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Energy expenditure in mechanical ventilation: is there an agreement between the Ireton-Jones equation and indirect calorimetry?

Gasto energético em ventilação mecânica: existe concordância entre a equação de Ireton-Jones e a calorimetria indireta?

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Statement of Conflict of Interest
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ABSTRACT

Objective: Assess the agreement between the energy expenditure measured by indirect calorimetry and that estimated by the Ireton-Jones formula of critically ill patients under assisted mechanical ventilation.

Methods: Participated in the study individuals able to interrupt ventilation support, admitted at the center of intensive care of the Hospital de Clínicas de Porto Alegre – RS, between August 2006 and January 2007. Energy expenditure was measured by indirect calorimetry using a specific monitor, as well as estimated by the Ireton-Jones formula. Values found were analyzed using the Student's t test and the Bland and Altman method and expressed in mean, ± standard deviation with a significance level of $p<0.05$.

Results: The study included forty patients with a mean age of 56±16 years and APACHE II score of 23±8. Energy expenditure measured by indirect calorimetry was of 1558±304kcal/24h, while that estimated by Ireton-Jones was of 1689±246kcal/24h. There was a significant statistical difference between means of energy expenditure measured and estimated of the same individual ($p<0.004$)**.** The agreement thresholds between indirect calorimetry and the Ireton-Jones equation were of – 680.51 to 417.81 kcal.

Conclusion: Energy expenditure estimated by the Ireton-Jones formula did not present good agreement with that measured by indirect calorimetry, however, considering aspects related to availability of the equipment, this equation may be useful in the nutritional planning for critically ill patients

Keywords: Calorimetry, indirect; Predictive value of tests; Energy metabolism; Respiration, artificial

INTRODUCTION

Estimate of energy requirements is an integral part of the nutritional care of critically ill patients and to determine the exact number of calories is one of the major difficulties in clinical practice. Acute disease and treatment modify the metabolism of critically ill patients increasing or reducing their energy expenditure.[1] Inaccuracy of the theoretical equations, widely used to estimate the energy requirements of individuals, is even more important for severe patients. They are liable to evolve towards a syndrome of multiple organ and systems dysfunction and a deterioration of the nutritional status, due to persistence of a hypermetabolic condition. Therefore, these equations may be suitable for patients with normal metabolic values, but probably are not reliable indicators for critically ill patients under mechanical ventilation.[2,3]

One alternative to reduce risks of an erroneous estimate of energy expenditure in critically ill patients is indirect calorimetry (IC). It is considered to be safe, non-invasive, precise and almost free of complications and classified as a reference method for determination of energy expenditure.[4]

Brandi et al. observed that IC may be used to estimate energy expended in patients who do not properly respond to estimated nutritional requirements, who have single failure or multiple organ and system dysfunction. It is used to assess the effects of nutritional therapy in patients with respiratory failure under mechanical ventilation and to monitor oxygen consumption (VO_2) during weaning from mechanical ventilation,[5] as well as to control energy expenditure during hypermetabolic response.[6] However it is known that Brazilian hospitals do not routinely use this method to assess patients, because the equipment is expensive and requires specialized workers for adequate handling.

As previously mentioned, a very practical and less expensive method to estimate energy expenditure comprises mathematical formulas. Currently, various equations are being studied, one of them is the Ireton-Jones (IJ).[7] Although it has been devised for critically ill patients, authors have shown that the IJ formula, as well as that of Harris Benedict, still intensely used by nutritional therapy profession may also present errors in relation to the estimate of energy expenditure.[3]

Energy requirements are affected by various factors not included in the predicting equations, such as infection, sepsis, cardiac surgery, metabolic and nutritional status, sedation and analgesia, ventilation mode and others. [8] Equations that include more variables may provide a more precise result in the determination of energy expenditure.[9]

The population must be studied and, in view of the reality experienced in underdeveloped countries, to choose low priced, easy to use methods allowing professionals to reach an approximate estimate of the energy expenditure of critically ill patients to administer nutritional treatment without worsening the pathological setting. As such, this work intended to assess the agreement between energy expenditure measured by IC and that estimated by the IJ equations in patients under assisted mechanical ventilation.

METHODS

This prospective observational study comprised 40 adult patients of both genders in the intensive care unit (ICU) of the Hospital de Clínicas de Porto Alegre, under assisted mechanical ventilation with pressure support (PSV), with an indication for weaning from ventilation support.

Pregnant women, patients with axillary temperature > 38°, hemodynamic instability, renal failure, fraction of inspired Oxygen (FiO_2) ≥ 0.6, alteration in sensory perceptual, agitation, sudoresis or tachycardia were excluded.[10]

The project of the current study was submitted and approved by the Research Ethics Committee of PUCRS and of HCPA. Participation was limited to patients or family members who signed the free and informed consent. They received a copy of the document, at the time of data collection at the origin survey.

Data collection

For data collection regarding indirect calorimetry, a Datex Ohmeda S/5 – Compact Airway Module MCAIOVX®, Finland monitor was used. The iCollect software was used to collect data measured by the monitor and store the means of the values obtained minute by minute for later computer analysis.

Patients under assisted mechanical ventilation in the PSV mode were kept with the head support at 45° at rest for 30 minutes. Patient temperature was taken and the endotracheal or tracheotomy tube was aspired for 5 minutes prior to data collection. Energy expenditure was measured for 30 minutes and the first 10 minutes were discarded for analysis. In the basal period, patients were under mechanical ventilation (Servo 300 and Servo 900C; Siemens-Elema, Solna, Sweden), with pressure support (PS) ranging from 10 to 15 cmH_2O. During assessment, patients were ventilated with a 10 cmH_2O PS, 5 cmH_2O positive end expiratory pressure, sensitivity of -1cmH_2O and 0.4 fraction of inspired Oxygen (FiO_2). Collection was interrupted in cases of intense coughing, incoercible vomiting, instability of vital signs (heart rate ≥ 110bpm, respiratory rate ≥ 30rpm or Spo_2 ≤ 90%) or hemodynamic instability (systolic arterial pressure ≤ 90mmHg), alteration in sensory perceptual, cardiac arrhythmia, respiratory or cardiac arrest.[10]

Data on dry weight and height were obtained from the patient's medical chart and nutritional assessment card. Patients were weighed on a digital scale when they were assessed in the emergency or with a bed-scale when weighed in the ICU.[11,12] Height was measured, based on the recumbent stature in which the individual is placed in supine position with the bed completely horizontal, from the extremity of the head to the base of the foot, on the right side of the body[13] or on the stadiometer when previously assessed at the unit of origin.

Energy expenditure was estimated by the improved Ireton-Jones equation,[7] according to chart 1.

Chart 1 – Reviewed Ireton-Jones equation to determine energy expenditure of critically ill patients

Energy expenditure (EE) = 1784 – 11 x age (years) + 5 x weight(kg) + 244 x gender+ 239 x trauma + 804 x burns

Variables: male gender = 1; female gender = 0; existing trauma = 1; no trauma = 0 existing burns = 1; no burns = 0.

The body mass index (BMI) was estimated based on the weight/height formula[2] and classified according to values of the World Health Organization (WHO), 1999.[14] Results obtained were recorded on a data collection card. All patients were submitted to the same procedure.[3,12]

Data analysis

Data were expressed in mean ± standard deviation, with a significance level of $p<0.05$. Differences between values found for energy expenditure measured by indirect calorimetry and estimated by the predictive Ireton-Jones formula were calculated using the Student's t test for paired samples.

The Bland and Altman method was used to assess agreement between the two techniques (confidence interval of 95%).[15] For statistical analysis of the data, the program Statistical Package for Social Science (SPSS) 15.0 was used.

RESULTS

Forty patients were included in the study with mean age of 56±16 years and mean value of the APACHE II score of 23±8. Clinical characteristics of patients are shown on table 1.

Table 1 – Sample characteristics

Variables	Total (N=40)
Age(years)	55.5 ± 15.9
Gender (male/female)	28 (70) / 12 (30)
Axillary temperature (ºC)	36.8 ± 0.6
Weight (kg)	68.9 ± 13.1
Height (cm)	167.2 ± 9.1
BMI kg/m²	24.7 ± 5.2
APACHE II	23.1 ± 8.0
Total MV time (days)	9 (2 – 12)
Reason for MV	
Septic shock	6 (15)
Depression of sensory perceptual	6 (15)
Anesthetic coma	5 (12.5)
Decompensated COPD	5 (12.5)
CAP	4 (10)
Others*	14 (35)
ICU stay (days)	9 (2 – 13)
Death	4 (10)
Nutritional Support	
Enteral nutrition	35 (87.5)
Without nutritional support	4 (10)
TPN	1 (2.5)

BMI – body mass index; APACHE – Acute Physiologic and Chronic Heatlh Evaluation; MV – mechanical ventilation ;COPD – Chronic obstructive pulmonary disease; CAP – Community acquired pneumonia; ICU – intensive care unit; TPN- total parenteral nutrition. *Others – muscle weakness, acute lung edema, cardiorespiratory arrest; carbon dioxide narcosis, tuberculosis, epileptic condition, convulsions. Values expressed in N(%), mean± standard deviation or median (25-75 interquartile amplitude).

Regarding the nutritional status assessed by BMI, most individuals (50%) were classified as eutrophic, 6% as low weight, 20% pre-obese, 10% obese class I, 2.5% obese class II and 2.5% obese class III according to the World Health Organization. A high prevalence of overweight and obesity patients was observed, totaling 35%.

The mean of energy expenditure measured by IC was 1558 ± 304kcal/24h and mean estimated by the IJ formula was 1911±246 kcal/24h ($p<0.004$). The values obtained by IC and IJ for the 40 individuals may be seen on figure 1. It is also possible to note that energy expenditure calculated by the IJ formula overestimated that measured by IC. It was observed that mean of the differences between IC and IJ was of -353.83Kcal, ranging between -904.77Kcal and 197.11Kcal. Values disclose that, there is a significant difference between the energy expenditure measured and estimated for the same individual.

When data were analyzed by the Bland and Altman method (Figure 2), it was found that the mean difference between individual results obtained in the measurement made with IC and that calculated by the IJ formula (central line) was significant, with most scores somewhat scattered in the space between the

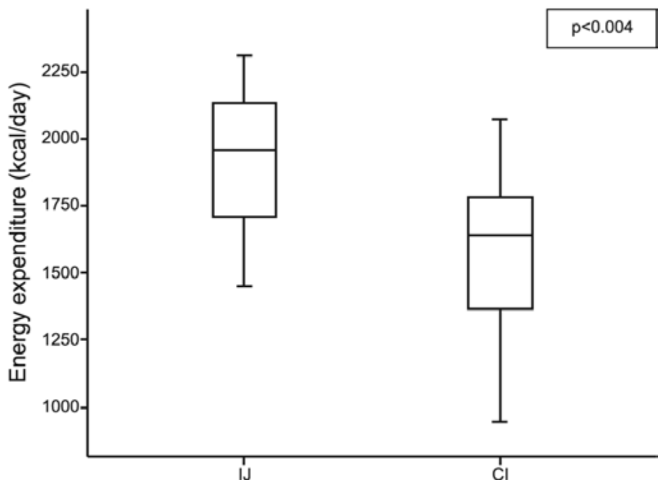

Figure 1 – Energy expenditure measured by indirect calorimetry and estimated by the Ireton-Jones equation.

Values expressed in mean and standard deviation; IJ - Ireton Jones; IC - indirect calorimetry

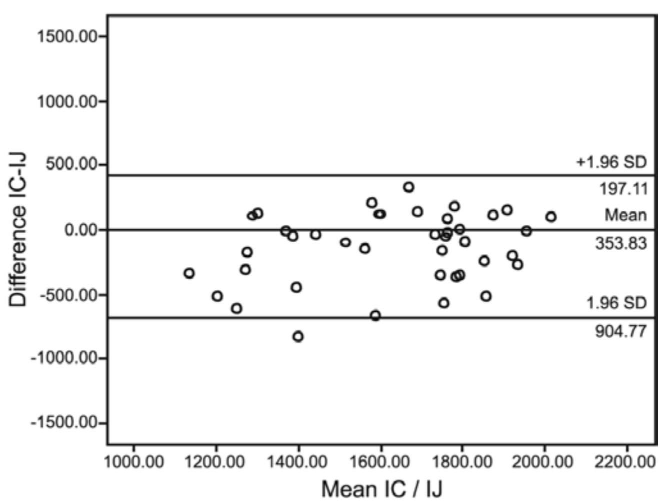

Figure 2 – Bland and Altman graph representing the difference of energy expenditure estimated by the Ireton-Jones equation and measured by indirect calorimetry versus the mean.

The solid line represents the mean between the energy expenditure measured and estimated (-353.83Kcal) and the dotted lines represent the thresholds of agreement (±1.96 standard deviations) between measured and estimated energy expenditure (variation from -904.77Kcal to 197.11Kcal).

recommended thresholds of agreement (upper and lower lines). Therefore, it was possible to verify that there was no good agreement between the values obtained in the two tests.

When assessing the patients in relation to age bracket and gender the lowest coefficient of variation of IC values was for women more than 60 years of age (1418±37.5kcal/day). The group comprised of men over 60 years of age presented the highest coefficient of variation of measured energy expenditure (1467±429kcal/day). All groups, adult and aged men and adult and aged women showed discrepant values for energy expenditure estimated by the IJ and measured by IC, while adult men presented a greater difference between means (160.6) in the two methods. These data suggest that variation of values found by IC and by IJ, although more pronounced in the group of adult men, are independent of gender or age bracket of the assessed individual.

DISCUSSION

Energy expenditure calculated by the Ireton-Jones formula did not present good agreement with that measured by indirect calorimetry. However, as the calorimeter is very expensive equipment, not available in the majority of services, the equation permits an estimate of the nutritional requirements of critically ill patients.

Cheng et al.[3] analyzed five equations in 46 patients under mechanical ventilation, and results disclosed that energy expenditure may be estimated in the majority of critically ill patients using the Harris-Benedict, Kleiber and Liu formulas, as long as a factor of injury is used. Faisy et al.,[16] in the following year, compared energy expenditure measured by IC and estimated by the Harris-Benedict equation observing a 25% higher expenditure in IC, however when using a correlation factor for injury this difference was not statistically significant. These findings were shown in another study of that same year.[17]

Results found in this work show that there is a significant difference between energy expenditure measured and that calculated for the same individual. According to Boullata et al.[18] equations that estimate the metabolic rate of hospitalized patients have an error of more than 10% in 1/3 of cases.

This discrepancy in results may be due to biases such as for instance obtaining of patients' anthropometric data. Weight, according to a pre-established methodology, was not mandatorily measured on the same day or week that IC was performed. The critically ill patient is very unstable, generally in a catabolic state and therefore is inclined to rapid body weight alterations. Alterations in body composition including water content or metabolically active quantity of mass or simply difficulty to assess the body weight of critically ill patients bring about new uncertainties in estimates based on anthropometric characteristics.[6]

Furthermore, accuracy of the equations used to estimate energy expenditure in critically ill patients is often compared with short measurement periods of IC which frequently do not represent the total energy expenditure of these patients.[19]

Another important factor that may interfere in the difference found between values of energy expenditure reached by IC and IJ was the difference between clinical conditions and diagnosis of patients, in addition to the large age variation between study participants. If the group were comprised by people of the same age bracket perhaps the values found would be more homogeneous. Furthermore, it is noteworthy that if a greater number of patients were assessed, results of this study might also be modified.

In a study with 50 critically ill patients, Dvir et al.[20] found a mean value of 1512 kcal/24h by IC. Results were compared and confirmed with another assessment method, the Bedside (a system of computerized information), showing the efficacy of calorimetry to measure energy expenditure. These results corroborate findings of our survey, whose estimate of caloric expenditure among patients, were similar.

Regarding obese individuals, although metabolic response to injury was not specifically investigated, it is suspected that effects would be similar to those observed in non obese patients.[7] There is still no definition about the best method to measure energy metabolism of diseased obese patients, mainly those with a BMI over 40kg/m^2.[21] In a study of critically ill patients with a BMI under 25kg/m^2 and between 25 and 30 kg/m^2 receiving enteral and/or parenteral nutrition and under mechanical ventilation, energy requirements were underestimated by IJ.[22] The undernourished patient also presents a similar behavior: a meta analysis about undernourished critically ill patients in the ICU, showed that values based upon IJ, although not significantly different (p>0.05) to the energy expenditure found by means of the reference standard, tended to overestimate energy requirements of the individuals in question.[23] However, these studies were carried out with small samples and in populations with peculiar characteristics. Furthermore, causes of admission to the ICU were uniformly assessed, a fact that may bias results.

Attention to the energy requirements must be among the first care to the patient in a severe condition, as metabolic alterations caused by acute disease make nutritional assessment a difficult clinical practice.[2]

Benefits of adequate nutritional intake for recovery of disease and control of chronic conditions have been well documented.[21] Greater use of indirect calorimetry may be considered the best method to establish nutritional requirements. It would simplify care of patients, allowing for better results in the treatment, since energy requirements are not always equal to required needs. Required needs must be established considering the clinical condition of the patient, nutritional status and tolerance of nutrients that will be offered in the diet.[8]

CONCLUSION

Routine use of indirect calorimetry to orient adequate caloric intake in these patients seems to be the best technique for assessment of the true energy expenditure, notwithstanding technical limitations such as the need of trained personnel with available time, need of a $FiO_2 < 0.6$ and high cost of the equipment. Considering that indirect calorimetry is not a routine in the intensive care units, predictive formulas, although with some discrepancies, may support nutritional planning of critically ill patents.

We suggest that studies with larger and more homogeneous populations, more extended time of register and control of caloric intake be carried out to achieve more consistent results.

RESUMO

Objetivo: Avaliar a concordância entre o gasto energético mensurado pela calorimetria indireta e o estimado pela fórmula de *Ireton-Jones* de pacientes críticos em ventilação mecânica assistida.

Métodos: Participaram do estudo indivíduos aptos a interromper o suporte ventilatório, internados entre agosto de 2006 e janeiro de 2007, no centro de terapia intensiva do Hospital de Clínicas de Porto Alegre – RS. O gasto energético foi mensurado pela calorimetria indireta usando monitor específico, assim como calculado pela fórmula de *Ireton-Jones. O*s valores encontrados foram analisados por meio do teste t de *Student* e pelo método de *Bland and Altman*, e expressos pela média ± desvio padrão, com nível de significância p<0,05.

Resultados: Foram incluídos no estudo quarenta pacientes, com idade média de 56±16 anos e índice APACHE II 23±8. O gasto energético mensurado pela calorimetria indireta foi de 1558±304kcal/24h, enquanto o estimado por *Ireton-Jones* foi de 1689±246kcal/24h. Houve diferença estatisticamente significativa entre as médias do gasto energético mensurado e estimado para o mesmo indivíduo (p<0,004). Os limites de concordância entre a calorimetria indireta e a equação de *Ireton-Jones* foram de –680,51 a 417,81 kcal.

Conclusão: O gasto energético estimado pela fórmula de *Ireton-Jones* não apresentou boa concordância com o medido pela calorimetria indireta, entretanto, considerando aspectos relacionados à disponibilidade do aparelho, esta equação pode auxiliar no planejamento nutricional dos pacientes críticos.

Descritores: Calorimetria indireta; Valor preditivo dos testes; Metabolismo energético; Respiração artificial

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