THE ÆTIOLOGY OF RICKETS IN INFANTS:

PROPHYLACTIC AND CURATIVE OBSERVATIONS AT THE VIENNA UNIVERSITY KINDERKLINIK.*

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THE following observations upon the ætiology of rickets form a summary of work carried out in Vienna during the last 18 months. The results throw light upon the subject, and, as the fully documented report will necessarily take several months to prepare, it has been thought advisable to publish a brief account in the meantime, showing the lines of inquiry, the results obtained, and the conclusions drawn. The inquiry was undertaken in the hope of obtaining a solution to the problem whether rickets in infants is to be attributed to faulty diet or to other unfavourable circumstances in the environment, and whether, in the former case, a relation could be established between incidence of the disease and a deficiency of a specific food constituent—viz., vitamin A. Vienna offered special advantages for work of this nature. Rickets was widespread and severe in the city, and many opportunities for study of the disease were available.

It is clear that effective clinical investigations dealing with the relation of diet to incidence of rickets can only be carried out under conditions in which strict control of diets, both quantitative and qualitative, can be exercised. The University Kinderklinik, under the direction of Professor Pirquet, provided special facilities for quantitative work. For some years the research work carried on in this institution has been largely devoted to the subject of nutrition in childhood, and in the development of Prof. Pirquet's Nem system, methods of allotting, controlling, and recording diets have been specially elaborated. The staff has received a degree of training and experience in the technical details of nutritional work which is probably without parallel elsewhere.†

Another consideration pointed to Vienna as particularly suitable for this inquiry. The diet in common use for infants in the klinik was of an unusual type, presenting special points of interest for a study upon prophylaxis of rickets. This diet, referred to below as Diet I., was originally devised by Prof. Pirquet and his staff as an expedient for a time of milk and fat shortage. It was of high caloric value, and contained from two-thirds to one-half its total energy value in the form of sugar. Such a diet, however, if continued over a long period, being high in carbohydrate, and relatively low in milk, milk fat, and vitamin A, might be regarded as disposing to rickets in the light of the various dietetic theories of the ætiology of the disease which have been advanced. In the Kinderklinik the disease had been known to develop in infants receiving this diet, but it was then considered by Pirquet and his colleagues that rickets was probably infective in origin, and that the diet was not implicated.

Prof. Pirquet offered full coöperation in an inquiry into the influence of diet on the prophylaxis and treatment of rickets, and made available 60 cots in the wards of the Kinderklinik and at the Am Tivoli Hospital, Meidling. This institution, also under Prof. Pirquet's direction, is staffed from the Kinderklinik, and the same system of general management and diet control is maintained. The wards at Meidling may therefore be regarded as an extension of those at the Kinderklinik. The medical direction at the Kinderklinik was undertaken by Assistent Dr. Hans Wimberger, and at Meidling by the physician-in-charge, Dozent Dr. Egon Rach.

The following observations on prophylaxis and cure of rickets may be summarised as a study of (1) influence of diet under constant conditions of general hygiene; (2) influence of one factor in general hygiene—viz., light, under constant conditions of diet.

Observations on Prophylaxis.

Types of Diet.—For the observations on prophylaxis two diets of contrasting type were in use in the same wards, under identical conditions of general hygiene and management. The surroundings of the infants were as nearly perfect as possible, the conditions being those of a first-class modern hospital, and the allowance of trained personnel about one to every two cots. The wards were large and well lighted, with a minimum air allowance per infant of 900 cubic feet. On admission babies were placed in two groups upon Diets I. and II. respectively, care being taken that the two groups of children should be as similar as possible in age and general development.

GROUP I.—Diet I. (commonly in use for infants at the Klinik) consisted of Vienna fresh milk undiluted, with the addition of 8–10 per cent. sugar; in certain cases the sugar addition was from 17–18 per cent. The milk was from stall-fed cows and of low vitamin-A value when tested; the cow's fodder in winter consisted of chaff, cereals, straw, and roots. Diet I. included cereals after the age of 5 months, and later additions of fresh fruit and vegetables. The caloric allowance of this diet was accurately adjusted in accordance with the Nem system.

GROUP II.—Diet II. consisted of a standardised full-cream dried milk prepared to yield a fluid containing 13 per cent. solids; protein 3·4 per cent., fat 3·4 per cent., sugar 5·3 per cent. For infants under 3 months it was usually necessary to employ a greater dilution and to add a small amount of sugar. Additions of cereals were made for older infants. The infants in this group received up to 8 g. daily of cod-liver oil.

In both groups, with a few exceptions made for special reasons, a daily allowance of 5–10 c.cm. of raw lemon juice, swede juice, or tomato juice was given as anti-scorbutic. There was no significant difference in vitamin-A value of the milk used in Diets I. and II. respectively.

The distribution of calories in Diets I. and II. in protein, fat, and carbohydrate was roughly as follows:

	Calories as—		
	Prot. %	Fat %	Carbo. %
Diet I. ..	11	24	65
Diet II. ..	20	45	35
Human milk	12	50	39*
Cows' ,,	20	49	30*

* Schall and Heisler.

It proved necessary to give a larger caloric allowance in Group I. than in Group II. in order to maintain normal growth. There was therefore less difference in the amount of milk taken than would

* Preliminary report to the Accessory Food Factors Committee appointed jointly by the Lister Institute and the Medical Research Council.

† For a complete account of the Nem system and the scientific basis upon which it is founded reference must be made to the works of Prof. Pirquet and his colleagues (System der Ernährung, 4 vols., Springer, Berlin, 1917–1919). The salient points, in so far as the present investigation is concerned, may be summarised as follows. The caloric needs of each child are calculated upon the basis of the sitting height as a standard measurement, regard being also taken to the age, degree of activity, and general progress. All food is prepared to be of standard composition and of standard caloric value, the food unit being the "Nem" or food value of 1 c.cm. of a standard human milk containing 1·7 per cent. protein, 3·7 per cent. fat, and 6·7 per cent. sugar, or cows' milk containing 3·4 per cent. protein, 3·7 per cent. fat, and 5 per cent. milk sugar. The fat content of the milk supplied is estimated daily, and, if necessary, the caloric value of the milk is adjusted by additions of sugar or of water. The careful quantitative work in the kitchen is supplemented by an elaborate system of record keeping in the ward. The amounts allotted for each infant are accurately measured, and if the child fails to take the prescribed amount the unconsumed residue is measured, so that for each meal the actual intake of food is recorded. The body-weight and temperature are registered daily, and a record is kept of appetite, activity, and clinical condition. Twice monthly a complete series of body measurements is made.

otherwise have been the case. The infants in Group I. received about 20 per cent. less milk than those in Group II., and nearly twice the amount of sugar. The balance of protein, fat, and carbohydrate in the two groups was totally different. In Diet I. more than 50 per cent. of the total calories were given in the form of sugar, 10–15 per cent. as protein, and 20–30 per cent. as fat; in Diet II. sugar accounted for 30 per cent., protein for about 20 per cent., and fat for 50 per cent. of the total.

The cod-liver oil given over the greater part of the time was a sample of unrefined Norwegian oil, of strong taste, and dark in colour. A sample of the oil was tested by Dr. S. S. Zilva at the Lister Institute and found to be rich in content of vitamin A, being active in one-ninth of a drop (2 mg.), as tested in growth experiments upon rats. It was given in the form of a 50 per cent. emulsion made with caragheen and sugar, and was well tolerated by the infants in the doses given. The vitamin-A content of the milks used in winter in Groups I. and II. respectively was also controlled by experiments with rats, and showed consistently low value.

Type of Cases and Methods of Diagnosis.—Sixty-four cases were under observation in the prophylactic series for periods of 5 to 15 months. The age on admission varied from 1 week to 5 months, and in 57 cases was under 3½ months. It was necessary to admit infants at this early age as evidence of rickets was so often present in those of 4 months old and upwards. All children included in the series showed no evidence of rickets on X ray examination at the time of admission, and were also as far as possible free from clinical stigmata of the disease and in good general condition, but many were young illegitimate babies already receiving artificial food and clinically below normal. After admission radiographic examination of the epiphyses was repeated at frequent intervals. Clinical examinations of each infant were made fortnightly, and records kept of ossification of the skull, size of fontanelle, enlargement of costo-chondral junctions, shape of the chest, size of epiphyses, enlargement of spleen, and general nutrition and development. Clinical diagnosis of rickets was based on the bone stigmata. Most important of these for early recognition of the disease in infancy were craniotabes and marked enlargement of the costo-chondral junctions; in some cases craniotabes was the earliest sign, in others rapid development of beading. Cranial bossing, enlargement of epiphyses at wrist and ankle, and bending of the long bones proved of less value for early diagnosis.

For classification of results the X ray diagnosis has been taken as the criterion of the presence or absence of rickets and as an indication of the stage of the disease, whether active, healing, or healed. In this way a uniform standard of diagnosis is established, based on the condition of the bones without reference to the clinical signs of rickets. It is not suggested that bone lesions are the only signs of the disease, but consideration of other evidence of rickets is deferred for later discussion.

On the whole, clinical and X ray diagnoses of rickets showed a close parallel, and the X ray standard was adopted because the radiographic plate provided the clearest and least subjective evidence and demonstrated the disease at an early stage. Clinical signs, especially craniotabes, were sometimes present before rickets could be diagnosed radiographically, and some cases were repeatedly normal in the X ray plate whilst showing clinical indications of rickets. These occurred during summer and winter, and on both types of diet, and in one such case the diagnosis of rickets was confirmed at a post-mortem examination. It follows that by adopting an X ray standard of diagnosis some slight and transient cases may be classed as non-rachitic, but this does not affect the general conclusions later set forth. These conclusions are based upon the development of a much more lasting and unmistakable degree of normality or abnormality in the bones.

TABLE I.—*Observations on Prophylaxis: Influence of Season, Diet, and Age.*

Total number of infants observed = 64 (26 cases appearing in Group B and 1 case in Group C appear also in Group A). Length of observation = 5 months. Rk. = Rickets diagnosed by X ray examination.

Group	Age of infants (months). Beginning of period.	End of period.	Total.	No. of infants. Receiving the different diets.	RK.
Summer Period: April–June to September–November.					
A	1 to 5	6 to 10	40	Diet I. .. 15	0
				Diet I. + C.L.O. 3	0
				Diet II. .. 22*	0
Winter Period: October–December to March–May.					
B	6 to 10	11 to 15	27	Diet I. .. 11	3
				Diet I. + C.L.O. 3	0
				Diet II. .. 13	0
C	½ to 4	5 to 9	24	Diet I. .. 13	11
				Diet II. .. 11†	0
Total			51	51	14

C.L.O. = Cod-liver oil. * Including one breast-fed infant.
† Including one partly breast-fed infant.

TABLE II.—*Winter Season: Additional Details of Positive Cases in Table I. (B and C) Diet I.*

Cases.	Sex.	Birth month.	Admission month.	Date X ray diag. of rickets.	Age rickets diag. (months).	Craniotabes. Date first diag.
Diet I.—B (three positive cases).						
J. M.	M.	Mch.	May	Apr. 21*	13	—
C. P.	M.	Apr.	,,	Jan. 4	8½	+Feb. 22
O. W.	M.	,,	,,	Feb. 24	10	—
C (all cases).						
E. R.	F.	July	Oct.	Feb. 1	6	+Feb. 23
M. H.	F.	Aug.	Nov.	Dec. 30	5	+Feb. 9
F. K.	M.	,,	Oct.	Feb. 27	6½	+Mar. 9
H. G.	F.	,,	Dec.	May 2	8	+Feb. 23
M. D.	F.	,,	Oct.	Mar. 13	6½	+Feb. 9
W. K.	M.	,,	,,	Feb. 28	6	+Mar. 8
L. H.	M.	,,	Nov.	Feb. 13	5½	+Jan. 26
E. D.	M.	Sept.	Oct.	Doubtful		—
M. Z.	F.	,,	,,	Mar. 13	6	+Mar. 9
H. U.	F.	Oct.	Nov.	Mar. 31*	5½	—
M. M.	F.	Nov.	,,	Mar. 29	5	—
N. B.	F.	,,	Dec.	Negative		—
M. B.	F.	Dec.	,,	Apr. 10	4	+Apr. 5

+ = Positive. — = Negative.
* Already showing signs of healing.

The results of the prophylactic observations as determined radiographically are set out in Table I. to show the influence of (1) season, (2) diet, and (3) age upon the incidence of rickets. During the summer *no* case of rickets was detected among a total of 40 infants on both types of diet. In the winter series of 51 cases under observation, 14 developed rickets in the spring. These positive cases *all* occurred among the 24 infants upon Diet I., and principally among the younger infants in Age Group C. This group contained 13 infants born between July and December, of whom 11 developed rickets by the beginning of April at ages varying from 4 to 8 months. It is clear, therefore, that the first six months of life is a period of great susceptibility.

Clinical Notes.

The general condition of the infants who developed rickets showed much variation, and during the onset of the disease had no constant relation to the appearance of early rachitic changes. Some infants maintained good condition throughout the observation and approximated to the normal rate of growth and development concurrently with the appearance of rickets in the bones, but the majority were below normal with some degree of inactivity, flaccidity, pallor, or retardation of growth. The relation between the clinical evidence and the X ray diagnosis of rickets is of great practical importance. All the positive cases in Table I, showed also clinical signs of rickets, the appearance of which coincided on the whole with the date of the X ray diagnosis. though there were usually clinical indications of the disease at an earlier period. Conversely the majority of cases normal radiographically were clinically non-rachitic.

Craniotabes occurred in 10 of the 14 cases radiographically positive (Table II.), but was also found in three other cases in which no diagnosis of rickets was made by X ray examination. The possibility of the confusion of craniotabes and congenital softness of the cranial bones was borne in mind, and the former condition was only diagnosed when softening supervened in areas previously ossified. Craniotabes sometimes appeared before X ray diagnosis of rickets could be made, and after treatment began disappeared more rapidly than any other clinical sign. From the close association of this condition with radiographic evidence of rickets and its rapid response to anti-rachitic treatment, it is reasonable to conclude that craniotabes is a sign of active rickets.

Rapid and marked enlargement of the costo-chondral junctions was noted in most of the cases of rickets diagnosed by X ray examination. Some enlargement occurred in all cases admitted, but only in those babies with other definite evidence of rickets was considerable increase noted. A series of histological examinations undertaken in the course of this investigation by Dr. A. Feller at the Pathologisches Institut has shown that minor degrees of enlargement, though often pathological, are not necessarily rachitic, but that marked grades are diagnostic of rickets when scurvy can be excluded. Deformity of the chest often accompanied other early signs of rickets and was easily aggravated by mild respiratory affection or by abdominal distension.

No definite case of tetany was diagnosed, although the condition was suspected in several instances. Abdominal distension was not often present in the infants under observation, and in only two cases diagnosed as rickets by X ray was the condition persistent. The spleen was sometimes palpable in the case of chest deformity or abdominal distension, but there was no evidence that early rickets was associated with splenic enlargement. Cranial bossing was present in one of the positive cases in Table I. and was doubtful in others. It was a useful sign when definite, but in the earliest stages of the disease was often doubtful or absent. It was noted in a few cases radiographically normal. Epiphyseal enlargement at the ends of the long bones presented difficulty in diagnosis as the normal limits of size are considerable and a normal increase often occurs after 8 months of age. Nevertheless slight epiphyseal enlargement in conjunction with other signs of the disease had diagnostic value. Only one of the 12 cases positive in X ray showed marked increase in size of wrists and ankles, but slight enlargement was observed in the majority of the others.

The results of this prophylactic series of cases show conclusively (1) that rickets has a marked winter incidence; (2) that protection in winter can be afforded by diet; and (3) that infants are very susceptible to the disease in the first six months of life.

Observations on Therapy.

The observations were made upon 14 infants who developed rickets in hospital while receiving Diet I., and upon 18 more severe cases admitted between January and April. One child was 2 years of age, and all others were from 4 to 18 months old when treatment began. Three methods of treatment were studied: (1) Treatment with cod-liver oil; (2) exposure to mercury vapour quartz lamp; (3) outdoor treatment in sun or shade. Children in groups (1) and (2), together with the untreated control cases, remained indoors during the period of observation. Except for the 2-year-old child, the diet of all cases was Diet I. (see above), the ordinary infants' diet of the Kinderklinik. The vitamin-A content of the milk used showed no increase during the period of observation. The infants who developed rickets while in hospital had, therefore, no change of diet when treatment was instituted. The allowance of milk was comparable for all infants, who were maintained under the same external conditions except in so far as their respective treatments involved a different arrangement. In the case of infants admitted with rickets, control observations were supplied either by a preliminary period of observation before treatment was begun, or by comparison with other untreated cases admitted in a similar condition. Admissions were so arranged that some such control cases were present in the ward during the whole period of observation from January to May. The observations upon infants who had developed rickets in hospital were controlled by the previous history of the individual child and by comparison with untreated cases in the same group.

(1) *Cod-liver Oil, 6 Cases.*—Cod-liver oil was given as 50 per cent. emulsion of unrefined oil. The daily dose was from 5–10 g., mixed with milk and given in the bottle. The initial dose was 1–2 g., and the amount was increased as quickly as possible until the full dose was reached in about 10 days. Healing processes were demonstrated radiographically in two to four weeks from the beginning of treatment, in the form of calcium deposition in the unossified tissue at the ends of the long bones. The bone picture was gradually restored to the normal in a period which depended on the severity of the condition when treatment was begun.

(2) *Exposure to Mercury Vapour Quartz Lamp, 7 Cases.*—The lamp employed was of the Hanau pattern as used ordinarily in the Klinik for dermatological therapy. Treatment was given three to four times weekly, beginning with five minutes' exposure at a distance of 80 to 100 centimetres, the time being gradually increased to 30 minutes and the distance reduced to 60 centimetres. The full dosage was attained in two to four weeks, the time varying with the age and condition of the child. The result was the same whether one limb, one side, or the whole body was exposed. Slight pigmentation followed long courses of treatment, but no other effects were observed on the skin. The results obtained were indistinguishable radiographically from those obtained with cod liver oil. Healing of rickets was apparent in from two to four weeks after a total exposure of from two to five hours.

(3) *Outdoor Treatment, 12 Cases.*—The first therapeutic exposure to sunlight was made early in March, 1922, and thereafter cases were exposed for varying periods according to weather conditions, many being out of doors for the whole day. The amount of clothing varied with wind and temperature, and was reduced until the whole body was exposed when the weather was favourable. Careful records were kept of the time of exposure in sun or shade and of the clothing worn. Seven cases were exposed to direct sunlight, three receiving maximum amounts from March onwards; two were shaded from direct rays of the sun; three others treated with sunlight had also additions of cod-liver oil in their diet. The rate of bone healing was most rapid in the last group, and in the others was roughly proportional to the amount of exposure. Each method of treatment was equally effective in restoring normal bone conditions, but this process sometimes took place independently of any definite improvement in the general condition. Response was relatively most marked in cases receiving cod-liver oil and exposure to sunshine simultaneously, and the children treated out of doors showed more rapid general improvement than those remaining in the wards while under treatment.

Control Cases.—Young infants who developed rickets on Diet I. in February, March, and April progressed unless treated, but in May tended to show slow recovery. During February, March, and April only one control case showed definite recovery from rickets without special treatment, and this child showed sudden improvement in bone condition in March. He occupied a cot in a corner of the ward exposed to the direct rays of the sun, and the healing is attributed to this fact. The occurrence stressed the extreme difficulty of obtaining a perfect control in such observations as these, and from that time still more stringent precautions were taken for obtaining uniform conditions of light intensity.

Cases admitted with rickets, while undergoing the preliminary periods of observation on Diet I., served to establish one important fact. By transfer to hospital, conditions of air space, ventilation, cleanliness, freedom of movement, and general hygiene were markedly improved for the majority, who had previously been in very inferior surroundings. This change did not of itself, however, bring about alteration in the rachitic condition. During April and May the windows in the wards were open for long periods and the children enjoyed plenty of fresh air.

The following cases illustrate the points dealt with above :—

CASE W. K.—Born August 25th, 1921. Admitted Oct. 19th, 1921, aged 2 months. Weight 4700 g. Normally developed child in good general condition: no stigmata of rickets. Received Diet I. Nov. 24th: Progress hitherto not satisfactory owing to intestinal disturbance. X ray shows normal bones. Dec. 29th (wt. 5500 g.): Has had abscess of scalp and otorrhœa for past month, now improving. Jan. 31st (wt. 6300 g.): General condition improving steadily, activity fair, costo-chondral junctions enlarging rapidly, no deformity of chest, early enlargement of epiphyses; X ray shows normal bone structure. Feb. 28th: Rickets diagnosed radiographically. March 8th (wt. 7200 g.): Steady general progress, though stigmata of rickets more marked; small area of craniotabes, marked beading, epiphyses enlarged. March 21st (wt. 7400 g.): Rachitic stigmata increasing slightly, in spite of excellent general condition. Treatment begun by exposure to mercury-vapour quartz lamp. April 14th (wt. 8000 g.): Has had treatment on 14 days. Total exposure 4½ hours, at distance of 80 cm. General condition excellent, activity greatly improved, no craniotabes, other clinical stigmata unchanged; X ray shows rapid healing of bones. May 9th (wt. 8600 g.): Further treatment on 13 days, with total exposure of 6½ hours at 80 cm. distance. Steady progress maintained, development normal, can just sit alone; rachitic stigmata diminishing; X ray plate shows bone almost normal.

CASE E. R.—Born July 21st, 1921. Admitted Oct. 24th, 1921, aged 3 months. Weight 3400 g. Small thin child, very pale, appears underfed; activity fair; no craniotabes, no beading, no epiphyseal enlargements. Received Diet I. Dec. 8th (wt. 4200 g.): Progressing steadily, though slowly; epiphyses normal radiographically. Feb. 1st (wt. 5100 g.): Progress maintained, costo-chondral junctions enlarging; X ray shows rachitic changes at epiphyses. Feb. 22nd: Slight craniotabes present. March 10th (wt. 5800 g.): Marked beading of ribs, early deformity of chest, slight epiphyseal enlargement, craniotabes progressing. General condition fairly good, well nourished, colour fair, activity below normal. Outdoor treatment with maximum exposure to sunshine begun; no alteration in diet. March 22nd (wt. 6200 g.): First evidence of healing shown by X ray plates; in preceding 12 days had been out of doors for 88 hours, and there had been 55 hours of sunshine. April 6th (wt. 6700 g.): Very marked improvement in general health, activity much increased, skin pigmented, colour good, tissues of normal tone; X ray plates show specially rapid rate of healing in bones. April 27th (wt. 7200 g.): Rapid general progress; clinical stigmata diminishing. May 27th (wt. 8300 g.): Aged 10 months. General condition excellent, no clinical stigmata of rickets; X ray plates show completely healed rickets.

CASE M. D.—Born August 28th, 1921. Admitted Oct. 25th, 1921, aged 2 months. Weight 3800 g. Small child, pallid, fairly well nourished, activity poor, skin harsh and dry, chest short and contracted, abdomen distended; no craniotabes, no costo-chondral enlargement. Received Diet I. Progress poor and weight stationary for first month. Dec. 1st (wt. 3700 g.): General condition worse than on admission, with marked spasticity, but improvement began from this date. Jan. 10th: Steady progress, spasticity disappeared and child normally active. Rickets gradually developed during the period of uninterrupted progress. January–March: Beading of ribs increased rapidly, with deformity of chest exaggerated by persistent distension of the abdomen. Feb 9th: Craniotabes noted. March 13th: X ray picture showed definite rachitic changes in bones at wrist and ankle. Clinical condition remained good, while craniotabes and other bone changes advanced. April 21st (wt. 6200 g.): Activity and general condition satisfactory, but had convulsions. Treatment begun with calcium lactate 3 g. daily, cod-liver oil 5 g., and maximum exposure to sunlight. Response was very rapid. May 2nd: Healing was evident in the X ray photograph and progressed very rapidly. May 18th: Craniotabes completely disappeared. June 3rd (wt. 7400 g.): Aged 9 months. General condition excellent; could crawl and tried to sit alone; some abdominal distension and contraction of the thorax present, but diminishing; X ray shows marked advance in bone healing.

CASE L. J.—Born Feb. 2nd, 1921. Admitted Jan. 28th, 1922, aged 12 months. Weight 6200 g. Small for age, but well developed, vigorous, active, very good general condition, colour fair; extensive craniotabes, costo-chondral junctions markedly increased in size, epiphyses enlarged; advanced rachitic changes shown radiographically. Received Diet I., remaining indoors. Feb. 7th: Two grammes of cod-liver oil added to diet, amount increased to 10 g. by Feb. 25th, thereafter 10 g. daily. March 3rd: First stages of healing in bone shown by X ray. March 22nd: Craniotabes completely disappeared; X ray plate shows rapid healing of bones. April 19th: Diminution in clinical bone stigmata noted. May 10th (wt. 7500 g.): Aged 15 months; rachitic stigmata disappearing; active and vigorous, walks round cot; general condition as on admission, except that marked pallor is present. Clinical history uncomplicated. May 25th (wt. 8000 g.): X ray shows healing of bones almost complete.

Discussion of Results.

Many of the above observations confirm the results of previous workers. The particular features of the present investigation have been the strict control of diet and of other external conditions and use of regular radiographic examinations for accurate diagnosis of onset, development, and healing of the disease.

Conclusive evidence of prophylaxis in infants during the winter by means of diet where food and external conditions have been strictly controlled has not previously been recorded. The protective action of Diet II. is probably to be attributed to the small quantity of cod-liver oil it contained; the other main difference between Diets I. and II. was the substitution of sugar by milk, but Diet I. proved *curative* in early spring when cod-liver oil was added, and no evidence was obtained to implicate the excess of carbohydrate, and smaller allowance of fat and protein, in Diet I. as rickets-producing. It must be admitted that no special investigation was made to elucidate this point, but the common occurrence of rickets in breast-fed children in Vienna is an interesting fact in this connexion.

The observation upon seasonal incidence is in accordance with the experience of all clinicians that rickets develops in winter and spring and is healed in summer. The results of sunlight therapy confirm the clinical observations of Hess and his co-workers (1921), and support the theory put forward by these authors that "seasonal incidence of rickets is due to the seasonal variation of sunlight." The value of sunlight in prevention of rickets in rats has recently been demonstrated by Hess, Unger, and Pappenheimer (1921), and Powers, Park, Shipley, McCollum, and Simmonds (1922). The observations made by Huldschinsky in 1919 that the rays of the mercury-vapour quartz lamp had a curative effect upon rickets have since been substantiated by numerous workers, and suggest that the action of sunlight out of doors may depend on the ultra-violet rays it contains. From a world-wide review of the epidemiology of rickets Hansemann (1906) concluded that the disease could not be explained by deficiency in diet, and that lack of fresh air and free movement of the children was responsible. Findlay (1909), Paton (1918, 1921), and Ferguson (1918), have arrived at a similar conclusion, Findlay laying particular stress upon the want of exercise, and Paton including general hygienic deficiencies in the chain of causation. Their observations and experiments, together with Miss Ferguson's analysis of the occurrence of rickets in Glasgow in relation to various hygienic conditions and opportunities for exercise in the open air certainly indicate that a faulty diet, if operating at all, is not the sole factor. We have obtained no evidence that fresh air or exercise produced any effect apart from the concomitant greater incidence of sunlight, and our observations, we think, prove that, with a minimal insolation, as during winter, diet is the controlling factor.

Perhaps the most interesting result is the identical action of cod-liver oil on the one hand, and light therapy on the other, on the bone lesions of rickets. This fact, while explaining the prevalence of rickets in winter in northern climates and large cities, may at the same time account for its prevention in Greenland, if large amounts of fish oils are consumed by the mothers and older children. The scientific aspect of the problem is particularly fascinating, for if the anti-rachitic action of cod-liver oil be attributed to the vitamin A it contains or some factor with a similar distribution (Mellanby, 1918, 1919, 1921, McCollum

and his co-workers 1921, Korenchevsky 1921), the possibility is suggested of a special photo-synthesis of this vitamin in the animal body under influence of sun radiation, an idea which is quite new to animal physiology. Experiments upon animals arranged to confirm or elucidate this idea are already in progress.

It was not possible to decide whether vitamin from sources other than cod-liver oil had any effect in prevention or cure of rickets. The large amount of sunshine out of doors would suffice to explain the prophylaxis observed in summer, so that any protective action of milk, if present, would have been masked by the action of the sun. It is improbable that a high value of vitamin was reached at any time in the Vienna milk, since the cows in and near the city are often stall-fed, even in summer. It was hoped to investigate the value of milk rich in vitamin A for the *cure* of rickets in spring, but this could not be carried out as such milk could not be procured.

The results of the present study place the age of greatest susceptibility to the onset of rickets earlier than that usually accepted by clinicians. The early age, however, is in accord with that determined by Schmorl (1909) after histological examination of post-mortem cases. This conclusion stresses the importance of observing *young* infants in attempts to elucidate the ætiology of rickets, and demonstrates the difficulty of ætiological studies made upon older children in which systematic control by X ray was not employed.

SUMMARY.

The foregoing observations show :—

1. That rickets developed during winter and spring under excellent hygienic conditions in infants receiving Diet I., composed of fresh milk from stall-fed cows and to which sugar was added, and was prevented in the case of children receiving Diet II., containing cod-liver oil, more milk, and less carbohydrate. Both milks were low in vitamin A.

2. That rickets did not develop in summer on either diet.

3. That rickets can be cured by cod-liver oil and by exposure to sunlight, or to the radiation of the mercury vapour quartz lamp.

4. That the first six months of life is a period of special susceptibility to the onset of the disease.

5. That rickets may develop in an infant whose general condition is good or improving, and that healing of the bones may occur independently of improvement in the general condition.

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NOTE ON THE X RAY DIAGNOSIS OF RICKETS.

By HANS WIMBERGER.

In infancy it is only the diaphyses, with their expanded ends, the metaphyses, which are to be seen in the Rontgen photographs. Certain long bones, however, show centres of ossification in the otherwise translucent epiphyses. In the normal long bone of an infant the ends of the metaphysis towards the epiphysis are terminated by a fine homogeneous, densely-calcified margin ; towards the diaphysis is a lighter transverse zone, very narrow, of ill-defined structure, out of which arise the fine meshed trabeculæ of the spongiosa. The peripheral margin of the compact bone is sharply differentiated from the soft tissues. The diagnosis of rickets by X ray is based principally upon careful observations of quantitative alterations in calcium content of the bones. This demands frequent photography, which must reach a high standard of technique. Changes in the *form* of the bones are a second diagnostic point when the disease is well established.

The first suggestions of rickets are shown radiographically in the primary calcification zone, which loses its homogeneity, appears wider and less well-defined, and may show definite defects of calcification. As calcium content is reduced in this area, the sharp end-margin of the metaphysis is lost and a fine fringe becomes visible, due to partially calcified trabeculæ projecting into the epiphyseal cartilage. As the disease progresses the terminal part of the bone is decalcified more rapidly at the centre than at the periphery ; here the projecting ends of the compact bone retain their lime salts longer, so the familiar cupped appearance of the ends of rachitic bones is produced. Such cupping, however, varies much in degree according to the original shape of the bone concerned and the severity and duration of rickets. Further, the terminal portion of the cancellous bone shows a coarsening of structure in X ray as the finer of the calcified trabeculæ are absorbed and replaced by an apposition of osteoid tissue only (osteoporosis). Decalcification can cause the compact bone of the shaft to become almost invisible, and in the most severe degree of osteoporosis, rachitic bones can no longer be differentiated from the soft tissues. In severe rickets a marginal shadow may appear along the shafts of the long bones. This represents the result of abnormal periosteal activity (osteophytic layer) during the disease and only becomes sharply defined after healing has set in and calcification has recommenced.

The beginning of healing after severe rickets is even more readily recognised radiographically than the onset of the disease. The first evidence is the appearance in the X ray plate of a new primary calcification zone between the epiphysis and the abnormal (radiographically invisible) tissue formed in the metaphysis during the rachitic period. The distance between this new zone and the diaphysis depends upon the duration of the disease. With progress in healing, lime salts are deposited in the intervening space as the rachitic portions of the metaphysis are restored. Past rickets of moderate or severe degree is recognisable for a long time (up to two years) afterwards,

(*Continued from previous column.*)

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