British Journal of Nutrition (2001), **86**, 725–731
DOI: 10.1079/BJN2001470

Contribution of body composition to nutritional assessment at hospital admission in 995 patients: a controlled population study

Ursula G. Kyle[1], Alfredo Morabia[2], Daniel O. Slosman[3], Nouri Mensi[4], Pierre Unger[5] and Claude Pichard[1]*

[1]*Clinical Nutrition and Diet Therapy,* [2]*Clinical Epidemiology,* [3]*Nuclear Medicine,* [4]*Central Clinical Laboratory,* [5]*Emergency Department, Geneva University Hospital, 1211 Geneva, Switzerland*

(Received 20 February 2001 – Revised 27 June 2001 – Accepted 16 August 2001)

Body weight, weight changes and BMI are easily obtainable indicators of nutritional status, but they do not provide information on the amount of fat-free and fat masses. The purpose of the present study was to determine if fat-free mass (FFM) and fat mass were depleted in patients with normal BMI or serum albumin at hospital admission. A group of 995 consecutive patients were evaluated for malnutrition by BMI, serum albumin, and 50 kHz bioelectrical impedance analysis and compared with 995 healthy adults, matched for age and height, and then compared with FFM and fat mass percentiles previously determined in 5225 healthy adults. A BMI of $\leq$20 kg/m^2 was noted in 17·3 % of patients and serum albumin of $\leq$35 g/l was found in 14·9 % of patients. In contrast, 31 % of all patients were below the tenth percentile for FFM, compared with 10·1 % of controls (χ^2, $P = 0{\cdot}0001$), while 73 % of patients with BMI $\leq$20 kg/m^2 and 31 % of patients with BMI 20–24·9 kg/m^2 fell below the tenth percentile for FFM. Furthermore, the FFM was lower in patients than controls and the differences with age in FFM (lower) and fat mass (higher) were greater in patients than in controls. BMI and albumin significantly underestimated the prevalence of malnutrition in patients at hospital admission compared with body composition measurements. Optimal nutritional assessment should therefore include objective measurement of FFM and fat mass.

Malnutrition: Bioelectrical impedance analysis: Fat-free mass: Fat mass: Albumin

Protein–energy malnutrition is a dynamic process as a result of an imbalance between energy (and protein) intake and expenditure and leads to low body fat-free mass (FFM) and fat mass. Malnutrition is common in the hospital setting. In the United States, 40 to 50 % of hospitalized patients are at risk of malnutrition (Bistrian *et al.* 1976) and up to 12 % are severely malnourished (Detsky *et al.* 1987). The situation is even worse in nursing home residents (Peter D Hart Research Associates Inc., 1993). Similar projections are also made for hospitals outside the United States (Bruun *et al.* 1999; Edington *et al.* 2000). Malnutrition tends to worsen during hospitalization (McWhirter & Pennington, 1994).

Malnutrition-related complications increase hospital care costs (Martyn *et al.* 1998). Therefore routine nutritional screening of patients for malnutrition at hospital admission can be cost-saving (Reilly *et al.* 1988; Sheils *et al.* 1999). Although no gold standard has been established, a number of nutrition screening and assessment tools are available that can be incorporated into routine care. Nutritional screening differentiates individuals who are at moderate or high risk of nutritional problems from those who are in good nutritional status. Significant weight loss over time, low weight or BMI, reduction in mid-arm circumference and skinfold measurements, changes in functional status, low serum albumin and reduced food intake are associated with poor nutritional status in adults. Furthermore, loss of FFM is a marker of malnutrition, because it is a consequence of negative imbalance between energy (and protein) needs and intake that occurs for more than a few days, when early markers are probably more functional parameters (e.g. muscle dysfunction).

Although body weight, weight changes (Reynolds *et al.* 1999) and BMI (Curtin *et al.* 1997) are easily obtainable, they do not provide information on the distribution of FFM and fat mass. BMI was shown to be inaccurate in assigning a fatness risk factor to individuals, especially among women (Morabia *et al.* 1999). Skeletal muscle atrophy is prevalent

Abbreviations: BIA, bioelectrical impedance analysis; FFM, fat-free mass; P, percentile rank.

* **Corresponding author:** Dr Claude Pichard, fax +41 22 372 9363, email pichard@cmu.unige.ch

in sick (Bruera, 1992) and elderly populations (Baumgartner *et al.* 1998) and is strongly associated with disability and morbidity (Dempsey *et al.* 1988). It is associated with depletion of FFM but normal body weight and has been documented in many pathologies, such as cancer (Costelli & Baccino, 2000), AIDS (Von Roenn *et al.* 1994), cardiac cachexia (Paccagnella *et al.* 1994), and chronic obstructive pulmonary disease (Engelen *et al.* 1994). Therefore, assessment of body compartments may substantially improve the assessment of malnutrition.

Bioelectrical impedance analysis (BIA) has been widely used for the simultaneous measuring of FFM and fat mass. It is an easy, safe and non-invasive bedside technique (Kyle & Pichard, 2000). BIA is valid for the estimation of FFM and fat mass, provided that an equation appropriate for the population is used. The BIA equation used in the present study was validated in healthy subjects (Kyle *et al.* 2001*a*), stable in- and outpatients (Kyle *et al.* 2001*b*), and elderly subjects (Genton *et al.* 2001). Percentile tables of FFM and fat mass, previously established in 5225 healthy adults (Kyle *et al.* 2001*c*) permit the evaluation of low FFM in patients.

The purpose of the present controlled population study was to determine if BIA-derived FFM and fat mass were depleted in patients with normal BMI or serum albumin and if FFM and fat mass differed in patients at hospital admission from healthy controls.

Subjects and methods

Patients

All adult patients admitted to the emergency centre for medical or surgical reasons and subsequently hospitalized were eligible for inclusion. Every 10th patient who met entry criteria was included in the study during a 3 month period. The study included 995 patients; two patients refused to participate in the study. Thirty-five patients with oedema, burns or treated with peritoneal- or haemodialysis and twenty-six patients with rehydration perfusion and major cardio-respiratory resuscitation were excluded. All patients were measured in the emergency room within 3 h after admission, by the same two co-workers of the Nutrition Unit. Patients were categorized as medical, surgical or trauma, depending on the service in which they hospitalized after admission.

Informed consent was obtained from all subjects. The study protocol complied with the requirements of the Geneva University Hospital Ethics Rules.

Controls

Healthy adults (525 men and 470 women), matched for age (±2 years) and height (±2 cm) of patients, were selected from our database. Our database consists of 5225 healthy adults between the ages of 15 and 98 years, who were non-randomly recruited in the greater Geneva area and represent the same population as the patients (Kyle *et al.* 2001*c*). This database was the source for FFM percentiles previously established (Kyle *et al.* 2001*c*). BMI, resistance, reactance, FFM, fat mass and percentage fat mass (adjusted for age and height) did not differ significantly ($P>0{\cdot}5$) between study-matched control subjects and the entire control population.

Measurements

Anthropometric measurements and bioelectrical impedance analysis. All measurements were performed during the hospital admission examination. Body height was measured to the nearest 0·5 cm and body weight to the nearest 0·1 kg on a chair scale or a hoist with attached weighing device for patients who were bed-ridden. The scales were cross-calibrated weekly. Subjects were in indoor clothing without shoes and heavy sweaters or jackets. Percentage ideal body weight was derived from the Metropolitan Life Insurance Company (1983) tables. Values used were the midpoints for medium frame for each height.

The FFM and fat masses were assessed by BIA as previously described by Lukaski (1986). Whole-body resistance (R) and reactance was measured with four surface electrodes placed on the right wrist and ankle. Briefly, an electrical current of 50 kHz and 0·8 mA was produced by a generator (RJL-101® analyzers, RJL Systems Inc, Clinton Twp, MI) and applied to the skin by the use of adhesive electrodes (3M Red Dot T, 3M Health Care, Borken, Germany) with the subject lying supine (Houtkooper *et al.* 1996). The skin was cleaned with ethanol–water (70:30, v/v). The RJL-101® generator (RJL Systems Inc, Clinton Twp, MI) was cross-validated at 50 kHz against the Xitron® analyzer (Xitron Technologies, Inc, San Diego, CA). The limit of tolerance between instruments was ±5Ω at 50 kHz using a calibration jig and *in vivo* measurements.

FFM was calculated by the following multiple regression equation that had been previously validated against dual-energy X-ray absorptiometry (Hologic QDR-4500, Hologic Inc., Waltham, MA) in 343 healthy subjects between 18 and 94 years of age (Kyle *et al.* 2001*a*):

$$\begin{aligned}\text{FFM} = & -4{\cdot}104 + (0{\cdot}518 \times \text{height}^2/\text{resistance}) \\ & + (0{\cdot}231 \times \text{weight}) + (0{\cdot}130 \times \text{reactance}) \\ & + (4{\cdot}229 \times \text{sex} \;\; (\text{men} = 1, \;\; \text{women} = 0)).\end{aligned}$$

DXA–measured FFM was 54·0 ± 10·7 kg. BIA-predicted FFM was 54·0 ± 10·5 kg, r 0·986, standard error of the estimate (SEE) 1·72 kg, technical error (TE) 1·74 kg. This BIA equation had further been tested in elderly subjects (Genton *et al.* 2001) and pre- and post-transplant patients (Kyle *et al.* 2001*b*) and found to be valid in elderly and diseased patients.

A standardized protocol was used for all our body composition studies. Therefore the methods used did not differ between the database of reference subjects and subjects included in the present study. Patients were assigned an age-appropriate percentile rank for FFM based upon our percentile tables of healthy Swiss subjects (n 5255 subjects between the ages of 15 and 98 years) (Kyle *et al.* 2001*c*). Percentile rank below the 5th percentile (P≤5) and 10th percentile (P≤10) were used to define FFM depletion.

Albumin. Blood samples were routinely drawn at the

same time as the samples necessary for diagnosis and treatment, before initiation of intravenous fluids. Albumin was measured by immunonephelometry (Fink *et al.* 1989). The normal range of our biochemistry laboratory for albumin was 35–55 g/l.

Statistical analysis

StatView statistical software package version 4.1 (Abacus Concepts, Berkeley, CA) was used for statistical analysis. The results are expressed as mean and standard deviation. The differences between age groups were analysed by ANOVA. Unpaired *t* tests were used to compare patients and controls. Chi-square tests were used to compare the differences between malnutrition indicators. Statistical significance was set at $P \leq 0{\cdot}05$ for all tests.

Results

The anthropometric characteristics of the controls and emergency centre men and women are shown in Table 1. Height was lower in older than younger male and female controls and patients, but did not differ significantly between controls and patients. Weight was higher in older patients and controls than younger subjects, and was lower in 75–100-year-old patients compared with 55–74-year-old controls.

Resistance was significantly higher in patients than controls and increased with age (data not shown). Higher resistance and lower reactance measured in patients than in controls and in older *v.* younger subjects translate into lower FFM (Table 2) found in patients than in controls and in older *v.* younger subjects.

Nutrition assessment parameters

Low serum albumin (albumin ≤35 g/l) (Table 3) was found in 14·9 % of patients. Low correlations were found between albumin and FFM (r 0·216, $P<0{\cdot}001$, data not shown). A BMI of ≤20 kg/m^2 was noted in 17·3 % of patients compared with 8·5 % of controls (Table 3). Of the patients, 31 % were below P≤10 for FFM, compared with 10·1 % of controls (χ^2, $P \leq 0{\cdot}0001$). Medical and surgical patients (35·5 and 30·5 %, respectively) had higher incidence of low FFM than trauma patients ($P \leq 0{\cdot}0001$) who did not differ from controls.

Further analysis (Table 4) showed that 72·9 % of patients with a BMI ≤20 kg/m^2 fell below P≤10, compared with 32·9 % of controls. Furthermore, 31·2 % of patients with a BMI of 20–24·9 kg/m^2, compared with 12·0 % of healthy controls, and 13·1 % of patients with a BMI 25–29·9 kg/m^2 compared with 2·7 % of controls fell below the FFM P≤10. These results show that a low FFM is noted in a higher proportion of patients than controls and is found in almost one third of patients with a 'normal' BMI of 20–24·9 kg/m^2. Thus BMI was not sensitive to evaluate FFM depletion. Body composition measurements by BIA are more sensitive to identify patients who are FFM-depleted than is BMI.

Fat-free and fat body mass

There were minimal differences in BMI between patients and controls (Table 2). FFM remained stable until 54 years

Table 1. Anthropometric and bioelectrical impedance characteristics of healthy male and female controls and patients (Mean values and standard deviations)

Age (years) …	All (15–95)		15–34		35–54		55–74		>75	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Men										
n	525		153		165		135		72	
Height (cm)										
controls	173·2	7·6	175·9	7·4	174·0*	7·1	171·9*	6·8	168·4**	7·5
patients	172·6	8·0	175·1	7·7	173·2*	7·2	171·5	8·4	168·2*	7·2
Weight (kg)										
controls	74·5	10·2	73·1	10·2	76·6*	10·1	75·4	10·1	71·3*	9·0
patients	72·5†	12·9	70·5†	12·3	73·2†	12·9	74·9	13·4	70·1*	12·1
IBW (%)										
controls	107·6	12·3	103·4	10·8	109·7**	11·9	110·1	12·9	107·0	13·1
patients	105·1†	16·7	100·2†	14·9	105·9*†	17·0	109·5	17·5	105·1	16·1
Women										
n	470		113		114		96		147	
Height (cm)										
controls	160·4	7·3	164·9	6·9	162·3**	6·2	159·6*	5·9	156·1**	6·7
patients	160·3	7·3	164·4	7·1	162·3*	6·2	159·6*	5·9	156·0**	6·8
Weight (kg)										
controls	60·7	9·6	58·3	6·2	59·3	8·1	64·2**	11·8	61·4*	10·5
patients	60·1	12·3	57·9	9·6	64·3**††	11·3	62·3	15·2	57·2**†	11·5
IBW (%)										
controls	103·8	16·1	95·7	8·5	99·5	11·6	110·2**	18·7	109·1	18·1
patients	102·7	19·8	95·3	14·1	107·8**††	18·4	107·3	25·5	101·5*††	18·5

IBW, ideal body weight (Metropolitan Life Insurance Company, 1983).
ANOVA comparison between age groups within a row: *$P<0{\cdot}05$, **$P<0{\cdot}001$.
Mean values were significantly different from those of the control group: †$P<0{\cdot}05$, ††$P<0{\cdot}001$ (unpaired *t* test).

Table 2. Body composition differences between age groups, and between controls and patients*

Age (years) …	All (15–95)		15–34		35–54		55–74		>75	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Men										
BMI (kg/m^2)										
controls	24·8	2·9	23·6	2·4	25·3††	2·7	25·5	3·0	25·2	3·3
patients	24·1‡	3·9	23·0‡	3·4	24·4†‡	3·9	25·4†	4·0	24·7	3·7
Fat-free mass (kg)										
controls	58·5	6·5	59·8	6·3	60·5	6·1	57·5††	5·6	52·6††	5·4
patients	54·9‡‡	7·6	56·6‡‡	7·1	56·0‡‡	7·2	54·3†‡‡	8·0	50·1†‡	6·6
Fat mass (kg)										
controls	16·1	5·8	13·3	5·2	16·1††	5·4	17·8†	5·7	18·7	5·4
patients	17·5‡‡	7·4	14·0	6·5	17·3††	7·3	20·6†††‡‡	7·0	20·0	7·1
Women										
BMI (kg/m^2)										
controls	23·7	3·9	21·5	2·0	22·5†	2·6	25·2††	4·3	25·3	4·3
patients	23·4	4·5	21·4	3·2	24·4†††‡‡	4·2	24·5	5·8	23·5‡	4·3
Fat-free mass (kg)										
controls	41·1	4·9	42·4	3·8	42·2	4·1	42·0	5·3	38·8††	5·0
patients	38·7‡‡	6·0	40·2‡‡	4·8	41·9†	4·9	38·7†††‡‡	6·1	35·2	5·7
Fat mass (kg)										
controls	19·6	6·9	15·9	3·8	17·1	5·2	22·2††	7·7	22·6	7·3
patients	21·4‡‡	7·9	17·7‡	6·1	22·4†††‡‡	7·5	23·6	10·0	22·1	7·1

* For details of subjects and procedures, see Table 1 and p. 726.
Comparison by ANOVA between adjacent age groups: †$P<0·05$, ††$P<0·001$.
Mean values were significantly different from those of the control group: ‡$P<0·05$, ‡‡$P<0·001$ (unpaired t test).

of age in male controls and 74 years of age in female controls, while FFM decreased in patients with age after 54 years. The male and female patients ≥75 years of age had about 16–17 % lower FFM than the youngest control men and women compared with 12 and 8·5 % lower FFM noted in ≥75 year-old male and female controls, respectively. Thus the decrease with age in FFM in patients was greater than the age-related decrease in the controls. The patients classified as FFM P<10 had 20 % lower FFM than controls (data not shown). Patients ≥75 years old classified as P<10, had 29 % lower FFM than the youngest controls and 19 and 23 % lower FFM than age-matched healthy control men and women, respectively. Thus FFM depletion is significant in patients at hospital admission.

The peak fat mass in 55–74-year-old male and female patients was about 55 and 48 % higher, respectively, than in the youngest control men and women (aged 15–34 years of age), compared with 40 and 34 % higher fat mass in control men and women, respectively.

These results show that FFM was lower in patients than controls and the differences with age in FFM (lower) and fat mass (higher) were greater in patients than in controls. Thus the higher fat mass observed in the older subjects obscures FFM depletion when BMI is used as a nutritional indicator, since there were insignificant differences in BMI between patients and controls.

Discussion

The purpose of a nutritional assessment is to identify patients with depleted body tissues and increased risks for complications. This is the first study that evaluates differences in FFM and fat mass of a large number of patients at hospital admission compared with healthy controls and shows patients had lower FFM and higher fat mass than controls. The prevalence of low FFM was much higher than was determined by low BMI and albumin.

Prevalence of nutritional risk

The higher prevalence of nutritional risk by definition of FFM P<10 suggests that BMI and serum albumin underestimated the prevalence of malnutrition at hospital admission (Table 3).

A low prevalence of malnutrition by criteria of BMI ≤20 kg/m^2 was found in Dublin in general surgical patients and surgical oncology patients (6–7 %) and skinfold measurements ≤15th percentile (Corish, 1999). Corish *et al.* (1999) expected a higher prevalence of malnutrition in their patients undergoing major surgery and found 37 % had indeed lost ≥10 % of body weight. This suggests that BMI does not identify patients at nutritional risk. It is possible that recent increases in weight and BMI invalidate anthropometric reference standards to define nutritional status in the USA and Western Europe, because they do not identify body compartments, i.e. FFM and fat mass.

BMI and nutritional risk

The lower prevalence of nutritional risk noted in patients by a BMI of ≤20 kg/m^2 than FFM P<10 (Table 3) suggests that BMI did not identify the subjects who were FFM-depleted in our study. We also found that patients with a normal BMI at the same time had below normal FFM. Furthermore, the incidence of a low FFM was common in patients with a BMI in the normal range (20–25 kg/m^2) and is noted in some overweight patients (BMI 25–29·9 kg/m^2).

The relationship between BMI and protein–energy

Table 3. Prevalence of malnutrition by various nutritional parameters and diagnostic categories at hospital admission*

	Controls		All patients		Medical patients		Surgical patients		Trauma patients		Difference between group values (χ^2 test)	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	df	*P*
Serum albumin†												
>35 g/l	N/A		556	85·1	387	83·0	138	89·6	31	93·9	2	0·048
≤35 g/l	N/A		97	14·9	79	17·0	16	10·4	2	6·1		
BMI (kg/m^2)												
>30	66	6·6	85	8·5	51	8·3	23	9·1	11	8·9	9	0·0001
25·0–29·9	307	30·9	252	25·3	155	25·1	67	26·5	30	24·2		
20·0–24·9	536	53·9	486	48·8	306	49·5	111	43·8	69	55·6		
≤20	86	8·6	172	17·3	106	17·2	52	20·6	14	11·3		
Fat-free mass‡												
P>25	743	74·7	515	51·8	292	47·2	132	52·2	91	73·4	9	0·0001
P10–25	153	15·4	169	17·0	107	17·3	44	17·4	18	14·5		
P5–10	49	4·9	89	8·9	56	9·1	28	11·1	5	4·0		
P<5	50	5·0	222	22·3	163	26·4	49	19·4	10	8·1		

N/A, not applicable; P, percentile.
* For details of subjects and procedures, see Table 1 and p. 726.
† *n* 653.
‡ Fat-free mass percentiles determined from age- and gender-appropriate reference tables (see pp. 727–728).

malnutrition remains debated. Galanos *et al.* (1997) found that BMI was an independent predictor of excess mortality within 180 d. An increased risk for mortality was noted in patients with low BMI (values P≤15). The authors speculated that the lack of a protective 'nutritional reserve' during serious illness might have worsened outcome in patients with low BMI. Ham (Ham, 1992) suggested that the optimal range for BMI is higher, i.e. 24–29 kg/m^2, for healthy elderly people. Schols *et al.* (1998) found an inverse relationship between BMI and survival in chronic obstructive pulmonary disease patients. They identified a BMI of ≤25 kg/m^2 as the threshold value below which the mortality risk was clearly increased.

Higher mortality rates reported in hospital patients with normal BMI might be due to unrecognized depletion of FFM. The low FFM noted in our subjects at hospital admission, including patients in the normal BMI range, might explain the increased nutritional risk and risk of illness. Potter *et al.* (1988) found lowest mortality in hospitalized patients occurred at moderate overweight, and the higher mortality in thin patients could not be explained by weight loss between hospitalizations. We hypothesize that weight loss in combination with already low FFM reserves could explain higher mortality in thin subjects, and moderate overweight would decrease the likelihood of low FFM, thus decreasing mortality in overweight subjects. Rajala *et al.* (1990) found that a weight loss over the first 24 months of follow-up resulted in five times the risk of mortality at 40 months. Reynolds *et al.* (1999) found that having a low BMI (≤23 kg/m^2) and weight loss of more than 4·5 kg in 1 year were both associated with increased risk of mortality over a 6 year period in community-dwelling women aged ≥65 years. It is therefore quite possible that weight loss, which results in loss of both FFM and fat mass, in combination with pre-existing FFM depletion in patients with low and moderate BMI could explain the increased risk for mortality in patients.

Body composition parameters

These results show that FFM was lower in patients than controls and the differences with age in FFM (lower) and fat mass (higher) were greater in patients than in controls. (Table 2). Patients classified as FFM P<10 had 20 % lower FFM than controls. This difference was even greater in patients aged ≥75 years. Furthermore, low FFM (P<10) is found in almost one third of patients admitted to hospital.

Our study confirms that FFM depletion and malnutrition is common in patients at hospital admission (Bistrian *et al.* 1976; Bruun *et al.* 1999; Edington *et al.* 2000). Higher mortality has been noted in patients with low muscle mass. Kotler *et al.* (1989) found that death occurred at 54 % of normal for body cell mass while it occurred at 66 % of ideal weight in AIDS patients (Kotler *et al.* 1989). Covinsky *et al.* (1999) found severely malnourished patients were at high risk for mortality during the first year after hospitalization and the risk remained elevated after adjustment for acute illness, severity, chronic co-morbidity and functional status at admission. They suggested that malnutrition might accelerate the fatal outcome of chronic diseases rather than simply act as a marker for pre-terminal status. Their analysis further suggested that malnourished patients are at risk for delayed recovery and/or accelerated functional decline following hospitalization. Volkert *et al.* (1992) demonstrated that the relationship between clinical nutritional assessment and outcomes was independent of other prognostic markers and was valid for patient outcomes other than mortality. We suggest that the low FFM is an important factor in patient outcome.

We are unable to confirm mortality rates in our patients. However the FFM depletion reported in one third of patients admitted to hospital in the present study confirms that nutritional risk is significant at hospital admission and is frequently unrecognized because body compartments are not routinely assessed at hospital admission. Both serum

Table 4. Comparative prevalence of malnutrition at hospital admission by BMI and bioelectrical-derived fat-free mass percentile rank (P)*

Fat-free mass† …	P<5		P5–10		P10–25		P>25		Total		Difference between group values (χ^2 test)	
	n‡	%	*n*‡	%	*n*‡	%	*n*‡	%	*n*§	%	df	*P*
Controls												
BMI* (kg/m^2)												
≥30	0	0	0	0	1	1·5	65	98·5	66	6·6	9	0·0001
25·0–29·9	5	1·6	3	1·0	29	9·4	270	87·9	307	30·9		
20·0–24·9	29	5·4	33	6·2	101	18·8	373	69·6	536	53·9		
≤20	16	18·6	13	15·1	22	25·6	35	40·7	86	8·6		
Total	50	5·0	49	4·9	153	15·4	743	74·7	995	100		
Patients												
BMI* (kg/m^2)												
≥30	1	1·2	0	0	1	1·2	83	97·6	85	8·5	9	0·0001
25·0–29·9	18	7·1	15	6·0	30	11·9	189	75·0	252	25·3		
20·0–24·9	95	19·5	57	11·7	115	23·5	219	45·3	486	48·8		
≤20	108	62·8	17	9·9	23	13·4	24	14·0	172	17·3		
Total	222	22·3	89	8·9	169	17·0	515	51·6	995	100		

* For details of subjects and procedures, see Table 1 and p. 726.
† Fat-free mass percentiles determined from age- and gender-appropriate reference tables (see pp. 727–728).
‡ Total *n* for row, 100.
§ Total *n* for column, 100.

albumin and BMI underestimated nutritional risk at hospital admission in the present study. This may be due to a lack of recognition of FFM depletion, in part due to higher fat mass noted in patients compared with controls. Therefore, body composition measurements, such as BIA, could improve nutritional assessment by assessing FFM and thus identifying those patients who are at risk due to already depleted FFM at hospital admission.

Limitations of study

We have no information on why patients were malnourished and therefore could not distinguish between malnourished secondary to inadequate intake and/or increased needs or losses. The cause of malnutrition as well as the relationship between malnutrition and patient outcome remains unknown, but this is not relevant for the purpose of the present study, which was to show that malnutrition is better perceived by BIA-derived FFM than by BMI.

The BIA methods used may be criticized, but have been optimized for the present study, namely: water and electrolyte abnormalities are known to influence body composition measurements, including BIA measurements. To limit the impact of such an interference, BIA measurements were performed before intravenous fluids for medications and treatment for dehydration were started, and care was taken to exclude patients with oedema, dehydration, dialysis, burns and major cardio-respiratory resuscitation (see p. 726). Mild non-visible hydration abnormalities (overhydration) might have been present in some patients. This would have resulted in the overestimation of FFM and underestimation of the prevalence of malnutrition.

BIA was validated against dual-energy X-ray absorptiometry. Dual-energy X-ray absorptiometry is not yet universally recognized as a body composition reference method because of methodological problems (e.g. recognition of abnormal hydration) and systematic differences between manufacturers. This does not, however, invalidate the study, because trends in FFM and fat mass would not be affected by systematic errors (e.g. over- or underestimation of FFM would be the same in all subjects).

It is not known to what extent acute phase protein responses might have affected the serum albumin levels reported in the present study.

Conclusion

The degree of malnutrition was significantly underestimated by BMI and serum albumin in patients admitted to the hospital, compared with BIA-derived FFM. The FFM was lower in patients than controls and the differences with age in FFM (lower) and fat mass (higher) were greater in patients than in controls. Thus body composition measurements identified patients with low FFM and low or high fat mass reserves. Optimal nutritional assessment should therefore include objective measurement of FFM and fat mass.

Acknowledgements

We thank the Foundation Nutrition 2000Plus and Head of the Public Health Department for the Canton of Geneva for their financial support. We are indebted to Maaike Kruseman, Natalie Bettex and all the dietitians at the Geneva University Hospital for data collection and the staff of the Emergency Centre for their collaboration during data collection.

References

Baumgartner RN, Koehler KM, Gallagher D, Romero L, Heymsfield SB, Ross RR, Garry PJ & Lindeman RD (1998) Epidemiology of sarcopenia among the elderly in New Mexico. *American Journal of Epidemiology* **147**, 755–763.

Bistrian BR, Blackburn GL & Vitale J (1976) Prevalence of

malnutrition in general medical patients. *Journal of the American Medical Association* **235**, 1567–1570.
Bruera E (1992) Clinical management of anorexia and cachexia in patients with advanced cancer. *Oncology* **49**, 35–42.
Bruun LI, Bosaeus I, Bergstad I & Nygaard K (1999) Prevalence of malnutrition in surgical patients: evaluation of nutritional support and documentation. *Clinical Nutrition* **18**, 141–147.
Corish CA (1999) Pre-operative nutritional assessment. *Proceedings of the Nutrition Society* **58**, 821–829.
Costelli P & Baccino FM (2000) Cancer cachexia: from experimental models to patient management. *Current Opinion in Clinical Nutrition and Metabolic Care* **3**, 177–181.
Covinsky KE, Martin GE, Beyth RJ, Justice AC, Sehgal AR & Landefeld CS (1999) The relationship between clinical assessments of nutritional status and adverse outcomes in older hospitalized medical patients. *Journal of the American Geriatrics Society* **47**, 532–538.
Curtin F, Morabia A, Pichard C & Slosman D (1997) Body mass index compared to dual-energy X-ray absorptiometry: evidence for a spectrum bias. *Journal of Clinical Epidemiology* **50**, 837–843.
Dempsey DT, Mullen JL & Buzby GP (1988) The link between nutritional status and clinical outcome: can nutritional intervention modify it? *American Journal of Clinical Nutrition* **47**, 352–356.
Detsky AS, Baker JP, O'Rourke K & Goel V (1987) Perioperative parenteral nutrition: A meta-analysis. *Annals of Internal Medicine* **107**, 195–203.
Edington J, Boorman J, Durrant ER, Perkins A, Giffin CV, James R, Thomson JM, Oldroyd JC, Smith JC, Torrance AD, Blackshaw V, Green S, Hill CJ, Berry C, McKenzie C, Vicca N, Ward JE & Coles SJ (2000) Prevalence of malnutrition on admission to four hospitals in England. *Clinical Nutrition* **19**, 191–195.
Engelen MPKJ, Schols AMWJ, Baken WC, Wesseling GJ & Wouters EFM (1994) Nutritional depletion in relation to respiratory and peripheral skeletal muscle function in outpatients with COPD. *European Respiratory Journal* **7**, 1793–1797.
Fink PC, Romer M, Haeckel R, Fateh-Moghadam A, Delanghe J, Gressner AM & Dubs RW (1989) Measurement of proteins with the Behring Nephelometer. A multicentre evaluation. *Journal of Clinical Chemistry and Clinical Biochemistry* **27**, 261–276.
Galanos AN, Pieper CF, Kussin PS, Winchell MT, Fulkerson WJ, Harrell FE Jr, Teno JM, Layde P, Connors AF Jr, Phillips RS & Wenger NS (1997) Relationship of body mass index to subsequent mortality among seriously ill hospitalized patients. SUPPORT Investigators The Study to Understand Prognoses and Preferences for Outcome and Risks of Treatments. *Critical Care Medicine* **25**, 1962–1968.
Genton LC, Karsegard VL, Kyle UG, Hans DB, Michel JP, Slosman DO & Pichard C (2001) Comparison of four bioelectrical impedance analysis formulas in healthy elderly subjects. *Gerontology* (In the press).
Ham RJ (1992) Indicators of poor nutritional status in older Americans. *American Family Physician* **45**, 219–228.
Houtkooper LB, Lohman TG, Going SB & Howell WH (1996) Why bioelectrical impedance analysis should be used for estimating adiposity. *American Journal of Clinical Nutrition* **64**, 436S–448S.
Kotler DP, Tierney AR, Wang J & Pierson RM (1989) Magnitude of body-cell-mass depletion and the timing of death from wasting in AIDS. *American Journal of Clinical Nutrition* **50**, 444–447.
Kyle UG, Genton L, Karsegard L, Slosman DO & Pichard C (2001*a*) Single prediction equation for bioelectrical impedance analysis in adults aged 20–94 yrs. *Nutrition* **17**, 248–253.
Kyle UG, Genton L, Mentha H, Nicod L, Slosman D & Pichard C (2001*b*) Reliable bioelectrical impedance analysis estimate of fat-free mass in liver, lung and heart transplant patients. *Journal of Parenteral and Enteral Nutrition* **25**, 45–51.
Kyle UG, Genton LC, Slosman DO & Pichard C (2001*c*) Fat free and fat mass percentiles in 5225 healthy subjects aged 15 to 98 years. *Nutrition* **17**, 534–541.
Kyle UG & Pichard C (2000) Dynamic assessment of fat-free mass during catabolism and recovery. *Current Opinion in Clinical Nutrition and Metabolic Care* **3**, 317–322.
Lukaski HC (1986) Validation of tetrapolar bioelectrical impedance measurements to assess human body composition. *Journal of Applied Physiology* **60**, 1327–1332.
McWhirter JP & Pennington CR (1994) Incidence and recognition of malnutrition in hospital. *British Medical Journal* **308**, 945–948.
Martyn CN, Winter PD, Coles SJ & Edington J (1998) Effect of nutritional status on use of health care resources by patients with chronic disease living in the community. *Clinical Nutrition* **17**, 119–123.
Metropolitan Life Insurance Company (1983) Build Study, 1979. Society of Actuaries and Association of Life Insurance Medical Directors of America, Philadelphia, US. Recording and Statistical Corporation (1980). New York, USA: Metropolian Life Insurance Company.
Morabia A, Ross A, Curtin F, Slosman DO & Pichard C (1999) Relation of BMI to a dual-energy X-ray absorptiometry measure of fatness. *British Journal of Nutrition* **82**, 49–55.
Paccagnella A, Calò MA, Caenaro G, Salandin V, Jus P, Simini G & Heymsfield SB (1994) Cardiac cachexia: Preoperative and post operative nutrition management. *Journal of Parenteral and Enteral Nutrition* **18**, 409–416.
Peter D Hart Research Associates Inc. (1993) *National Survey on Nutritional Screening and Treatment of the Elderly*, Washington, DC: Peter D Hart Research Associates Inc.
Potter JF, Schafer DF & Bohi RL (1988) In-hospital mortality as a function of body mass index: an age-dependent variable. *Journal of Gerontology* **43**, M59–M69.
Rajala SA, Kanto AJ, Haavisto MV, Kaarela RH, Koivunen MJ & Heikinheimo RJ (1990) Body weight and the three-year prognosis in very old people. *International Journal of Obesity* **14**, 997–1003.
Reilly JJ, Hull SF, Albert N, Waller A & Bringardener S (1988) Economic impact of malnutrition: a model system for hospitalized patients. *Journal of Parenteral and Enteral Nutrition* **12**, 371–376.
Reynolds MW, Fredman L, Langenberg P & Magaziner J (1999) Weight, weight change, mortality in a random sample of older community-dwelling women. *Journal of the American Geriatrics Society* **47**, 1409–1414.
Schols AM, Slangen J, Volovics L & Wouters EF (1998) Weight loss is a reversible factor in the prognosis of chronic obstructive pulmonary disease. *American Journal of Respiratory and Critical Care Medicine* **157**, 1791–1797.
Sheils JF, Rubin R & Stapleton DC (1999) The estimated costs and savings of medical nutrition therapy: The Medicare population. *Journal of the American Dietetic Association* **99**, 428–435.
Volkert D, Kruse W, Oster P & Schlierf G (1992) Malnutrition in geriatric patients: diagnostic and prognostic significance of nutritional parameter. *Annals of Nutrition and Metabolism* **36**, 97–112.
Von Roenn JH, Armstrong D, Kotler DP, Cohn DL, Klimas NG, Teckmedyan NS, Cone L, Brennan PJ & Weitzman SA (1994) Megestrol acetate in patients with AIDS-related cachexia. *Annals of Internal Medicine* **121**, 393–399.