Hair Growth in Kwashiorkor

R. T. SIMS*

From the Department of Paediatrics and Child Health, University of Natal, Durban, S. Africa

The hair shaft is a dead structure composed of proteins. It is formed from cells which are generated in the matrix of the hair bulb and move towards the skin surface. As the cells of the hair cortex migrate from the matrix to the fully keratinized region of the hair they rapidly synthesize and accumulate proteins (Sims, 1964). Any factor that depresses the rate at which cells in general synthesize proteins could produce changes in hair growth by lowering the mitotic rate of cells in the hair matrix, and by reducing the amount of protein accumulated in the cortical cells. A survey of 100 patients in a hospital in Britain showed that illness—especially haemorrhage from a peptic ulcer—can be associated with a reduction of hair shaft diameter (Sims, 1967).

Kwashiorkor is a disease of infancy and early childhood associated with protein malnutrition (Williams, 1933), hypoalbuminaemia (Gillman and Gillman, 1951), and low concentrations of serum amino acids (Edozien, Phillips, and Collis, 1960). It would be reasonable to expect each of these three features to be linked with a low rate of protein synthesis in other tissues of the body. The purpose of this investigation was to make quantitative estimates of the changes in hair growth found in children with kwashiorkor, and to relate them to the rate of protein synthesis of tissues in general.

Hård (1963) has shown that anaemia and a low serum iron concentration may be present in women with diffuse loss of hair, so a relation was sought between these variables and hair growth changes in the kwashiorkor patients, as anaemia is usually present in this condition (Trowell, Davies, and Dean, 1954).

Material and Methods

Specimens of hair were taken from 24 Zulu children admitted to the King Edward VIII Hospital, Durban. 12 of these were in the Paediatric Unit suffering from kwashiorkor and 12 were boarders at the hospital receiving physiotherapy for post-poliomyelitic paralysis of various muscles.

Received October 7, 1966.

* Present address: Anatomy School, University of Cambridge, Downing Street, Cambridge.

The diagnosis of kwashiorkor was made by two paediatricians, Dr. Joan Scragg and Dr. B. T. Naidoo, and myself. The criteria used for the clinical diagnosis were (1) a history of a diet deficient in protein, (2) oedema associated with hypoalbuminaemia, (3) mental changes of apathy and irritability, (4) the dermatosis of kwashiorkor, and (5) retarded growth. A detailed survey of the clinical features of kwashiorkor at the King Edward VIII Hospital has been published by Scragg and Rubidge (1960). All investigations were made within 24 hours of the patient's admission to the Unit, to minimize any possible effects from treatment.

The problem of finding suitable controls for these observations was a difficult one. For various cultural reasons it is not possible to assume that Zulu infants enjoy an adequate balanced diet even in prosperous families. The only group of children known to be free of active disease and on an adequate balanced diet are boarders at the hospital receiving physiotherapy. They live at the hospital because their homes are too far away for them to make daily visits as out-patients. The control patients were selected to match the sex and age of the kwashiorkor patients as closely as possible.

A sample of hair was plucked from each patient's scalp in the region of the vertex. Care was taken not to deform the shaft during plucking and handling. Observations were made on three actively growing hairs from each subject. The hair bulb and adjacent 5 mm. of shaft were cut from the rest of the hair with scissors. The hair bulb was then inserted between the stylet and inner surface of a hypodermic needle on a syringe. The plunger of the syringe was clamped so that the barrel, needle, and hair could be rotated. The largest and smallest diameters of the hair shaft just above the level of the follicle were measured at a magnification of 60 × with an ocular micrometer in a Watson Bactil microscope. Calibration of the ocular micrometer showed that one division corresponded to 11 μ.

A circular area of scalp about 3 cm. in diameter was shaved in the region of the bregma so that no hair was visible above the skin surface. To determine the time taken for hair growth to begin, the area was examined daily until hair was palpable and visible. Then the length of hair grown in 10 days from the day hair was first detected, was measured with a hand lens (focal length 5 cm.) and an ocular micrometer. The micrometer was engraved with a square with sides 1 cm. long and divided into millimetres. Measurements were made to the nearest 0.25 mm.

On the day of their admission a sample of blood was

taken from the patients with kwashiorkor for the estimation of Hb, serum albumin, serum globulin, and serum iron. The methods used were: Hb by the cyanmethaemoglobin method with Drabkin's reagent; serum albumin and globulin by electrophoresis as described by Joubert, Hookins, and Hunter (1959); and serum iron by the method of Bothwell and Mallett (1955).

Results

The well-known phenomenon that plucking hair from the scalp requires little effort and causes no discomfort to kwashiorkor patients was experienced in the present study. It was difficult to pluck hair from the control group of patients because the force required to pull a hair out of the scalp was often greater than that required to make the hair slip through the fingers.

The main observations are presented in Tables I, II, and III. Table I gives the number, sex, and age of the 12 control patients with the largest and smallest diameters of 3 hairs, the number of days after the shave with no hair growth, and the length of hair grown in 10 days. The 95% confidence intervals for the means of the hair diameters are

$77 \pm 6\mu$ and $39 \pm 1\mu$, and that for the length of hair grown in 10 days 2.3 ± 0.125 mm.

Table II gives the number, sex, and age of the 12 kwashiorkor patients with the largest and smallest diameters of 3 hairs, the number of days after admission with no hair growth, and the length of hair grown in the succeeding 10 days. The 95% confidence intervals for the means of the hair diameters are $50 \pm 6\mu$ and $29 \pm 3\mu$ and that of the length of hair grown in 10 days 1.3 ± 0.3 mm.

Table III gives the results of the estimations of Hb, serum iron, serum albumin, and serum globulin on the blood of kwashiorkor patients.

Discussion

The ease with which hair can be plucked from kwashiorkor patients is a common feature of the disease. Although the exact mechanism for the retention of hairs in their follicles is not known, it must depend upon structures composed of proteins, as there is no other structural compound present in follicles. It follows that ease of plucking in this disease is probably a consequence of reduced

TABLE I
Hair Diameter and Rate of Hair Growth in Controls

Control No., Sex, and Age (yr.)	Diameters of 3 Hairs (μ)		Hair Growth	
	Largest	Smallest	No. of Days After Shave With No Growth	Length of Hair Grown in 10 Days (mm.)
P1 F 5	88	55	0	2.25
	88	55		
	88	44		
P2 M 2	99	44	0	2.0
	110	44		
	88	44		
P3 F 2	66	33	0	2.5
	66	33		
	66	44		
P4 M 3	66	33	0	2.25
	66	33		
	66	33		
P5 F $1\frac{1}{2}$	66	33	0	2.5
	66	33		
	55	33		
P6 F 2	88	33	0	2.5
	88	44		
	77	33		
P7 M 2	55	22	0	2.0
	66	33		
	66	33		
P8 M $1\frac{1}{2}$	88	55	0	2.5
	66	33		
	88	44		
P9 F 2	88	44	0	2.25
	99	44		
	77	33		
P10 M 2	88	33	0	2.5
	66	33		
	55	44		
P11 F 1	66	33	0	2.25
	55	33		
	55	33		
P12 M 2	55	33	0	2.5
	55	33		
	55	33		
Mean $\pm$ standard deviation	77 ± 15	39 ± 3		2.3 ± 0.2

TABLE II
Hair Diameter and Rate of Hair Growth in Cases of Kwashiorkor

Case No., Sex, and Age (yr.)	Diameters of 3 Hairs (μ)		Hair Growth	
	Largest	Smallest	No. of Days After Admission With No Growth	Length of Hair Grown in Next 10 Days (mm.)
1 F 6	66 33 22	33 22 22	5	1.25
1 F 3	44 44 55	33 33 33	5	2.5
3 F 2	44 44 55	22 22 22	5	1.25
4 M 5	88 55 77	55 33 44	0	2.0
5 F 1½	77 33 55	44 22 33	0	2.0
6 F 1½	44 44 44	22 22 33	3	1.0
7 M 2	44 44 44	33 22 33	4	1.0
8 M 1½	33 44 44	22 22 33	21	1.0
9 F 2	55 33 55	33 22 33	4	1.0
10 M 2	66 44 55	33 22 33	0	1.0
11 F 2	44 55 44	22 44 22	0	1.0
12 M 2	33 22 66	22 22 44	2	1.0
Mean $\pm$ standard deviation	50 $\pm$ 17	29 $\pm$ 9		1.3 $\pm$ 0.5

TABLE III
Levels of Albumin, Globulin, Hb, and Iron in Kwashiorkor Patients

Case No.	Serum Albumin (mg./100 ml.)	Serum Globulin (mg./100 ml.)	Hb (g./100 ml.)	Serum Iron (μ g./100 ml.)
1	1.3	3.0	7.3	492
2	1.9	2.2	8.5	87
3	2.1	2.2	8.9	73
4	1.4	2.7	8.1	55
5	2.1	2.0	9.4	38
6	2.5	1.9	9.6	152
7	1.1	2.6	8.7	41
8	1.0	2.9	5.2	35
9	2.3	2.3	7.9	87
10	2.2	2.7	8.9	35
11	1.8	2.6	9.2	32
12	1.5	2.7	9.0	36

protein synthesis in the skin, though abnormalities in the types of proteins synthesized cannot be eliminated.

The 95% confidence intervals of the longest and shortest diameters of the hairs taken from the patients with kwashiorkor are $50 \pm 6\mu$ and $29 \pm 3\mu$, as compared with $77 \pm 6\mu$ and $39 \pm 1\mu$ respectively for the controls. The confidence intervals for the kwashiorkor patients are well below those for the controls, so it is concluded that the hair of

kwashiorkor patients is significantly thinner than the hair of the control patients. As this applies to both the largest and smallest diameters the area of cross-section of hair is reduced in kwashiorkor.

Scatter diagrams were plotted separately of the largest and smallest hair diameters shown in Table II against the concentrations of serum albumin, serum globulin, Hb, and serum iron shown in Table III. In all the diagrams there is a wide scatter of the points plotted and no discernible trend suggestive of

an association between hair diameter and the other variables. Therefore, it is unlikely that the changes in hair diameter are secondary to the changes in levels of Hb, serum proteins, and serum iron.

It is clear, from the measurements recorded in Tables I and II, that there is a gross reduction in the rate of hair growth in the kwashiorkor patients, even while they are recovering under treatment. No detectable growth occurred for 2 days or more in 8 of the 12 kwashiorkor patients, while growth occurred immediately in all 12 control patients. In one kwashiorkor patient no hair growth occurred for 21 days after admission to the unit, in spite of the fact that he was recovering from the condition.

The results show that both the area of cross-section and the rate of increase in length of hairs are reduced in kwashiorkor. Since the product of these two variables gives the rate of increase in volume of hairs, an estimate of the change in this parameter can be made. With the assumption that the hairs are elliptical on cross-section, the average volume of each growing hair produced per day by the well-fed controls is $514\mu^3$ and that for the kwashiorkor patients on admission is about $59\mu^3$. The low figure for the kwashiorkor patients reflects the fact that no measurable hair growth was found in 8 of them on admission.

From a consideration of the cell dynamics of hair growth, it has been shown that the volume of hair produced in unit time (V_t) can be expressed by the equation $V_t = Q \times V_m \times R_m \times I_v$, where Q is the proportion of matrix cells entering the hair shaft proper, V_m is the volume of the hair matrix, R_m is the proportion of matrix cells that divide in unit time, and I_v is the relative increase in cell volume (Sims, 1965). Changes in all of the variables on the right-hand side of the equation could contribute to the gross depression of hair growth in kwashiorkor.

Hair is composed almost entirely of proteins, so a reduction of hair growth denotes a reduction of protein synthesis by hair follicles. The full significance of the complete arrest of hair growth is emphasized by the results of animal experiments. Mitchell, Kammlade, and Hamilton (1928) found that sheep kept in continuous negative nitrogen balance for over 200 days lost 20% of their body weight but grew wool in normal amounts and composition. The wool protein must have been obtained by raiding the proteins of other tissues, so that wool growth was independent of food intake. Löwenthal and Montagna (1955) found that when the food intake of mice was reduced by half, growing hair continued to grow without any change.

In view of these findings the present observations indicate either that the amount of protein in the

patients' diet was desperately low for a long period, or that some special metabolic disturbance that depresses hair growth supervenes in kwashiorkor. This aspect of the problem merits further study, because Gillman and Gillman (1951) have suggested that a nutritionally-based endocrine imbalance could be implicated in the metabolic disturbances of advanced kwashiorkor.

Summary

Measurements were made of hair diameters and rate of hair growth in 12 well-fed controls and 12 kwashiorkor patients.

The average volume of hair each follicle produces in a day was $514\mu^3$ for the controls and $59\mu^3$ for the kwashiorkor patients.

This gross reduction of hair growth reflects a profound depression of protein synthesis in kwashiorkor, implying either a long period on a low protein diet, or perhaps some underlying endocrine imbalance of nutritional origin.

I wish to thank Dr. T. Gillman of the A.R.C. Experimental Pathology Department, Babraham, for bringing this problem to my attention and for his valuable advice throughout the progress of this work; Professor H. L. Wallace for permission to undertake this work in his Department; Dr. Joan Scragg for allowing me to study patients under her care; and Professor E. B. Adams for laboratory facilities.

The work was performed during the tenure of a Wellcome Trust Research Travel Grant.

REFERENCES

- Bothwell, T. H., and Mallett, B. (1955). The determination of iron in plasma or serum. *Biochem. J.*, **59**, 599.
- Edozien, J. C., Phillips, E. J., and Collis, W. R. F. (1960). The free aminoacids of plasma and urine in kwashiorkor. *Lancet*, **1**, 615.
- Gillman, J., and Gillman, T. (1951). *Perspectives in Human Malnutrition*. Grune and Stratton, New York.
- Hård, S. (1963). Non-anemic iron deficiency as an etiologic factor in diffuse loss of hair of the scalp in women. *Acta dermat. venerol. (Stockh.)*, **43**, 562.
- Joubert, S. M., Hookins, K. W., and Hunter, W. G. (1959). A comparative study of serum protein moieties in European, African, and Indian adult populations of Durban. *S. Afr. J. Lab. clin. Med.*, **5**, 1.
- Löwenthal, L. A., and Montagna, W. (1955). Effects of caloric restriction on skin and hair growth in mice. *J. invest. Derm.*, **24**, 429.
- Mitchell, H. H., Kammlade, W. G., and Hamilton, T. S. (1928). Relative energy value of alfalfa, clover and timothy hay for the maintenance of sheep. *Bull. Ill. Agr. Expt. Stn.*, **317**, 1.
- Scragg, J., and Rubidge, C. (1960). Kwashiorkor in African children in Durban. *Brit. med. J.*, **2**, 1759.
- Sims, R. T. (1964). The incorporation and fate of H^3 -tyrosine in the hair cortex of rats observed by radioautography. *J. cell Biol.*, **22**, 403.
- (1965). The dynamics of hair growth. In *Comparative Physiology and Pathology of the Skin*, ed. A. J. Rook and G. S. Walton, p. 119. Blackwell, Oxford.
- (1967). Beau's lines in hair. *Brit. J. Derm.*, **79**, 43.
- Trowell, H. C., Davies, J. N. P., and Dean, R. F. A. (1954). *Kwashiorkor*. Arnold, London.
- Williams, C. D. (1933). A nutritional disease of childhood associated with a maize diet. *Arch. Dis. Childh.*, **8**, 423.