Prediction of mortality in patients in acute medical wards using basic laboratory and anthropometric data

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Summary: The value of anthropometric and biochemical indices in predicting short-term mortality among patients in general medical wards was assessed in 294 patients admitted consecutively to a district hospital over a one month period. Using a stepwise logistic regression model and supported by the linear discriminant analysis method, mortality within 3 months could be predicted with sensitivity of 83% and specificity of 84% using the following variables: sex, functional ability, urea, total protein, alkaline phosphatase and albumin-adjusted calcium. Addition of anthropometric values and biochemical nutritional indices did little to improve the accuracy of the prediction, contrary to previous findings among surgical patients and elderly residents of long-term care institutions.

Introduction

Malnutrition is a common finding in hospitalized patients^{1–7} and several studies have shown that nutritional status is an important predictor of prognosis.^{8–18} Many of these studies have been done in surgical patients.^{11,14–16} Buzby *et al.*¹¹ have described a multiparameter index of nutritional status called prognostic nutritional index (PNI) which includes serum albumin, serum transferrin, triceps skin-fold thickness and delayed hypersensitivity skin-test reactivity. PNI predicts post-operative morbidity and mortality.¹¹ This index has been subsequently validated in a prospective study of patients undergoing surgery.^{19,20} However, the applicability of this index in other situations has been questioned.²¹

In this study, we have used some nutritional parameters and other routine biochemical and haematological tests to derive a prognostic index applicable to general medical patients.

Subjects and methods

All patients admitted over a one month period to the general medical wards of a district general

hospital were recruited into the study. All subjects were seen by a nurse interviewer, who collected information on the diagnosis of the patients, the subsequent length of hospital stay, and recorded arm anthropometric measurements. Arm circumference was measured at the mid-point between the acromion and olecranon processes. Triceps skin-fold thickness was measured with Holtain calipers at the same point. The average of three readings was used. Arm muscle circumference (AMC) was derived from the following equation:

$$\text{AMC (cm)} = \text{arm circumference (cm)} - \frac{\pi}{10} \times \text{triceps skin fold thickness (mm)}$$

Corrected arm muscle area (CAMA), was calculated using the following equation as suggested by Heymsfield *et al.*²²

$$\text{Male: CAMA (cm}^2\text{)} = \frac{(\text{AMC})^2}{4\pi} - 10$$

$$\text{Female: CAMA (cm}^2\text{)} = \frac{(\text{AMC})^2}{4\pi} - 6.5$$

The functional ability of each patient (Ability) was also noted. This represented a brief assessment of mobility and activities of daily living, and was graded into three categories: (1) independent; (2) assistance required; and (3) bedridden. Twenty millilitres of venous blood and a random urine sample were collected from each patient in the

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non-fasting state within 48 hours of admission for routine blood tests (complete blood picture, renal and liver function tests) as well as the following: prealbumin, retinol binding protein, transferrin; thiamine, riboflavin and pyridoxine status; serum folate, cyanocobalamin, retinol, vitamin E; plasma copper, zinc and magnesium; and total lymphocyte count. Plasma electrolytes, urea, creatinine, liver function tests, calcium, phosphate and uric acid were estimated by automated methods (Parallel™ Analyser, American Monitor Corp., Indiana, USA). Urine iodine, potassium, calcium and creatinine were determined on a Astra 8 analyser (Beckman Co. Ltd, CA, USA). An aliquot of plasma was stored at -70°C for batch assay of prealbumin, retinol binding protein, and transferrin by immunoturbidimetric methods using polyclonal antibodies (Dako, Bucks, UK) on a centrifugal analyser (Cobas Bio, Roche Diagnostic, Basle, Switzerland).²³ Urine total protein, albumin, retinol binding protein and N-acetyl-β-D-glucosaminidase (NAG) were determined by previously described methods.²⁴ Biochemical status of thiamine, riboflavin and pyridoxine was estimated by measurement of red cell coenzyme activities using automated methods.²⁵ Cyanocobalamin and serum folate were estimated by a radioimmunoassay method using kits from Diagnostic Products Corporation (LA, CA 90045, USA). Plasma retinol and vitamin E were measured by a fluorometric method after extraction with hexane.²⁶ An aliquot of plasma was stored at -20°C for batch assay of copper, zinc, and magnesium by atomic absorption spectrophotometry, after protein precipitation with trichloroacetic acid to release bound metal ions. Haemoglobin, red cell counts and other red cell parameters, white cell and lymphocyte counts were determined using a Technicon H-6000 haematology analyser (Technicon Instruments Co., Tarrytown, NY, USA).

Data were analysed using the Statistical Package for Social Sciences (Vers. 3.0) and BMDP on an IBM PC. Unpaired Student's *t*-test and Mann-Whitney *U*-test were used in the comparison of variables between survivors and non-survivors. Multivariate logistic regression analysis was used to arrive at a predictive equation and a prognostic index. Linear discriminant analysis was used as an alternative method to further support the results.

Results

A total of 294 patients were studied during the one month period. Their age and sex distribution are shown in Table I. Sixty per cent were over the age of 60 years and 64% of patients stayed in the hospital for less than 7 days. Of the 294 patients, 39 patients died within 3 months. In this group of 39 there were

Table I Distribution of patients studied by sex and age

Age group (years)	Number	F/M
< 40	63	26/37
40-60	54	16/38
61-80	132	61/71
> 80	45	30/15

25 males and 14 females, and the mean age of the group was 72.9 (± 11.6, range 43-95 years). The mean length of survival was 10.5 ± 12.8 days (median 6 days, range 1-61 days). Table II gives the list of diagnoses in this group of non-survivors and in all patients. Some patients have multiple diagnoses.

A total of 60 variables were available. Table III lists the variables that were significantly different between the survivors and non-survivors. Thirty-two variables were significantly different (*P* < 0.01), eight variables were marginally significantly different (*P* < 0.05) and 14 variables were not different between the two groups (*P* > 0.05). Owing to inadequate sample volume or other technical reasons, results for some measurements were not available in all patients. Furthermore most of these acutely ill patients were bedridden and therefore accurate assessment of height and weight were not available in many patients. The variables where more than 15 values were missing were not included in further analysis (plasma retinol, lymphocyte count, height and weight).

A stepwise logistic regression analysis was then applied based on the variables shown in Table III, with survival and death as the binary outcome. After excluding cases with missing data, 231 cases were included for analysis. The results are sum-

Table II Diagnostic grouping in all patients and in non-survivors

	Number (%)	
	All patients	Non-survivors
Gastrointestinal bleeding	44 (15)	4 (10)
Heart failure	38 (13)	3 (7.7)
Infection	29 (10)	12 (31)
Chronic obstructive airways disease	29 (10)	3 (7.7)
Cerebrovascular disease	29 (10)	7 (18)
Diabetes mellitus	21 (7)	-
Hypertension	18 (6)	-
Malignancy	9 (3)	4 (10)
Others	79 (27)	6 (15)
Total	296 (100)	39 (100)

Table III Variables that were significantly different in subjects who died compared with the 'survivors'

	<i>Survived</i>	<i>Died</i>	<i>P value</i>
Age (years)	64.0 (255) (16–97)	75.0 (39) (43–95)	0.001
Functional ability	1.0 (255) (1–3)	3.0 (39) (1–3)	0.0001
Mid arm circumference (cm)	25.0 (250) (14–36)	24.0 (39) (14–34)	0.0005
Biceps skinfold thickness (mm)	5.0 (250) (1–64)	3.0 (39) (1–18)	0.0004
Triceps skinfold thickness (mm)	13.0 (250) (2–35)	8.0 (39) (2–38)	0.0003
Arm muscle circumference (cm)	21.5 (250) (12.1–28.9)	20.1 (39) (12.7–26.2)	0.0063
Corrected arm muscle area (cm ²)			
Male	28.9 (133) (6.0–50.2)	22.8 (25) (5.8–44.6)	0.0011
Female	26.3 (117) (5.2–60.0)	21.6 (14) (6.3–40.1)	0.099
Systolic blood pressure (mmHg)	120.0 (250) (60–220)	130.0 (39) (80–220)	0.0138
Plasma urea (mmol/l)	7.1 (252) (2.3–92.0)	14.4 (39) (4.4–70.0)	0.0001
Plasma creatinine (μmol/l)	86.0 (248) (44–1233)	143.0 (36) (48–1289)	0.0001
Plasma albumin (g/l)	37.0 (245) (10–49)	32.5 (38) (16–46)	0.0001
Plasma alkaline phosphatase (IU/l)	66.0 (252) (23–566)	94.5 (38) (50–719)	0.0001
Total protein (g/l)	72.0 (246) (11.0–92.0)	74.2 (39) (45.0–99.0)	0.01
Plasma ALT (IU/l)	12.0 (252) (1–1227)	18.5 (38) (1–1840)	0.0059
Plasma albumin-adjusted calcium (mmol/l)	2.3 (245) (1.53–3.77)	2.4 (38) (1.43–3.18)	0.0005
Plasma phosphate (mmol/l)	1.0 (253) (0.11–3.11)	1.1 (38) (0.58–3.10)	0.0009
Plasma uric acid (mmol/l)	0.4 (254) (0.14–1.70)	0.6 (39) (0.20–1.50)	0.0001
Plasma glucose (mmol/l)	5.8 (254) (1.6–36.6)	8.4 (39) (3.3–31.0)	0.0001
Plasma ferritin (pmol/l)	338.0 (254) (15–9450)	1117.0 (39) (26–9999)	0.0000
Plasma vitamin B12 (pmol/l)	418.0 (250) (57–1606)	489.5 (30) (0–172)	0.0002
Plasma folate (μmol/l)	18.0 (250) (4–54)	13.5 (38) (0–40)	0.0022
Plasma transferrin (g/l)	2.0 (253) (0.40–3.66)	1.4 (38) (0.58–3.02)	0.0001
Plasma prealbumin (mg/l)	158.0 (253) (30–700)	91.0 (38) (30–368)	0.0020
Plasma retinol* (mg/l)	0.44 (222) (0.11–1.53)	0.31 (35) (0.10–1.00)	0.0035
Thiamin RBC TK activity (%)	8.7 (247) (0.1–42.2)	12.5 (37) (0.3–72.8)	0.0011
RBC count (× 10 ⁹ /dl)	4.4 (245) (1.32–7.28)	3.6 (38) (2.27–6.32)	0.0015
Haemoglobin (g/dl)	12.4 (245) (3.2–19.5)	10.5 (38) (5.7–18.9)	0.004
Haematocrit	0.3 (245) (0.10–0.55)	0.3 (38) (0.19–0.53)	0.0043

Table III continued

Table III (cont'd)

	Survived	Died	P value
Urine total protein/creatinine ratio (mg/mmol)	26.8 (252) (0.2–445)	27.3 (38) (1.4–386.7)	0.0005
Urine albumin creatinine ratio (mg/mmol)	25.5 (241) (2.0–974.7)	87.8 (38) (5.2–910.0)	0.0026
Urine NAG/creatinine ratio (IU/mmol)	34.5 (253) (2.3–899.2)	74.7 (38) (2.6–615.3)	0.0001
Urine potassium/creatinine ratio (mmol)	4.2 (255) (1.01–18.3)	4.4 (39) (1.77–12.42)	0.0059

*Variables not used in the logistic regression analysis. Results are given as median, sample size and range. Significance differences by Mann–Whitney *U*-test. Variables which were not significantly different were: diastolic BP, pulse rate, plasma sodium, potassium, bilirubin, calcium, magnesium, blood HbA1, plasma retinol-binding protein, red cell glutathione reductase and aspartate transaminase activity, MCV, MCH, urine calcium/creatinine ratio. Variables which were of borderline significance were: plasma copper, plasma zinc, plasma fructosamine, plasma cholesterol, MCHC, WBC count, urine sodium/creatinine ratio, urine RBP/Cr.

Table IV Results of stepwise multiple logistic regression using all variables in Table III as inputs

Variables	Coefficient	Standard error (S.E.)	Coefficient/ S.E.	P to remove
Urea	0.61E-01	0.22E-01	2.77	0.0032
Albumin-adjusted calcium	5.13	1.63	3.15	0.0008
Red cell transketolase activity (RTK)	0.70E-01	0.28E-01	2.47	0.0083
Total protein	0.50E-01	0.27E-01	1.86	0.0465
Alkaline phosphatase	0.76E-02	0.35E-02	2.15	0.0213
Functional ability	1.52	0.34	4.43	0.0000
Sex	0.51	0.26	2.01	0.01318
Constant	– 23.42	5.03	– 4.65	

Notes: (1) Model chi-square = 44.87, df = 7, *P* < 0.0001. Goodness of fit chi-square (Hosmer–Lemeshow) = 5.078, df = 8, *P* = 0.749. (2) Classification functions by linear discriminant analysis using the same seven variables:
 $D_S = 0.516 \text{ urea} + 111.713 \text{ albumin-adjusted calcium} + 0.967 \text{ total protein} - 0.022 \text{ alkaline phosphatase} - 0.252 \text{ functional ability} + 0.306 \text{ red cell transketolase activity} + 6.532 \text{ sex} - 170.348.$
 $D_D = 0.610 \text{ urea} + 116.85 \text{ albumin-adjusted calcium} + 1.001 \text{ total protein} - 0.010 \text{ alkaline phosphatase} + 1.094 \text{ functional ability} + 0.381 \text{ red cell transketolase activity} + 7.541 \text{ sex} - 192.9.$
A subject is classified as belonging to the death group if $D_D > D_S$.

marized in Table IV and the prediction equation is
 $\ln(O_d) = 0.0613 (\text{urea}) + 5.1313 (\text{albumin-adjusted calcium}) + 0.0699 (\text{transketolase activity}) + 0.0503 (\text{total protein}) + 0.00757 (\text{alkaline phosphatase}) + 1.523 (\text{ability}) + 0.513 (\text{sex}) - 23.42$

where O_d is the odds for death, which is defined as the probability for death given a set of particular prognostic characteristics of the variables included

in the model (*P*), divided by the probability for survival given the same characteristics ($1 - P$). The two sexes are coded as – 1 for female and 1 for male. Based on this model, the O_d was transformed into a conditional probability ($P = O_d / (1 + O_d)$). *P* was then used as a prognostic index to predict death as an outcome²⁷ for all the subjects in the study. The sensitivities and specificities by different cut-off points were plotted in Figure 1. The two curves intersect at the cut-off of *P* at 0.12, yielding equal

sensitivity and specificity of 80%. The cut-off of *P* at 0.242 was selected as it gives better specificity (90.7%) at the same sensitivity (80%).

The model fits the data well and the diagnostic statistics of the residuals (for example, normal probability of the deviances, plots of standardized residuals, leverage and change in coefficients) show no indication of outliers or violation of the model assumptions. Further support of the applicability of the prediction equation and the choice of the cut-off point comes from the reanalysis of the data by an independent statistical method. Using the same subjects, the same set of variables are all significant by discriminant analysis. The classification functions are listed in Table IV, they yield sensitivity of 82.9% and specificity of 86.3%, which are comparable to the figures given by the prediction equation with the chosen cut-off (80.0% and 90.7%).

The analysis was repeated using the common biochemical and haematological tests which are routinely done on most if not all patients on admission. Since RTK is not commonly available in routine laboratories, it was omitted. This ensures that the prediction equation has a wider basis for application and further reduces the number of parameters of the equation to six. The number of cases with missing data was also smaller than for Table IV. A total of 258 cases were available for analysis. Table V gives the results of the stepwise analysis and from this *P* of 0.175 was chosen as the cut-off value, which corresponds to sensitivity/specificity of 82.7% and specificity of 83.9%. Linear discriminant analysis using the same variables gives similar results (83.8%/84.1%).

Figure 1 Sensitivity (—) and specificity (----) of prognostic index at different cut-off values.

We have previously reported a prediction score which was based on elderly living in chronic care institutions.²⁸ This score was calculated for the present group of patients and the score was found to be significantly different between survivors and non-survivors (4.03 ± 0.22 ($n = 203$) in survivors vs 2.21 ± 0.76 ($n = 33$) in non-survivors). The distribution of this score is given in Table VI and the sensitivity and specificity of the score (a score value of 0) were 27% and 89% respectively.

Discussion

We have previously described the nutritional status of general medical patients²⁹ and found poor protein, energy and vitamin status especially in

Table V Results of stepwise regression model using the 17 'common' variables as inputs

Variables	Coefficient	Standard error (S.E.)	Coefficient/ S.E.	P to remove
Sex	0.54	0.25	2.16	0.0155
Functional ability	1.54	0.33	4.69	0.0000
Urea	0.68E-01	0.20E-01	3.44	0.0001
Total protein	0.51E-01	0.27E-01	1.88	0.0353
Alkaline phosphatase	0.84E-02	0.37E-02	2.31	0.0097
Albumin-adjusted calcium	3.52	1.34	2.62	0.0034
Constant	-19.01	4.33	-4.39	

Notes: (1) Common variables included were age, sex, ability, systolic blood pressure, urea, creatinine, total protein, albumin, alkaline phosphatase, ALT, albumin adjusted calcium, phosphate, uric acid, glucose, red cell count, haemoglobin and haematocrit. (2) Model chi-square = 41.53, $df = 6$, $P < 0.0001$. Goodness of fit chi-square (Hosmer-Lemeshow) = 5.917, $df = 8$, $P = 0.657$. (3) Classification functions by discriminant analysis using the same six variables:

$$D_s = 0.627 \text{ urea} + 104.433 \text{ albumin-adjusted calcium} + 0.960 \text{ total protein} - 0.024 \text{ alkaline phosphatase} + 0.099 \text{ functional ability} + 6.328 \text{ sex} - 160.737.$$

$$D_d = 0.734 \text{ urea} + 108.782 \text{ albumin-adjusted calcium} + 0.988 \text{ total protein} - 0.013 \text{ alkaline phosphatase} + 1.565 \text{ functional ability} + 7.400 \text{ sex} - 180.642.$$

A subject is classified as belonging to the death group if $D_d > D_s$.

Table VI Distribution of discriminant function score (Woo *et al.*, 1989²⁸) in survivors and non-survivors

Score	Number of subjects		% of subjects who had died
	Alive at 3 month	Death at 3 month	
-2.5	5	4	44
0	17	5	23
2.5	43	10	19
5.0	57	7	11
7.5	56	3	5
10.0	20	3	13
>10.0	5	1	17

those over 60 years of age. In the present study, we have examined the differences between those who died within 3 months and those who survived in an attempt to derive a prognostic index. Not surprisingly variables which are indicative of protein calorie malnutrition such as skinfold thickness, arm muscle circumference, plasma albumin, transferrin and prealbumin were significantly lower in non-survivors (Table III). In addition, plasma urea, creatinine and albumin-adjusted calcium were also significantly different, possibly reflecting the higher proportion of patients in medical wards with renal failure or neoplasm contributing to short-term mortality. When these many variables were included in the logistic regression analysis, none of the anthropometric measurements contributed to the prediction. This is in contrast to the studies in surgical patients^{7,11,12,17} and agrees with our previous study in elderly living in chronic care institutions²⁸ and with other studies especially those in the elderly.^{10,30}

When all the variables were included in the analysis, the nutritional parameter which contributed to the prediction model was thiamine status (percentage activation of red cell transketolase). None of the other nutritional parameters (for example, albumin, transferrin, prealbumin, plasma, copper, zinc, etc.) were found to be of significance. This finding is different from our previous observation in the elderly²⁹ and from other reports.^{7,8,10,12,13} There are differences in the characteristics of the patient population in different settings. Infection is a common cause of mortality among surgical patients and elderly residents of long-term care institutions, and nutritional status is important in

determining the susceptibility to infection and the outcome.³¹ Among patients in acute medical wards, there is probably a larger proportion with endstage disease such as renal and liver failure, or malignancy. This may account for the inclusion of urea, alkaline phosphatase, and plasma calcium as predictor variables in medical patients and not in surgical or long-term care institutional patients. This study highlights the need for different prognostic indices for different patient population groups.

In our previous study of elderly subjects in chronic care institutions apart from nutritional markers (transferrin, prealbumin and haemoglobin), fructosamine and glycosylated haemoglobin were found to predict mortality.²⁸ In this present study, data were available in 236 patients (203 survivors and 33 non-survivors). When the score derived from the previous study was applied to this group of patients, although it was significantly lower in non-survivors, the sensitivity was poor (27%). Using predictors consisting of functional ability, albumin-adjusted calcium, plasma urea, thiamine status, alkaline phosphatase, sex and total protein in that order, a much higher sensitivity (when a cut-off value of 0.242 was used) of 80% was obtained. When we reanalysed the data using only simple haematological and biochemical data, the resulting equation was equally good. Therefore, among patients in acute medical wards, a combination of simple bedside observations and routine biochemical tests are sufficient for predicting short-term mortality. Anthropometry and expensive biochemical tests are not needed. However, this does not imply that the nutritional status of these patients can be neglected, as this study only examines short-term mortality; other outcomes such as length of recovery, readmission frequency, or general well-being after discharge which may well be affected by nutritional status³² were not examined.

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References

1. Bistran, B.R., Blackburn, G.L., Hallowel, E. & Heddle, R. Protein status of general surgical patients. *JAMA* 1974, **230**: 858-860.

2. Wood, B., Kelleher, D., Lo, L. *et al.* Nutritional status in hospital inpatients: implications for nutritional support services. *Aust NZ J Med* 1985, **15**: 435-441.

3. Bistrian, B.R., Blackburn, G.L., Vitale, J. & Cockrane, D. Prevalence of malnutrition in general medical patients. *JAMA* 1976, **235**: 1567–1570.
4. Hill, G.L., Pickford, I., Young, G.A. *et al.* Malnutrition in surgical patients. An unrecognised problem. *Lancet* 1977, **1**: 689–692.
5. Steffee, W.P. Malnutrition in hospitalized patients. *JAMA* 1980, **244**: 2630–2635.
6. Elmståhl, S. Hospital nutrition in geriatric long-stay medicine, Thesis, University of Lund, Sweden, 1987.
7. Dempsey, D.T., Buzby, G.P. & Mullen, J.L. Nutritional assessment in the seriously ill patient. *J Am Coll Nutr* 1983, **2**: 15–22.
8. Lowe, E.F., Stein, M., Woolley, T., Waycaster, M. *et al.* Prognostic nutritional index: its usefulness as a predictor of clinical course. *J Am Coll Nutr* 1983, **2**: 231–240.
9. Freeman, M., Frankmann, C., Beck, J. & Valdivieso, M. Prognostic nutrition factors in lung cancer patients. *JPEN* 1982, **6**: 122–127.
10. Harvey, K.B., Moldawer, L.L., Bistrian, B.R. & Blackburn, G.L. Biological measures for the formulation of a hospital prognostic index. *Am J Clin Nutr* 1981, **34**: 2013–2022.
11. Buzby, G.P., Mullen, J.L., Matthews, D.C., Hobbs, C.L. & Rosato, E.F. Prognostic nutritional index in gastrointestinal surgery. *Am J Surg* 1980, **139**: 160–167.
12. Phillips, P. Grip strength, mental performance and nutritional status as indicators of mortality risk among female geriatric patients. *Age Ageing* 1986, **15**: 53–56.
13. Bozzetti, F., Migliavacca, S., Gallus, G. *et al.* 'Nutritional' markers as prognostic indicators of postoperative sepsis in cancer patients. *JPEN* 1985, **9**: 464–470.
14. Leite, J.F., Antunes, C.F., Monteiro, J.C. & Pereira, B.T. Value of nutritional parameters in the prediction of post-operative complications in elective gastrointestinal surgery. *Br J Surg* 1987, **74**: 426–429.
15. Bland, B.D. & Shoemaker, W.C. Probability of survival as a prognostic and severity of illness score in critically ill surgical patients. *Crit Care Med* 1985, **13**: 91–95.
16. Braga, M., Baccari, P., Scaccabarozzi, S. *et al.* Prognostic role of preoperative nutritional and immunological assessment in the surgical patient. *JPEN* 1988, **12**: 138–142.
17. Kalfarentzos, F., Spiliotis, J., Velimezis, G., Dougenis, D. & Androulakis, J. Comparison of forearm muscle dynamometry with nutritional prognostic index, as a preoperative indicator in cancer patients. *JPEN* 1989, **13**: 34–36.
18. Kudlackova, M., Andel, M., Hajkova, H. & Novakova, J. Acute phase proteins and prognostic inflammatory and nutritional index (PINI) in moderately burned children aged up to 3 years. *Burns* 1990, **16**: 53–56.
19. Smale, B.F., Mullen, J.L., Buzby, G.P. & Rosato, E.F. The efficacy of nutritional assessment and support in cancer surgery. *Cancer* 1981, **47**: 2375–2381.
20. Goodwin, W.J. Jr & Torres, J. The value of the prognostic nutritional index in the management of patients with advanced carcinoma of the head and neck. *Head Neck Surg* 1984, **6**: 932–937.
21. Jones, T.N., Moore, E.E. & Vanway, C. Factors influencing nutritional assessment in abdominal trauma patients. *JPEN* 1983, **7**: 115–116.
22. Heymsfield, S.B., McManus, C., Smith, J., Stephens, V. & Nixon, D.W. Anthropometric measurement of muscle mass: revised equations for calculating bone-free muscle mass area. *Am J Clin Nutr* 1982, **36**: 680–690.
23. Cheung, C.K. & Swaminathan, R. Automated immunoturbidimetric methods for the determination of retinol binding protein, prealbumin and transferrin in urine. *Clin Biochem* 1989, **22**: 425–427.
24. Cheung, C.K., Yeung, V.T.F., Cockram, C.S. & Swaminathan, R. Urinary excretion of albumin and enzymes in non-insulin-dependent Chinese diabetes. *Clin Nephrol* 1990, **34**: 125–130.
25. Mak, Y.T. & Swaminathan, R. Assessment of vitamin B₁, B₂ and B₆ status by coenzyme activation of red cell enzymes using a centrifugal analyser. *J Clin Chem Clin Biochem* 1988, **26**: 213–217.
26. Woo, J., Ho, S.C., Mak, Y.T., Shek, C.C. & Swaminathan, R. Vitamin A and E status in healthy elderly Chinese in Hong Kong. *Eur J Clin Nutr* 1988, **42**: 689–695.
27. Brown, B.W. Jr. Prediction analysis for binary data. In: Miller, R.G., Efron, B., Brown, B.W. & Moses, L.W. (eds) *Biostatistics Casebook*. Wiley, New York, 1980.
28. Woo, J., Chan, S.M., Mak, Y.T. & Swaminathan, R. Biochemical predictors of short term mortality in elderly residents of chronic care institutions. *J Clin Path* 1989, **42**: 1241–1245.
29. Woo, J., Mak, Y.T. & Swaminathan, R. Nutritional status of general medical patients. Influence of age and disease. *J Nutr Biochem* 1991, **2**: 274–280.
30. Kergoat, M.-J., Leclerc, B.S., Petit Clerc, C. & Imback, A. Discriminant biochemical markers for evaluating the nutritional status of elderly patients in long term care. *Am J Clin Nutr* 1987, **46**: 849–861.
31. Chandra, R.K. Nutritional regulation of immunocompetence and risk of infection in old age. *Immunology* 1989, **67**: 141–147.
32. Williams, C.M., Lumbers, M. & Driver, L.T. Nutritional demands during rehabilitation from acute illness. *Geriatr Med* 1990, **20**: 13–16.