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Original article

Mid upper arm circumference and Powell-Tuck and Hennessy's equation correlate with body mass index and can be used sequentially in gastrostomy fed patients

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SUMMARY

Background & aims: Body Mass Index (BMI) is a simple and widespread method to assess undernutrition. However its use may be limited in bedridden patients. Aims:1) compare BMI, Mid Upper Arm Circumference (MUAC) and Powell-Tuck and Hennessy's regression equation for BMI (BMIPTH) in gastrostomy fed patients, 2) validate its correlation for sequential use and 3) select the best cut-off of MUAC and BMIPTH to predict risk of undernutrition.

Methods: Prospective study including adult patients who underwent endoscopic gastrostomy (PEG). BMI, MUAC and BMIPTH adjusted for sex and age were determined at the day of gastrostomy (0), first (1) and third (3) months of follow up. Correlations between BMI and MUAC and BMIPTH were calculated at all time-points using Spearman's test. MUAC's Area Under ROC (AUROC) to predict risk of undernutrition (BMI $\leq$ 18,5 kg/m^2 in non-elderly (<65 years) and BMI $\leq$ 22,5 kg/m^2 in elderly ($\geq$65 years)) was calculated with DeLong method and Youden Index was used to select the best cut-off for this outcome.

Results: 405 PEG patients were included (69,9% males, median age 62,9 $\pm$ 15,3 years). Head and neck cancer and neurological disorders were the main indications for gastrostomy. BMI correlated moderately with BMIPTH0 (ρ = 0.646–0.694), MUAC0 (ρ = 0.669) and MUAC1 (ρ = 0.699). BMI correlated strongly with BMIPTH1 (ρ = 0.764–0.794), BMIPTH3 (ρ = 0.714–0.732) and MUAC3 (ρ = 0.725). MUAC and BMIPTH's accuracy was not significantly different to predict undernutrition neither in elderly (AUROC 0.835 $\pm$ 0.033 Vs. 0.836 $\pm$ 0.033 respectively, p = 0.319) nor in non-elderly patients (AUROC 0.857 $\pm$ 0.027 Vs. 0.888 $\pm$ 0.053 respectively, p = 0.256). MUAC <26 cm (positive predictive value (PPV) 83.5%) or BMIPTH <22 kg/m^2 (PPV 83.5%) in elderly and MUAC <25 cm (PPV 90.7%) or BMIPTH <21 kg/m^2 (PPV 91.7%) in non-elderly can accurately predict risk of undernutrition in PEG patients.

Conclusions: MUAC and BMIPTH correlated with BMI not only at the day of PEG placement but also at the 1st and 3rd month of follow up and were equivalent to predict risk of undernutrition according to the new cut-offs defined for this population.

1. Introduction

Enteral nutrition using percutaneous endoscopic gastrostomy (PEG) tubes is a safe and well tolerated method of artificial nutrition [1]. It is indicated when a period of inadequate nutritional intake exceeding 2–4 weeks is expected, namely in cancer (mainly head and neck) and neurologic (such as cerebrovascular stroke or amyotrophic lateral sclerosis) patients [2].

Under tube feeding, patient's nutritional status must be monitored in order to prevent and/or correct undernutrition. However

Abbreviations: AUROC, area under the ROC curve; BMI, Body Mass Index; BMIPTH, Powell-Tuck and Hennessy's regression equation for BMI; cm, centimetres; kg, kilogram; m, metres; MUAC, mid upper arm circumference; PEG, percutaneous endoscopic gastrostomy.

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patients fed by PEG tubes are commonly bedridden and the most widely used tools to assess nutritional status are inadequate for these patients, leading enteral feeding teams to depend on anthropometric values and laboratory data [3].

ESPEN criteria defines undernutrition as state resulting from lack of intake or uptake of nutrition that leads to altered body composition (decreased fat free mass) and body cell mass conditioning diminished physical and mental function and impaired clinical outcome from disease [4]. BMI is a widespread used and objective anthropometric criteria to assess the risk of undernutrition, as lowest values indicate underweight [4–6]. It is calculated using patient's weight and height [5]. However BMI has some drawbacks and practical limitations, namely in bedridden and immobile patients in who precise weight and height measurements might be difficult [7]. Considering this limitation, Powell-Tuck and Hennessy described an equation using the mid upper arm circumference (MUAC) adjusted for age and sex that closely correlated with BMI and ultimately shown to be a useful measure of nutritional status, particularly in bedridden patients [8]. In fact, MUAC is an objective measure whose correct use is easily learnt and don't require expensive equipment or patient's collaboration [9]. Furthermore, a reasonably close relationship between MUAC itself and BMI has been demonstrated in normal adult populations [10,11].

The aims of this study were to 1) compare BMI, MUAC and Powell-Tuck and Hennessy's regression equation for BMI (BMIPTH) in gastrostomy fed patients, 2) validate its correlation for sequential use and 3) select the best cut-off of MUAC and BMIPTH to predict undernutrition.

2. Materials and methods

2.1. Study design

Prospective cohort study including all patients with available data on BMI, MUAC and BMIPTH submitted to PEG and followed in the Artificial Feeding Team outpatient clinic from January 2006 to December 2015.

Demographic, clinical and laboratorial data were collected prospectively and recorded as part of the Artificial Feeding Team database for each patient. Anthropometric parameters were calculated at the day of PEG procedure (0) and at first (1) and third (3) months of follow up.

Weight was measured in kilograms (kg) to one decimal place with an error of 0.05 kg using a KERN® electronic calibrated scale. Patients were weighted in supine position with their shirt, socks and underwear.

Height was measured in supine position, with patient's feet together, knees straight and head aligned according to the Frankfort horizontal plane. It was registered in metres (m) and rounded to tenths, with an error of 0.005 m.

MUAC was measured using an extendable measuring tape with the patient sitting or lying down, identifying the non-dominant arm's middle section between the acromion and the olecranon, without compressing the tissue [12]. It was registered in centimetres (cm), with an error <0,05 cm. Patient's individual limitations and clinical settings were taken into account when obtaining MUAC measurements, namely in stroke and other neurological patients, where the non-affected arm was chosen.

BMI was calculated using Quételet expression with data collected as previously described: BMI = Weight (kg)/Height (m) [2,5].

BMIPTH was calculated as follows [8]:

- Men: $BMIPTH = 1.02 \times MUAC + 0.03 \times Age - 6.7$
- Women: $BMIPTH = 1.10 \times MUAC + 0.023 \times Age - 8.0$

World Health Organization and Lipschitz classifications were used to stratify nutritional status in 3 categories according to patient's age [6,13]. In the elderly (≥65 years) undernutrition was defined as BMI < 22.5 kg/m^2, normal weight as BMI 22.5–27 kg/m^2 and overweight/obesity as BMI > 27 kg/m^2. In non-elderly undernutrition was defined as BMI ≤ 18.5 kg/m^2, normal weight as BMI 18.5–24.9 kg/m^2, overweight/obesity as BMI ≥ 25 kg/m^2.

Exclusion criteria were:

1. Age under 18 years.
2. Patients whose complete evaluation could not be obtained, including age, sex, weight, height and mid upper arm circumference measured as described above.

This study was approved by local ethic committee.

2.2. Statistical analyses

Normality was assessed using the Kolmogorov–Smirnov test. Mean and standard deviation or median and interquartile range were used for continuous variables. Frequencies were used for categorical variables. Continuous variables were compared using Student's *t*-test or Mann–Whitney test and Chi-square test or Fisher test were used for categorical variables. Statistical analysis was performed using the SPSS software version 21 (SPSS, Chicago, IL, USA).

Correlation between BMI, MUAC and BMIPTH were calculated at each time-point using Spearman's correlation test.

MUAC's performance in predicting undernutrition was analysed calculating the area under the receiver operating characteristics (AUROC) curves using DeLong method and the MedCalc software version 12.5 (MedCalc Software, Mariakerke, Belgium). These curves were compared among the different scores using Hanley & McNeil test and the best cut-off to predict undernutrition was selected using the Youden index test. A p-value < 0.05 was considered statistically significant.

3. Results

Of a total of 608 patients screened, 204 had at least one exclusion criteria and 405 were finally enrolled. The mean age was 62.9 ± 15.3 years (range 19–96), 187 (46.2%) were 65 years or older and the majority were male (n = 283, 69.9%) – Table 1. Neurologic disease was the main indication for enteral nutrition using PEG tube (60.5%), followed by head and neck cancer (38.0%) – Table 1.

Table 1
Characteristics of included patients.

		All (n = 405)	
Age (years; mean ± s.d. (range))		62.9 ± 15.3 (19–96)	
≥65 years		187 (46.2%)	
Male sex		239 (69.9%)	
PEG indication			
Neurologic disease		245 (60.5%)	
Stroke		125 (51.0%)	
Dementia		56 (22.8%)	
Amyotrophic lateral sclerosis		31 (12.7%)	
Head and neck cancer		154 (38.0%)	
Nutritional status	**Non-elderly (n = 218)**	**Elderly (n = 187)**	**Total**
Undernutrition	85 (39.0%)	120 (64.2%)	205 (50.6%)
Normal weight	100 (45.9%)	43 (23.0%)	143 (35.3%)
Overweight/obesity	33 (15.1%)	24 (12.8%)	57 (14.1%)

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