Classification of Protein-calorie Undernutrition in Children

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Since the first description of kwashiorkor by Williams (1935), this condition has been found to be prevalent in many economically backward countries. Nevertheless, the minimum criteria for the diagnosis of kwashiorkor have never been agreed. Brock and Autret (1952) accepted a diagnosis of kwashiorkor if there was retarded growth, alterations in skin and hair pigmentation, oedema, fatty infiltration, cellular necrosis, or fibrosis of the liver, and a high mortality in the absence of improved protein in the diet. The essential characteristics, according to Trowell, Davies, and Dean (1954), were subnormal weight, oedema, mental apathy, frequent stools, dyspigmentation of the hair, and enamel-paint dermatosis; while according to Jelliffe (1955), they were growth failure, mental change, oedema, liver change, gastro-intestinal disorder, dyspigmentation, dermatosis, anaemia, and variable avitaminoses.

Marasmic infants, on the other hand, are described as grossly underweight, with atrophy of muscle and subcutaneous fat, and with shrunk, wizened face. There are no hair and skin changes and oedema is minimal (Barness, 1964; Vitteri, Béhar, and Arroyave, 1964).

A third category of protein-calorie malnutrition in children is recognized by some and variously designated as marasmic kwashiorkor or atrophic kwashiorkor (Venkatachalam, 1964): these children are supposed to have the signs of both kwashiorkor and marasmus in variable measure.

It is easy to recognize and diagnose classical cases of either kwashiorkor or of marasmus, but there is considerable difference of opinion about the diagnosis of this third variety of protein-calorie undernutrition of children. Some would diagnose all oedematous children suffering from protein-calorie malnutrition as kwashiorkor (Nicholls, Sinclair, and Jelliffe, 1961; Vitteri *et al.*, 1964), believing that the skin and hair changes are not invariably present in

this syndrome, and that a fatty liver is not necessarily clinically enlarged.

We suggest here certain criteria for the diagnosis of kwashiorkor and marasmus. It is also proposed that a third variety of protein-calorie undernutrition in children be named *nutritional oedema*.

Material and Methods

The proposed classification is based on systematic observations on 87 children, aged 6 months to 4 years, admitted to the Institute of Child Health, Calcutta, for treatment of primary protein-calorie undernutrition. The dietetic histories were taken by a single observer and the calculations were based on the average intake for three days before hospitalization. Calories and protein were calculated from standard food tables (Aykroid, Gopalan, and Balasubramanian, 1963). The biochemical methods are standard, with some modifications (Uma Ganguly, K. K. Chatterjee, and K. L. Mukherjee, unpublished observations, 1967).

Dietetic Findings in Different Forms of Protein-calorie Undernutrition

The 87 children were classified as kwashiorkor, marasmus, or nutritional oedema, partly on a basis of the dietetic history and partly on the clinical and biochemical findings. In Table I the number of children in each of the three groups is given, together with the average composition of the daily diet received by the children in each group.

Diagnostic Features of Different Forms of Protein-calorie Undernutrition

Kwashiorkor

Dietetic history. The diet leading to kwashiorkor is characterized by a high carbohydrate and very low protein and fat content (Table I). The average consumption of calories was 80 cal./kg., and of protein, 0.25 g./kg. The calorie intake was slightly less than 80% of the recommended intake per kg. body weight, and one-third of the intake of a

TABLE I

Average Composition of Daily Diet in 87 Children with Kwashiorkor, Marasmus, or Nutritional Oedema

Diagnosis	No. of Children	Calories	Protein (g.)	Fat (g.)	Carbohydrates (g.)
Kwashiorkor	40	320	1.0	0.8	76
Marasmus	32	120	1.6	1.1	26
Nutritional oedema	15	175	2.0	3.9	33

normal baby of that age. Carbohydrates contributed more than 95% of the calories, and protein only 1.3%. Thus the diet in kwashiorkor contains excessive carbohydrate, while the calorie intake per kg. body weight is only slightly below normal. Whether excess carbohydrate intake in the presence of protein deficiency is toxic by itself and is responsible for some of the classical signs of kwashiorkor has yet to be determined.

Growth failure. Children suffering from kwashiorkor have growth failure and loss of weight. The two are not synonymous (Platt, Heard, and Stewart, 1964): growth failure implies a cessation or retardation of dimensional growth of all tissues of the body including the skeleton, while loss of weight indicates a breakdown of tissues already formed. Cellular breakdown does not necessarily involve a complete dissolution of the cells but only a leeching of cellular material, such as protein (Waterlow, 1956) and ribonucleic acid. Kwashiorkor is an explosive process, and growth failure has therefore not been present long enough to be conspicuous. That is probably the reason why in kwashiorkor the different organs are not unduly small relative to the actual weight of the baby (H. Pal and K. L. Mukherjee, unpublished observations, 1967), and why the delay in the appearance of ossification centres is less than in marasmus or nutritional oedema, where the process of protein-calorie malnutrition is more chronic and prolonged (S. K. Bose, R. N. Saikia, and K. L. Mukherjee, unpublished observations, 1965).

Loss of weight in kwashiorkor is profound, but again involves different tissues unequally. The muscle mass bears the brunt of the malnutrition and becomes reduced in amount; it is doubtful whether the number of muscle cells is reduced, rather, the individual cells are depleted of protein. The liver is not unduly small, and may even be heavier than normal if the weight is expressed per kg. body weight.

Presence of oedema. Oedema is invariably present in kwashiorkor, is generalized, and is gravity-dependant. Ascites may be present and in some cases hydrothorax. The oedema fluid is transudate in type, protein content being less than 0.15%.

Fatty liver. Fatty liver is a constant manifestation of kwashiorkor. Of 40 patients, 34 had clinical enlargement of the liver to more than 2 cm. below the costal margin at the midclavicular line on the right side, the liver being smooth, firm, and not tender. All the livers, regardless of whether they were clinically enlarged or not, were fatty, the fat content varying from 25 to 40% of the wet weight. The average weight of the liver at necropsy was 88 g./kg. (H. Pal and K. L. Mukherjee, unpublished observations, 1967), the normal weight for this age being less than 50 g./kg.

Skin changes. In kwashiorkor there are always some skin changes, though they may not be conspicuous. In most instances the dermatoses are of the usual flaky paint type, but in some the changes may be confined to small petechial-like spots around hair follicles, especially over the extremities and the front of the lower trunk. The skin is thin and in extreme cases the epidermis peels off leaving raw exposed areas.

Hair changes. It is rare for any kwashiorkor patient to be without hair changes. The hair is sparse, silken, dyspigmented, becoming in some cases golden. In extreme cases there may be alopecia.

Subcutaneous fat. In kwashiorkor the amount of subcutaneous fat is moderate. In patients in whom there is no oedema of the abdominal wall, the amount of subcutaneous fat can best be assessed by examination of the abdominal wall about 2 cm. above the umbilicus. The amount of subcutaneous fat in the anterior abdominal wall was estimated by extraction of weighed pieces of subcutaneous tissues from the same site in necropsies of kwashiorkor and marasmus patients. The fat content per g. tissue was 200 times greater in kwashiorkor than in marasmus (H. Pal and K. L. Mukherjee, unpublished observations, 1967). We have noted that the fatty liver of protein-calorie under-nutrition is consistently associated with the presence of a moderate amount of subcutaneous fat, but it is uncertain whether they are causally related.

Vitamin deficiencies. In kwashiorkor signs of vitamin deficiencies, such as keratitis, keratomalacia, glossitis, and cheilosis, are commonly found.

Marasmus.

Dietetic history. The diet leading to marasmus is low in both calories and protein (Table I). The child eats less because of unavailability of food and also because of poor appetite.

The average consumption of calories was 33 cal./kg., and of protein 0.45 g./kg. The calorie intake was less than one-third of the recommended intake per kg. body weight and less than one-eighth of the intake for a normal baby of that age. The difference in the dietetic intakes in kwashiorkor and marasmus was impressive. Whereas the calorie intake per kg. body weight in kwashiorkor was not very low, in marasmus it was only one-third of the requirement, while the protein intake in kwashiorkor was half of that in marasmus.

Growth failure. There is a profound growth failure in marasmus, but the pattern of growth failure in marasmus is different from that in kwashiorkor (S. K. Bose, R. N. Saikia, and K. L. Mukherjee, unpublished observations, 1965). The skeletal age is more retarded, the thickness of the long bones is less, and the zone of provisional calcifications less well developed in marasmus than in kwashiorkor. Loss of weight is extreme and all the organs are small and shrunken.

Oedema. This is absent in marasmus.

Liver. There is no fatty liver in marasmus. The organ is small, and shrunken, and because it is so small, needle biopsies often fail. The average weight of the liver at necropsy was found to be 33 g./kg. (normal at this age, about 50 g./kg.).

Skin changes. Usually there are no changes in the skin except thinning of the epidermis and, in some cases, scaliness. There is no flaky paint dermatoses like those seen in kwashiorkor.

Hair changes. These are absent in marasmus, apart from slight silkiness and sparseness of the hair in some cases.

Subcutaneous fat. Subcutaneous fat is virtually non-existent.

Vitamin deficiencies. It is rare to find keratitis and keratomalacia, perhaps because almost complete cessation of growth diminishes vitamin A requirements.

Nutritional oedema.

Dietetic history. The average consumption of calories was 36 cal./kg. and of protein 0.41 g./kg. The diet closely resembles the diet in marasmus, and differs from kwashiorkor in having a smaller calorie and a higher protein intake per kg. body weight.

Growth failure. As in marasmus, there is profound growth failure in nutritional oedema involving retardation of dimensional growth and loss of weight. The loss of weight involves all the tissues of the body, and though the extracellular fluid is expanded, the body weight averages less than 40% of the expected weight.

Oedema. Oedema is the prominent feature in this condition, and in extreme cases there may also be hydrothorax or ascites.

Fatty liver. There is a slight accumulation of fat, mostly around the portal tract. The fat content of the liver has varied from 6 to 10%. The average weight of the liver at necropsy was 48 g./kg. (H. Pal and K. L. Mukherjee, unpublished observations, 1967) (normal for this age about 50 g./kg.).

Skin changes. As in marasmus, there is no skin change except thinning of the epidermis and perhaps some scaliness. Crazy-pavement dermatosis is absent.

Hair changes. Usually there are no hair changes except slight silkiness and sparseness of the hair in some cases.

Subcutaneous fat. This is virtually absent.

Vitamin deficiencies. These are rarely found.

The physical findings in these three syndromes of protein-calorie undernutrition of children are summarized in Table II. Besides different physical

TABLE II

Physical Findings in Kwashiorkor, Marasmus, and Nutritional Oedema

	Kwashiorkor	Marasmus	Nutritional Oedema
Diet deficient in calories	+	+++	+++
Diet deficient in protein	+++	+++	+++
Growth failure	++	+++	+++
Oedema	++	Nil	++
Liver	Enlarged and fatty	Shrunken, not fatty	Not grossly fatty
Crazy pavement dermatoses	Present	Absent	Absent
Dyspigmentation of hair	Present	Absent	Absent
Subcutaneous fat	Present	Absent	Absent
Associated vitamin deficiencies	Present	Absent	Absent

+ = mild; ++ = moderate; +++ = marked.

TABLE III

Biochemical Findings in Kwashiorkor, Marasmus, and Nutritional Oedema*

	Kwashiorkor	Marasmus	Nutritional Oedema
Serum protein	Reduced	Normal	Reduced
Plasma lipids	Increased	Slightly low	Low
Blood glucose	Reduced	Normal	Normal
Plasma non-esterified fatty acids	Increased	Normal	Increased
Liver fat	Increased	Normal	Increased
Liver protein	Reduced	Normal	Reduced
Liver water	Reduced	Normal	Normal
Liver glycogen	One-third normal	Normal	Much reduced
Liver glucose-phosphatase	Normal	Very low	Low

* Uma Ganguly and K. L. Mukherjee, unpublished observations, 1967; H. Pal and K. L. Mukherjee, unpublished observations, 1967.

findings there are also chemical differences in the three syndromes of protein-calorie undernutrition, and we have briefly summarized those recorded in our studies in Table III.

Discussion

There have been attempts from time to time to consider protein-calorie malnutrition in children as a single entity, the three conditions of kwashiorkor, marasmic kwashiorkor, and marasmus being related to the age of the patient, the degree of dietetic deprivation, and the period of such deprivation (Scrimshaw and Béhar, 1961). However, there is no instance of a marasmic baby developing fully fledged kwashiorkor, while the experiment of feeding a marasmic baby a high-calorie low-protein diet has not been done, nor would it be ethical to do so. The facts here assembled are more logically interpreted on a basis of kwashiorkor and marasmus being separate entities, distinct in aetiology, physical manifestations, and biochemical findings.

The third variety of protein-calorie malnutrition, *nutritional oedema*, should also be considered a separate variety of protein-calorie malnutrition of children, rather than a mixture of kwashiorkor and marasmus. It is distinguished from kwashiorkor by the absence of subcutaneous fat, with no skin changes, no mental changes, no hypoglycaemia, low plasma lipids, and distinctive liver changes. It is distinguished from marasmus by the presence of oedema, hypoproteinaemia, increased non-esterified fatty acids, and distinctive liver changes. The term 'marasmic kwashiorkor' for this condition is inappropriate, for it would signify that the syndrome is primarily one of kwashiorkor with some added manifestations of marasmus, whereas there are few similarities between kwashiorkor and nutritional oedema except oedema and hypoproteinaemia. Although kwashiorkor in India was called 'nutritional oedema syndrome' by Venkatachalam, Srikanthia, and Gopalan (1954), these authors did

not distinguish between classical kwashiorkor and nutritional oedema, as is here proposed. Nutritional oedema, as here defined, is seen to resemble marasmus closely in dietetic history and in physical findings, except for the presence of oedema. We believe that when a marasmic child is subjected to some prolonged stress, such as diarrhoea, it develops hypoproteinaemia and oedema.

General acceptance of the suggested classification of the various syndromes of protein-calorie undernutrition in children would greatly facilitate comparison of findings by workers in different parts of the world.

Summary

On a basis of dietetic history, and of physical and biochemical findings in 87 cases of protein-calorie undernutrition in children, three distinct syndromes are defined, kwashiorkor, marasmus, and nutritional oedema.

REFERENCES

- Aykroid, W. R., Gopalan, C., and Balasubramanian, S. C. (1963). *The Nutritive Value of Indian Foods and the Planning of Satisfactory Diets*, 6th ed., p. 49. (Spec. Rep. Ser. no. 42.) Indian Council of Medical Research, New Delhi.
- Barness, L. A. (1964). Nutritional disturbances. In *Textbook of Pediatrics*, ed. W. E. Nelson, p. 408. W. B. Saunders, Philadelphia and London.
- Brock, J. F., and Autret, M. (1952). Kwashiorkor in Africa. *Wld Hlth Org. Monogr. Ser.*, 8, 8.
- Jelliffe, D. B. (1955). Infant nutrition in subtropics and tropics. *ibid.*, 29, 99.
- Nicholls, L., Sinclair, H. M., and Jelliffe, D. B. (1961). *Tropical Nutrition and Dietetics*. Baillière, London.
- Platt, B. S., Heard, C. R. C., and Stewart, R. J. C. (1964). Experimental protein deficiencies. In *Mammalian Protein Metabolism*, ed. H. N. Munro and J. B. Allison, Vol. 2, p. 445. Academic Press, New York and London.
- Scrimshaw, N. S., and Béhar, M. (1961). Protein malnutrition in young children. *Science*, 133, 2039.
- Trowell, H. C., Davies, J. N. P., and Dean, R. F. A. (1954). *Kwashiorkor*, p. 116. Arnold, London.
- Venkatachalam, P. S. (1964). In discussion to Widdowson, E. M. Early nutrition and later development. In *Diet and Bodily Composition* (Ciba Foundation Study Group No. 17),

- ed. G. E. W. Wolstenholme and M. O'Connor, p. 16. J. & A. Churchill, London.
- , Srikantia, S. G., and Gopalan, C. (1954). Clinical features of nutritional oedema syndrome in children. *Indian J. med. Res.*, **42**, 555.
- Vitteri, F., Béhar, M., and Arroyave, G. (1964). Clinical aspects of protein malnutrition. In *Mammalian Protein Metabolism*, ed. H. N. Munro and J. B. Allison, Vol. 2, p. 523. Academic Press, New York and London.
- Waterlow, J. C. (1956). The protein content of liver and muscle as a measure of protein deficiency in human subjects. *W. Indian med. J.*, **5**, 167.
- Williams, C. D. (1935). Kwashiorkor, a nutritional disease of children associated with a maize diet. *Lancet*, **2**, 1151.