assessment, as it is anatomically well defined and flat in shape[45]. However, few have looked into it as a marker of nutritional status[46].

**THE PHASE ANGLE**

In view of the limitations of BIA, the clinically established bioelectrical impedance parameter is the PA. The PA was originally described by Baumgartner et al[23] for the diagnosis of metabolic disorders. The data is obtained through BIA and is directly calculated through the arc tangent formula (Xc/R). The tissues’ capacitance (Xc) is related to cellularity, cell-size and integrity of cellular membrane. The resistance (R) is dependent on the hydration state of the tissues. The ratio of components results in a geometric graphic, where the ratio of R and...
Xc results in an angle called the PA.

BIA is represented by the vector Z, which is a combination of the perpendicular vectors R and Xc. The vector Z has a module M, and the horizontal axis defines the PA \(^{[52]}\).

The PA reflects the cellular vitality and integrity, where normal values (according to gender and age) indicate preserved cellular activity\(^{[34,53,54]}\), being highly predictive of clinical progression in a number of diseases\(^{[55]}\).

It has been suggested that the PA can become an important tool in assessing nutritional status in any situation, being superior to anthropometric and biochemical methods\(^{[46]}\).

There are reference values according to age and gender\(^{[46]}\), and some authors prefer to establish cutoff points according to the disease being studied\(^{[47]}\).

The PA has also been studied as a prognostic marker in different clinical situations, such as tumors, acquired immunodeficiency syndrome, and heart and liver diseases\(^{[54]}\).

In a review, Llames et al\(^{[55]}\) concluded that the PA may be sufficient to monitor the nutritional status of an individual. In a population-based study, they observed a higher PA in men than in women, except in individuals over 70 years of age. When stratified by age and gender, the values tend to increase as BMI increases in values of up to 35 kg/m\(^2\); however, there is a decrease in PA in groups with BMI above 35 kg/m\(^2\)\(^{[55]}\).

There are few studies evaluating the PA in cirrhotic patients.

Selberg et al\(^{[46]}\), in a prospective study of 305 patients with cirrhosis, correlated the PA with muscle mass, muscle strength, and survival rates. They observed that patients with a PA equal to or lower than 5.4 degrees showed lower survival rates than those with PA values above 6.6 degrees. In those with PA under 4.4 degrees, survival was even (and significantly) lower. Variables such as total body potassium, anthropometric measurements and BIA were evaluated separately; however, only the PA proved to be an isolated predictor of survival. The authors concluded that the PA appears to be superior to conventional methods in the clinical assessment of patients with cirrhosis.

In a retrospective study, Pirlich et al\(^{[53]}\) evaluated the cellular mass composition of 41 cirrhotic patients (20 with ascites and 21 without) through BIA, which was considered the reference method. The study shows that the PA is a tool that is able to detect body cellular mass and to identify its decrease in cirrhotic patients. The PA offers reliable PCM estimates even in patients with large amount of ascites, proving to be superior to commonly used techniques.

In a cohort that assessed 66 cirrhotic patients stratified by their clinical condition through the Child-Pugh score and followed-up during a 17-mo period, the established PA for this population was 5.18 degrees. Patients with values below this angle were considered to have poor prognosis and shorter survival rates. It is worth highlighting that as the patients’ clinical situation worsened, the PA decreased, showing a prognostic value\(^{[57]}\).

Corroborating these findings, we assessed the nutritional status of 129 cirrhotic patients through different methods and demonstrated that the only method that is able to correlate malnutrition with the staging of liver disease, evaluated through the Child-Pugh classification, was the PA. We set the PA cutoff point as 5.4 degrees, and patients with values below this discriminatory level showed a worse prognosis. We should point out the discrepancies between the results of different evaluation methods (anthropometry, HGS and BIA) used to diagnose PCM, once the diagnosis for malnutrition may vary from 5.4% to 69.3% in the same population, depending on the assessment method employed\(^{[46]}\). The PA evaluated through the BIA presented a sensitivity and specificity of 68.9%-70.0% and 49.2%-56%, respectively, when compared to the HGS\(^{[34]}\).

Later, another study performed in our center evaluated 195 cirrhotic patients, reinforcing the idea that the PA is a good prognostic marker when compared to other methods, as it is the only one that correlates with the real clinical condition of the patient\(^{[58]}\).

Recently, Ruiz-Margain et al\(^{[59]}\) assessed 249 compensated cirrhotic patients in a prospective cohort study with a 48-mo follow-up period. The PA cutoff point for malnutrition was lower than or equal to 4.9 degrees. This study also concluded that the PA is a good prognostic marker, associating the PCM with mortality rate.

A cohort study conducted in our center evaluated 32 cirrhotic patients enlisted for liver transplantation\(^{[36]}\). The patients were interviewed and evaluated on the day of or on the day before the transplant, and 1, 6, and 12 mo after surgery. The assessment of nutritional status was performed applying diagnostic procedures in sequence: Anthropometry, HS, APMT and PA. Methods that better demonstrated the real prevalence of malnourished patients before transplantation were PA (25%), AMC (21.9%) and AC (18.8%). The percentage of malnourished patients was significantly higher after 1 mo of transplantation when compared to the percentage in 6 mo and 1 year after transplantation. It was suggested that the PA could be widely used with this population, since the results are consistent, reliable and reproducible.

Wagner et al\(^{[60]}\) evaluated nutritional methods that informed the nutritional status of 71 post-transplantation patients. Patients were divided into 3 groups according to time since transplantation: 5 years, between 5 and 10 years, and over 10 years. They used the PA cutoff point as below 5 degrees in order to diagnose malnutrition. The PCM diagnosis was made in 81.2%, 31.6% and 31.7% in each group, respectively \((P = 0.008)\). In this study, the PA showed a higher prevalence of malnutrition among the population of patients in the first years after liver transplantation.
CONCLUSION

The cirrhotic patient is malnourished per se, regardless of etiology and the severity of the disease. The early characterization of the nutritional status in patients with cirrhosis means an early nutritional intervention, with a positive impact on patients’ overall prognosis. Compared to the usually accepted methods for nutritional diagnosis, the PA obtained through BIA is the only appropriate way of assessing sarcopenia. The early nutritional intervention, with a positive impact on patients’ overall prognosis. Compared to the usually accepted methods for nutritional diagnosis, the PA obtained through BIA is the only appropriate way of assessing sarcopenia.

REFERENCES

1. Carvalho L, Parise ER. Evaluation of nutritional status of nonhospitalized patients with liver cirrhosis. Arg Gastroenterol 2006; 43: 269-274 [PMID: 17406753 DOI: 10.1590/S0004-28032006000400005]

2. D’Amico G, Garcia-Tsao G, Pagliaro L. Natural history and prognostic indicators of survival in cirrhosis: a systematic review of 118 studies. J Hepatol 2006; 44: 217-231 [PMID: 16298014 DOI: 10.1016/j.jhep.2005.10.013]

3. Maharsli S, Sharma BC, Srivastava S. Malnutrition in cirrhosis increases morbidity and mortality. J Gastroenterol Hepatol 2015; 30: 1507-1513 [PMID: 25794421 DOI: 10.1111/jgh.12999]

4. Vilstrup H, Amodio P, Bajaj J, Cordoba J, Ferenci P, Mullen KD, Weissenbom K, Wong P. Hepatic encephalopathy in chronic liver disease: 2014 Practice Guideline by the American Association for the Study of Liver Diseases and the European Association for the Study of the Liver. Hepatology 2014; 60: 715-735 [PMID: 25042402 DOI: 10.1002/hep.27210]

5. Tandon P, Ney M, Irwin I, Ma MM, Gramlich L, Sawyer MB, Esfandiarz N, Sawyer MB, Knetemar N. Severe muscle depletion predicts postoperative length of stay but is not associated with survival after liver transplantation. Liver Transpl 2014; 20: 640-648 [PMID: 24768005 DOI: 10.1002/lt.23863]

6. Montano-Loza AJ, Meza-Junco J, Baracos VE, Prado CM, Ma M, Meeberg G, Beaumont C, Tandon P, Esfandiarz N, Sawyer MB, Knetemar N. Severe muscle depletion predicts postoperative length of stay but is not associated with survival after liver transplantation. Liver Transpl 2014; 20: 640-648 [PMID: 24768005 DOI: 10.1002/lt.23863]

7. Lenz K, Buder R, Kapun L, Voglmayr M. Treatment and management of ascites and hepatorenal syndrome: an update. Therap Adv Gastroenterol 2015; 8: 83-100 [PMID: 25729433 DOI: 10.1177/1758888314546763]

8. D’Amico G, Garcia-Tsao G, Pagliaro L. Natural history and prognostic indicators of survival in cirrhosis: a systematic review of 118 studies. J Hepatol 2006; 44: 217-231 [PMID: 16298014 DOI: 10.1016/j.jhep.2005.10.013]

9. Lenz K, Buder R, Kapun L, Voglmayr M. Treatment and management of ascites and hepatorenal syndrome: an update. Therap Adv Gastroenterol 2015; 8: 83-100 [PMID: 25729433 DOI: 10.1177/1758888314546763]

10. van der Schueren MA, Singer P. Diagnostic criteria for malnutrition in nonhospitalized patients with liver cirrhosis. J Hepatol 2014; 61: 269-274 [PMID: 17406753 DOI: 10.1016/j.jhep.2005.10.013]

11. Finger TE, Danilova V, Barrows J, Bartel DL, Vigers AJ, Stone L, Hellekant G, Kinnaman SC. ATP signaling is crucial for portal hypertension. Liver Int 2009; 29: 1396-1402 [PMID: 19602136 DOI: 10.1111/j.1478-3231.2009.02077.x]
communication from taste buds to gustatory nerves. Science 2005; 310: 1495-1499 [PMID: 16322458 DOI: 10.1126/science.1118435]

Plauth M, Merli M, Kondrup J, Weimann A, Ferenci P, Müller MJ. ESPEN guidelines for nutrition in liver disease and transplantation. Clin Nutr 1997; 16: 43-55 [PMID: 16844569 DOI: 10.1016/S0261-5614(97)80022-2]

Tajika M, Kato M, Mohri H, Miwa Y, Kato T, Ohashi H, Moriwaki H. Prognostic value of energy metabolism in patients with viral liver cirrhosis. Nutrition 2002; 18: 229-234 [PMID: 11882395 DOI: 10.1016/S0898-9007(01)00754-7]

Abbott WJ, Thomson A, Steadman C, Bothwell C, Kerlin P, Wall DR, Lynch SV. Child-Pugh class, nutritional indicators and early liver transplant outcomes. Hepatogastroenterology 2001; 48: 823-827 [PMID: 11462932]

Fernandes SA, Bassani L, Nunes FF, Aydos ME, Alves AV, Marroni CA. Nutritional assessment in patients with cirrhosis. Arg Gastroenterol 2012; 49: 19-27 [PMID: 22481682 DOI: 10.1590/ S0004-28032010000100005]

Detsky AS, Baker JP, Mendelson RA, Wolman SL, Wesson DE, Jeejeebhoy KN. Evaluating the accuracy of nutritional assessment techniques applied to hospitalized patients: methodology and comparisons. JPN J Parenter Enteral Nutr 1984; 8: 153-159 [PMID: 6538911 DOI: 10.1177/10148601840008002153]

Aidos MED, Fernandes SA, Nunes FF, Bassani L, Leonhardt LR, Harter DL, Pivatto B, Miranda D, Marroni CA. One-year follow-up of the nutritional status of patients undergoing liver transplantation. Nutr Hosp 2016; 33: 8-13

Figueiredo FA, Perez RM, Freitas MM, Kondo M. Comparison of three methods of nutritional assessment in liver cirrhosis: subjective global assessment, traditional nutritional parameters, and body composition analysis. J Gastroenterol 2006; 41: 476-482 [PMID: 16799890 DOI: 10.1007/s00535-006-1794-1]

Ritter L, Gazzola J. [Nutritional evaluation of the cirrhotic patient: an objective, subjective or multicompartamental approach?]. Arg Gastroenterol 2006; 43: 66-70 [DOI: 10.1590/S0004-28032006000100016]

Hasse J, Strong S, Gorman MA, Liepa G. Subjective global assessment: alternative nutrition-assessment technique for liver-transplant candidates. Nutrition 1993; 9: 339-343 [PMID: 8400590]

Nutritional status in cirrhosis. Italian Multicentre Cooperative Project on Nutrition in Liver Cirrhosis. J Hepatol 1994; 21: 317-325 [PMID: 8736699]

Álvares-da-Silva MR, Silveira TRD. Hand-grip strength or muscle mass in cirrhotic patients: who is the best? Nutrition 2006; 22: 218-219 [DOI: 10.1016/j.nut.2005.06.001]

Álvares-da-Silva MR, Gottschall CA, Pruneli RD, Pinto RD, Waechter FL, Cardoso F, Sampao JA, Smith MM, Fracincosi CFM, Pereira-Lima LM. Nutritional evaluation in liver transplantation [abstract]. Hepatology 1998; 28: 746(A)

Oliveira DR, Frangella VS. [Adductor pollicis muscle and hand grip strength: potential methods of nutritional assessment in outpatients with stroke]. Einstein (Sao Paulo) 2010; 8: 467-472 [PMID: 20766031 DOI: 10.1590/S1679-45082010AO1763]

Bragagnolo R, Caporossi FS, Dock-Nascimento DB, de Aguilar-Nascimento JE. [Adductor pollicis muscle thickness: a fast and reliable method for nutritional assessment in surgical patients]. Rev Col Bras Cir 2009; 36: 371-376 [PMID: 20069147 DOI: 10.1590/S1000-69912009000500003]

Lameu EB, Gerude MF, Corrêa RC, Lima KA. Adductor pollicis muscle: a new anthropometric parameter. Rev Hosp Clin Fac Med Sao Paulo 2004; 59: 57-62 [PMID: 15122418 DOI: 10.1590/S0041-87812004000200002]

Pereira RA, Caetano AL, Cuppuri L, Kannimura MA. Adductor pollicis muscle thickness as a predictor of handgrip strength in hemodialysis patients. J Bras Nefrol 2013; 35: 177-184 [PMID: 24100736 DOI: 10.9353/jbn.2010.2800.20130002]

Romeo FG, Augusti L. Nutritional assessment in cirrhotic patients with hepatic encephalopathy. World J Hepatol 2015; 7: 2940-2954 [PMID: 26730273 DOI: 10.4245/wjh.v7.i30.2940]

Ellis KJ. Human body composition: in vivo methods. Physiol Rev 2000; 80: 649-680 [PMID: 10747204]

Baumgartner RN, Heymsfield SB, Lichtman S, Wang J, Pierson RN. Body composition in elderly people: effect of criterion estimates on predictive equations. Am J Clin Nutr 1991; 53: 1345-1353 [PMID: 2035461]

Mátar JA. Application of total body bioimpedance to the critically ill patient. Brazilian Group for Bioimpedance Study. New Horiz 1996; 4: 493-503 [PMID: 8968982]

Pirlich M, Schütz T, Spachos T, Ertl S, Weiss ML, Lohs H, Plauth M. Bioelectrical impedance analysis is a useful bedside technique to assess malnutrition in cirrhotic patients with and without ascites. Hepatology 2000; 32: 1208-1215 [PMID: 11093726 DOI: 10.1053/jhep.2000.20524]

Norman K, Stobius N, Pirlich M, Bosy-Westphal A. Bioelectrical phase angle and impedance vector analysis--clinical relevance and applicability of impedance parameters. Clin Nutr 2012; 31: 854-861 [PMID: 22698802 DOI: 10.1016/j.clnu.2012.05.008]

Llames L, Baldemoro V, Iglesias ML, Rodota LP. [Values of the phase angle by bioelectrical impedance; nutritional status and prognostic value]. Nutr Hosp 2013; 28: 286-295 [PMID: 23822677 DOI: 10.3305/nh.2013.28.2.6306]

Selberg O. Selberg D. Norms and correlates of bioimpedance phase angle in healthy human subjects, hospitalized patients, and patients with liver cirrhosis. Eur J Appl Physiol 2002; 86: 509-516 [PMID: 11944090 DOI: 10.1007/s00421-001-0570-4]

Peres WA, Lento DF, Baluz K, Ramalho A. Phase angle as a nutritional evaluation tool in all stages of chronic liver disease. Nutr Hosp 2012; 27: 2072-2076 [PMID: 23588459 DOI: 10.3305/nh.2013.28.2.6306]

Fernandes SA, Gonzalez, MC, Assunção MC, Barros L, Miranda D, Pivatto B, Harter DL, Marroni CA. Is the phase angle, a prognostic indicator for nutritional status in cirrhotic patients? J Antivir Antiretrovir 2013; S3: 1-4 [DOI: 10.4172/jaa.S3-004]

Ruíz-Margáin A, Macias-Rodríguez RUI, Duarte-Rojo A, Rios-Torres SL, Espinosa-Cuevas A, Torre A. Malnutrition assessed through phase angle and its relation to prognosis in patients with compensated liver cirrhosis: a prospective cohort study. Dig Liver Dis 2015; 47: 309-314 [PMID: 25618555 DOI: 10.1016/j.dld.2014.12.015]

Wagner D, Adunca C, Kniepeiss D, Jakoby E, Schaffelner S, Kandlbauer M, Fahrleitner-Pammer A, Roller RE, Kornprat P, Müller H, Iberer F, Schütz T, Matzouranis KH. Serum albumin, subjectively assessed global assessment, body mass index and the bioimpedance analysis in the assessment of malnutrition in patients up to 15 years after liver transplantation. Clin Transplant 2011; 25: E396-E400 [PMID: 21457329 DOI: 10.1111/j.1399-0011.2011.01442.x]
