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Bioelectrical impedance analysis in estimating nutritional status and outcome of patients with chronic obstructive pulmonary disease and acute respiratory failure

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Abstract *Objective*: To evaluate bioelectrical impedance analysis (BIA) in estimating the nutritional status and outcome of patients with chronic obstructive pulmonary disease (COPD) and acute respiratory failure (ARF) in comparison with measurements of anthropometric parameters and plasma levels of visceral proteins
Design: Retrospective study
Setting: A ten-bed intensive care unit (ICU) in a university teaching hospital
Patients: 51 COPD patients with ARF in whom BIA data, anthropometric parameters, and measurements of visceral proteins were available
Measurements and results: BIA results in patients requiring mechanical ventilation (MV) vs. those who did not showed lower active cell mass (ACM; 37.5 ± 6.5 % vs. 42.4 ± 7.2 % body weight, $P = 0.01$) and a higher extra-/intracellular water volume ratio (ECW/ICW; 1.25 ± 0.2 vs. 1.04 ± 0.2, $P = 0.0001$), suggesting a more severe alteration in the nutritional status among those on MV. Anthropometric data showed the opposite results, since body weight, body mass index (BMI), triceps skinfold thickness (TSF), and fat mass were significantly higher in the invasively ventilated patients, whereas middle-arm muscle circumference (MAMC) did not differ between the two groups. The marked inflation of the extracellular compartment (ECW, ECW/ICW) that was well shown by BIA in the invasively ventilated patients presumably lead to inaccurate anthropometric results (overestimation of TSF and fat mass, and erroneous measure of MAMC). A higher death rate (38 % vs. 0 %, $P = 0.01$) was observed in the patients with ACM depletion (ACM ≤ 40.6 % body weight, $n = 26$) than in those without ACM depletion ($n = 25$). Low albumin level (< 30 g/l) was associated with increased mortality (33 % vs. 7 %, $P = 0.04$), but the differences in the other biological and anthropometric parameters (prealbumin and transferrin levels, body weight, BMI, TSF, MAMC, fat mass, and fat-free mass) were not associated with mortality
Conclusion: This study suggests that the decrease in BIA-derived ACM is a good indication of malnutrition and of poor outcome in COPD patients with ARF.

Key words Chronic obstructive pulmonary disease · Acute respiratory failure · Nutrition · Body composition · Bioelectrical impedance · Anthropometry

Introduction

Acute respiratory failure (ARF) in patients with chronic obstructive pulmonary disease (COPD) is a commonly encountered situation in the intensive care unit (ICU). Mortality among these patients is approx. 20% [1]. Malnutrition is associated with higher morbidity and mortality [2, 3]. Nutritional assessment based on body weight may lead to misinterpretations owing to water retention and edema, which are frequent in these patients.

Assessing body composition is therefore an important issue in the nutritional evaluation of COPD patients with ARF [4]. Densitometry, isotope dilution, and whole-body counting of potassium-40 are the reference methods for assessing body composition, but these techniques are sophisticated, costly, time-consuming, and inconvenient, and therefore they are unsuitable for clinical practice, especially in ICU patients [5, 6]. Bioelectrical impedance analysis (BIA) seems to be a very attractive method in the clinical assessment of body composition since it is noninvasive, quick, portable, inexpensive, and easy to use. Most studies have been performed with the single-frequency (50 kHz) method, which allows an estimation of the total body water (TBW) volume and of the fat-free mass (FFM) [5, 6, 7]. However, the studies comparing BIA with gold-standard methods have yielded conflicting results, especially in COPD patients [8, 9, 10, 11]. Another drawback of the single-frequency method is that it is unable to distinguish extra- from intracellular compartments. The two-frequency method utilizes a low frequency (5 kHz) at which the current flows through the extracellular water (ECW) and a high frequency (1 MHz) at which the current flows through both ECW and intracellular water (ICW) [12]. This technique can therefore be used for estimating the active cell mass (ACM): ACM = FFM–ECW. It has been shown that ACM is a main determinant of resting energy expenditure [13], and that ACM is decreased in malnourished patients [14]. The two-frequency BIA method also allows estimation of the ECW/ICW ratio, which has been shown to be proportional to the exchangeable sodium/potassium (Na/K) ratio [13]. The Na/K ratio is approx. 1 in healthy individuals and exceeds 1.25 in malnourished patients [13, 15]. The two-frequency method could be particularly useful for assessing the nutritional status of COPD patients with ARF in whom water inflation is frequently observed. However, this method has been validated in normal subjects [16, 17] but, to our knowledge, has not been used in COPD patients with ARF. The aim of this study was to evaluate the value of the two-frequency BIA method in estimating the nutritional status and the outcome of COPD patients with ARF and to compare this with measurements of anthropometric parameters and plasma levels of visceral proteins.

Patients and methods

Patients

Data for COPD patients admitted to the ICU of our department for ARF were analyzed retrospectively over 3 years (1993–1996). During this period routine nutritional assessment and evaluation of body composition were systematically carried out in every COPD patient admitted to our ICU ($n = 338$). This included anthropometric measurements, BIA, and laboratory measurements of the nutritional proteins in plasma. COPD was diagnosed according to the criteria of the American Thoracic Society [18]. Respiratory function tests were performed either prior to the acute episode or within 6 months following the acute episode. Patients were excluded from analysis when their nutritional assessment or body composition evaluation was incomplete or carried out later than the fifth day after admission. We also excluded patients with cancer, severe hepatic disease, renal failure (defined as creatinine clearance < 50 ml/min), a past history of surgery or ICU admission over the previous 6 months, and a previous inclusion in this study.

Finally, a total of 51 of 338 COPD patient files were retained for analysis. All patients underwent arterial puncture on admission for arterial blood gas analysis. A simplified acute physiological score [19] was calculated on the 24th h after admission in the ICU. Patients requiring invasive mechanical ventilatory assistance received assisted volume control ventilation via an orotracheal tube by means of a Servo 900 C ventilator (Siemens, Solna, Sweden). Indications of invasive mechanical ventilation were: signs of CO_2 narcosis or respiratory muscle fatigue and failure or contraindication to noninvasive mask ventilation. Daily alcohol intake, smoking history, and previous systemic corticosteroid treatment were systematically documented from the patient or his family.

Nutritional assessment and evaluation of body composition

Anthropometry

Skinfold thicknesses were measured by the same physician in triplicate on the nondominant side by means of Holtain caliper, with the patient lying down. The triceps skinfold thickness (TSF), biceps skinfold thickness, and middle-arm circumference (MAC) were measured midway between olecranon and acromion. The subscapular skinfold thickness was measured 2 cm below the scapula, with the patient lying in the lateral decubitus position. The suprailiac skinfold thickness was measured at the upper anterior iliac spine in the dorsal decubitus position. Fat mass (FM) was estimated from the sum of the four skinfold thicknesses using the Durnin tables [20], expressed as a percentage of body weight, calculated by Siri's equation [20]. FFM is the difference between body weight (measured using electronic device, Samery, Saint Quentin sur le Home, France) and FM. Middle-arm muscle circumference (MAMC) indicates body muscle mass and is calculated as follows: MAMC = MAC–(πTSF).

Skinfold thicknesses and MAMC are expressed as percentages of reference values according to the patient age and sex [21]. Ideal body weight (IBW) was determined according to the Metropolitan Life Insurance Company tables [22]. Body mass index (BMI) was calculated as follows: BMI = weight (kg)/height^2 (m^2).

Bioelectrical impedance analysis

We used the two-electrode, two-frequency impedance analyzer Analycor 3 (Eugédia, Chambly, France). This uses a 0.5-mA alternating current. Very thin, sterile, stainless steel electrodes were in-

Table 1 Description of the COPD patients. Arterial blood gas was sampled at admission to ICU (*MV* mechanical ventilation, *SAPS* simplified acute physiological score, *FEV_1* forced expiratory volume in 1 s, *FVC* forced vital capacity, *TLC* total lung capacity, *RV* residual volume – helium dilution method, *ARF* acute respiratory failure)

	Total Patients n = 51	Intubated Patients n = 30	Non intubated Patients n = 21	*P* Intubated vs non intubated
Age (y)	69 ± 11	72 ± 9	64 ± 12	0.01
Gender (M/F)	42/9	24/6	18/3	NS
SAPS	13 ± 5	14 ± 4	10 ± 7	NS
FEV_1 (% pred)	37 ± 16	38 ± 19	36 ± 12	NS
FVC (% pred)	74 ± 18	73 ± 17	76 ± 20	NS
FEV_1/FVC (% pred)	44 ± 15	46 ± 18	42 ± 10	NS
TLC (% pred)	101 ± 17	97 ± 18	105 ± 14	NS
RV/TLC (% pred)	127 ± 43	113 ± 44	143 ± 38	0.04
PaO_2/FiO_2 (mm Hg)	230 ± 72	207 ± 70	263 ± 62	0.004
$PaCO_2$ (mm Hg)	54 ± 12	58 ± 12	49 ± 9	0.01
pH	7.33 ± 0.09	7.30 ± 0.1	7.36 ± 0.04	0.03
Smoking (%)	67	79	50	NS
Alcohol abuse (%)	27	27	29	NS
Systemic corticosteroid treatment > 4 weeks (%)	29	30	29	NS
Cause of ARF:				
Unknown	5	3	2	NS
Pulmonary emoblism	2	0	2	NS
Left ventricular failure	2	2	0	NS
Pneumonia	7	7	0	0.01
Pneumothorax	3	0	3	NS
Bronchitis	32	18	14	NS

serted subcutaneously. The two-frequency BIA method uses a low frequency (5 kHz) and a high frequency (1 MHz). This method estimates TBW volume at high frequency and ECW volume at low frequency. The difference between TBW and ECW corresponds to ICW volume. ACM was calculated as follows: ACM = FFM–ECW.

The regression equations for calculating FFM and ECW have been validated in healthy subjects by comparison between BIA and densitometry [17] and isotopic methods [16]: FFM (kg) = $6.37 + 0.64\ BW + 0.40\ H^2/Z_1 - 0.16\ A - 2.71\ S$; ECW (kg) = $0.72 \times H^2/Z_2$, where BW = body weight (kg); H = height (cm); A = age (years); S = sex (1 for men, 2 for women); Z_1 = impedance (ohms) measured at 1 Mhz; and Z_2 = impedance measured at 5 kHz. FM was calculated as follows: FM = body weight–FFM. The patients had been lying in the supine position for at least 2 h before beginning the measurements.

Visceral proteins

Plasma albumin (half-life 20 days), transferrin (half-life 8 days), and prealbumin (transthyretin, half-life 48 h) were measured before the fifth day following ICU admission. Albumin was measured by spectrophotometry, and transferrin and prealbumin by nephelometry. The normal ranges of our biochemistry laboratory are as follows: albumin: 35–50 g/l, transferrin: 2–3.5 g/l, prealbumin: 200–400 mg/l.

Statistical analysis

The series was divided in two groups according to the need for invasive mechanical ventilation. The common criteria of malnutrition were: weight < 90 % IBW, BMI < 20 kg/m^2, TSF < 80 % pred., MAMC < 80 % pred., anthropometric FFM < 63 % IBW (women) or < 67 % IBW (men), albumin < 30 g/l, prealbumin < 200 mg/l, and transferrin < 2 g/l [26]. For the cutoff value we took the median of the ACM/body weight (ACM/BW) ratio in the 51 patients (i. e., 40.6 %). The BIA criteria of malnutrition were arbitrarily defined as ACM/BW ≤ 40.6 and ECW/ICW ratio ≥ 1.25. The results are expressed as means ± standard deviations. The statistics were calculated using StatView 4.5 software (Abacus Concepts, Berkeley, Calif., USA). Analysis of variance was used to compare quantitative variables. Bonferroni-Dunn corrections were made for statistically significant differences. The χ^2 test as corrected by Yates was used to compare categorical variables. A difference was considered statistically significant when the *P* value was lower than 0.05. Linear regression analysis was used to determine the correlation between ECW/ICW and ACM/BW, on the one hand, and plasma levels of albumin and prealbumin, on the other.

Results

Characteristics of the patients

Table 1 summarizes the general characteristics of the patients, especially lung function tests and arterial blood

Table 2 Nutritional parameters in COPD patients with acute respiratory failure (MV mechanical ventilation, *IBW* ideal body weight, *BMI* body mass index, *TSF* triceps skinfold thickness, *MAMC* middle-arm muscle circumference, *FM* fat mass, *FFM* fat-free mass, *ACM* bioelectrically calculated active cell mass, *TBW* bioelectrically estimated total body water, *ECW* bioelectrically estimated extracellular water volume, *ICW* bioelectrically estimated intracellular water volume)

	Total Patients n = 51	Intubated Patients n = 30	Non Intubated Patients n = 21	*P* Intubated vs Non Intubated
Weight (kg)	61 ± 14	64 ± 14	57 ± 14	NS
Weight (% IBW)	96 ± 20	100 ± 19	89 ± 20	0.04
BMI (kg/m^2)	22 ± 5	23 ± 4	20 ± 4	0.01
TSF (% pred)	98 ± 54	116 ± 54	72 ± 43	0.03
MAMC (% pred)	76 ± 12	77 ± 12	75 ± 12	NS
FM (kg, anthropometry)	15.3 ± 7.8	17.2 ± 7.3	12.8 ± 7.8	0.04
FFM (kg, anthropometry)	45.6 ± 9.3	47 ± 9.6	43.5 ± 8.8	NS
TBW (kg, impedance)	37.6 ± 10.7	41.3 ± 10.3	32.4 ± 8.4	0.02
ECW (kg, impedance)	20.3 ± 6.6	22.8 ± 6.1	16.6 ± 5.6	0.006
ICW (kg, impedance)	17.3 ± 4.2	18.4 ± 4.6	15.8 ± 3.1	0.02
FM (kg, impedance)	16.5 ± 6.7	17.3 ± 6.8	15.2 ± 6.6	NS
FFM (kg, impedance)	44.6 ± 10.6	47.2 ± 10.1	41 ± 10.4	0.04
ACM/Weight (%)	39.5 ± 7.2	37.5 ± 6.5	42.4 ± 7.2	0.01
ECW/ICW (impedance)	1.16 ± 0.2	1.25 ± 0.2	1.04 ± 0.2	0.0001
Albumin (g/L)	30 ± 8	27 ± 8	36 ± 7	0.0002
Prealbumin (mg/L)	184 ± 108	160 ± 93	219 ± 104	0.03
Transferrin (g/L)	2.1 ± 0.8	1.9 ± 0.8	2.3 ± 0.6	NS

gases data in the intubated and the nonintubated patients.

Nutritional parameters

The results of anthropometry, BIA, and measurements of plasma levels of visceral proteins are summarized in Table 2. Nutritional parameters are given for the overall study group and separately for the intubated and nonintubated patients. Weight (% IBW), BMI, TSF, and anthropometry FM were significantly higher in intubated than in nonintubated patients. MAMC and anthropometric FFM did not differ significantly between the two groups.

BIA data showed significantly higher TBW, FFM, ECW, and ICW values in intubated than in nonintubated patients. The BIA FM did not differ between the two groups. Intubated patients showed a significantly lower ACM/BW ratio (37.5 ± 6.5 % vs. 42.4 ± 7.2 %, $P = 0.01$) and a significantly higher ECW/ICW ratio (1.25 ± 0.2 vs. 1.04 ± 0.2, $P = 0.0001$) than nonintubated patients. Plasma levels of albumin and prealbumin were significantly lower in intubated than in nonintubated patients. Plasma transferrin levels did not significantly differ between the two groups.

The results of BIA, anthropometry, and visceral proteins measurements did not significantly differ between the patients who had received systemic corticosteroid treatment for at least 4 weeks in the previous 6 months ($n = 15$) and those who had not ($n = 36$).

Comparison between the commonly used malnutrition criteria and bioelectrical criteria defining malnutrition

ACM/BW and ECW/ICW ratios showed no significant differences between patients with anthropometric criteria of malnutrition and those who did not (Table 3). The patients with low levels of plasma albumin (< 30 g/l) or prealbumin (< 200 mg/l) had a significantly lower ACM/BW ratio and significantly higher ECW/ICW ratio than those with normal levels. We found no significant difference in ACM/BW or ECW/ICW ratio between patients with low plasma transferrin levels and those with normal levels. Significant correlations were found between ACM/BW ratio and plasma albumin level ($r = 0.38$, $P = 0.005$), ECW/ICW ratio and plasma albumin level ($r = 0.43$, $P = 0.001$), ACM/BW ratio and plasma prealbumin level ($r = 0.32$, $P = 0.01$), and ECW/ICW ratio and plasma prealbumin level ($r = 0.27$, $P = 0.04$).

ICU mortality according to presence or absence of malnutrition criteria

Low values of weight (% IBW), BMI, TSF, and anthropometric FFM were not associated with increased ICU mortality (Table 4). Paradoxically, higher ICU mortality was observed in patients with normal MAMC than in those with low MAMC. ICU mortality was significantly higher in patients with low plasma albumin level (< 30 g/l) but did not significantly differ between those with low or normal levels of plasma prealbumin or transferrin. Lower ACM/BW ratios (≤ 40.6 %) was as-

Table 3 Comparison between commonly used malnutrition criteria and bioelectrical impedance criteria defining malnutrition (*IBW* ideal body weight, *BMI* body mass index, *TSF* triceps skinfold thickness, *MAMC* middle-arm muscle circumference, *ACM* bioelectrically calculated active cell mass, *ECW* bioelectrically estimated extracellular water volume, *ICW* bioelectrically estimated intracellular water volume, *FFMA* anthropometric calculated fat-free mass – Durnin's method, *M* male, *F* female)

	n	ACM/Weight (%)	*p*	ECW/ICW	*p*
Weight < 90% IBW	24	38 ± 7.5	NS	1.14 ± 0.2	NS
Weight ≥ 90% IBW	27	41 ± 6.8		1.18 ± 0.2	
BMI < 20 kg/m^2	17	38.3 ± 7.8	NS	1.10 ± 0.2	NS
BMI ≥ 20 kg/m^2	34	40.1 ± 6.9		1.19 ± 0.2	
TSF < 80% pred	23	38.3 ± 8.8	NS	1.12 ± 0.2	NS
TSF ≥ 80% pred	28	40.5 ± 5.5		1.19 ± 0.2	
MAMC < 80% pred	34	40.5 ± 6.7	NS	1.16 ± 0.2	NS
MAMC ≥ 80% pred	17	37.5 ± 7.9		1.15 ± 0.2	
FFMA < 63 (F) 67 (M) % IBW	19	37.1 ± 7.3	NS	1.16 ± 0.2	NS
FFMA ≥ 63 (F) 67 (M) % IBW	32	40.9 ± 6.8		1.16 ± 0.2	
Albumin < 30 g/L	24	37.1 ± 7.2	0.02	1.25 ± 0.2	0.001
Albumin ≥ 30 g/L	27	41.6 ± 6.6		1.08 ± 0.2	
Prealbumin < 200 mg/L	28	37.3 ± 6.5	0.01	1.21 ± 0.2	0.02
Prealbumin ≥ 200 mg/L	23	42.2 ± 7.1		1.09 ± 0.2	
Transferrin < 2 g/L	22	37.8 ± 7.4	NS	1.20 ± 0.2	NS
Transferrin ≥ 2 g/L	29	40.8 ± 6.6		1.13 ± 0.2	

Table 4 ICU patient death according to presence or absence of malnutrition criteria (*IBW* ideal body weight, *BMI* body mass index, *TSF* triceps skinfold thickness, *MAMC* middle-arm muscle circumference, *ACM* bioelectrically calculated active cell mass, *ECW* bioelectrically estimated extracellular water volume, *ICW* bioelectrically estimated intracellular water volume, *FFMA* anthropometric calculated fat-free mass – Durnin's method, *M* male, *F* female)

	n	ICU Death (%)	*P*
Weight < 90% IBW	24	21	NS
Weight ≥ 90% IBW	27	19	
BMI < 20 kg/m^2	17	12	NS
BMI ≥ 20 kg/m^2	34	23	
TSF < 80% pred	23	22	NS
TSF ≥ 80% pred	28	18	
MAMC < 80% pred	34	9	0.01
MAMC ≥ 80% pred	17	41	
FFMA < 63 (F) 67 (M) % IBW	19	16	NS
FFMA ≥ 63 (F) 67 (M) % IBW	32	22	
Albumin < 30 g/L	24	33	0.04
Albumin ≥ 30 g/L	27	7	
Prealbumin < 200 mg/L	28	28	NS
Prealbumin ≥ 200 mg/L	23	9	
Transferrin < 2 g/L	22	32	NS
Transferrin ≥ 2 g/L	29	10	
ACM ≤ 40.6% Weight	26	38	0.01
ACM > 40.6% Weight	25	0	
ECW/ICW ≥ 1.25	16	37	NS
ECW/ICW < 1.25	35	11	

sociated with significantly higher ICU mortality. Patients with an increased ECW/ICW ratio tended to have higher mortality, but the difference was not statistically significant.

Nutritional characteristics and outcome of patients according to their ACM

Patients with a ACM/BW ratio of 40.6% or lower compared with those with ACM/BW higher than 40.6% were older and demonstrated significantly higher ECW/ICW ratio and need for invasive mechanical ventilation, and significantly lower plasma albumin and prealbumin

Table 5 Nutritional characteristics and outcome of patients according to their ACM (*SAPS* simplified acute physiological score, *FEV_1* forced expiratory volume in 1 s, *BW* body weight, *IBW* ideal body weight, *BMI* body mass index, *TSF* triceps skinfold thickness, *MAMC*: middle-arm muscle circumference, *FM* fat mass, *FFM* fat-free mass, *ACM* bioelectrically calculated active cell mass, *ECW* bioelectrically estimated extracellular water volume, *ICW* bioelectrically estimated intracellular water volume)

	ACM ≤ 40.6 % BW n = 26	ACM > 40.6 % BW n = 25	*P*
SAPS	14 ± 5	11 ± 5	NS
Age (y)	74 ± 8	63 ± 11	0.0003
Invasive ventilation (%)	81	36	0.003
FEV_1 (% pred)	39 ± 19	36 ± 14	NS
Body weight (kg)	59 ± 16	63 ± 13	NS
Weight (% IBW)	94 ± 20	97 ± 20	NS
BMI (kg/m^2)	22 ± 5	22 ± 5	NS
TSF (% pred)	95 ± 51	102 ± 57	NS
MAMC (% pred)	79 ± 13	73 ± 10	NS
FM (kg, anthropometry)	14.5 ± 7	16 ± 8.4	NS
FFM (kg, anthropometry)	44.7 ± 10.7	46.5 ± 7.7	NS
FM (kg, impedance)	16.3 ± 7	16.6 ± 6.6	NS
FFM (kg, impedance)	43.2 ± 12	46.1 ± 9	NS
ICW (kg, impedance)	17.8 ± 4.8	16.8 ± 3.5	NS
ECW/ICW (impedance)	1.27 ± 0.2	1.04 ± 0.1	< 0.0001
Albumin (g/L)	27 ± 8	34 ± 7	0.01
Prealbumin (mg/L)	146 ± 87	224 ± 100	0.004
Transferrin (g/L)	1.9 ± 0.9	2.2 ± 0.6	NS

levels (Table 5). No significant difference was found between the patients with lower vs. higher ACM/BW regarding anthropometric parameters (body weight, BMI, TSF, MAMC, FM, and FFM), BIA-estimated FFM and FM, plasma transferrin level, simplified acute physiological score, or forced expiratory volume in 1 s.

Discussion

The results of this study suggest that BIA using the two-electrode, two-frequency method is an appropriate technique for assessing nutritional status and prognosis in COPD patients with ARF. The decrease in BIA-derived ACM seems to be a good indicator of malnutrition and poor outcome in these patients.

Malnutrition is frequent in COPD patients, especially during acute exacerbations requiring mechanical ventilation [23, 24]. Malnutrition results from an imbalance between increased resting energy expenditure and insufficient energy supply [25]. Malnutrition is usually defined in COPD patients by body weight loss. However, the use of body weight as the only criterion of malnutrition may lead to underestimating the prevalence and severity of malnutrition. A decreased BIA-measured FFM is observed in 10 % of stable COPD patients, without an associated body weight loss [26]. This emphasizes the importance of assessing body composition in COPD patients, in whom water retention is frequent, especially during ARF.

FM, FFM, and muscle mass can be estimated at bedside by measuring TSF and MAMC. This anthropometric method, which has been validated in normal subjects [20], has not previously been compared with gold-standard techniques in COPD patients with acute exacerbation. Our study shows that anthropometry yields paradoxical results: the FM was higher in intubated patients (in whom more severe alterations in the nutritional status are expected) than in patients not requiring mechanical ventilation. Also, MAMC , which is a theoretical indicator of muscle mass, did not differ between intubated and nonintubated patient groups. Water retention and edema distort anthropometric measurements and result in an overestimate of TSF and FM, and an erroneous calculation of MAMC. On the other hand, BIA demonstrated a more severe alteration in the nutritional status in ventilated vs. nonventilated patients, since the ACM was lower in ventilated patients, which likely indicates a more marked decrease in muscle mass. BIA also revealed higher values of total extracellular and intracellular water volumes in the mechanically ventilated patients, which explains why malnutrition could be present despite a normal weight.

Decreased ACM has an important prognostic value as it is associated with higher mortality. The anthropometric parameters had no effect on mortality. Connors et al. [2] found that BMI was negatively correlated with long-term survival following an acute exacerbation in COPD patients, but their study did not note whether the patients were weighed soon after admission to ICU or only later, which may have an effect on water retention.

We found that decreased plasma albumin levels are associated with higher ICU mortality. Several studies have shown that a low plasma albumin level is a factor of poor outcome in COPD patients with ARF [1, 2]. However, it is well known that albumin is not an indicator of the nutritional status in critically ill patients who have an inflammatory response and leaky capillaries [4]. In COPD patients with ARF in whom bronchitis and pneumonia are the main causes of the exacerbation it is likely that a reduced albumin level essentially reflects the severity of the inflammatory response [27]. As the plasma concentration of C-reactive protein was not measured in our study, the correlation between albumin and systemic inflammation could not be determined.

Our study has several limitations. We arbitrarily chose a cutoff value of 40.6 % for the ACM/BW ratio. Prospective studies are needed to define a threshold value for ACM/BW as a malnutrition index and/or as a prognostic criterion. The two-electrode two-frequency BIA technique should be compared with reference methods for estimating body compartments, but these methods cannot be easily performed in ICU patients. It is unknown how the BIA equations that we used for estimating the ACM are affected by the acute inflammatory process. The inflammatory response may play a role in the loss of ACM [28]. Further studies are therefore necessary to confirm the value of BIA-derived ACM as a nutritional and prognostic index in COPD patients with acute exacerbation and to evaluate the role of the inflammatory status on ACM.

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