THE DAY AND NIGHT OUTPUT OF URINE IN ENURESIS

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The excretion of urine is one of several bodily activities which is subject to a daily rhythm. It has been clearly demonstrated how the rate of urine output is reduced during the hours normally devoted to sleep and how this rhythmic reduction in flow persists in spite of regular fluid intake throughout the 24 hours and in spite of alteration in the periods of sleep and activity (Mills, 1951). The average adult secretes just over half the amount of urine by night that he does by day, though individual variation is wide, and this applies to children from infancy upwards (Beyer and Kayser, 1949).

The belief that there is a group of nocturnal enuretic children who wet the bed because they lack this ability to inhibit the urine flow at night is now quite widely held. Friedell (1927) studied 39 enuretics and found that eight of them passed urine of relatively low specific gravity at night; it was this group which he found particularly resistant to treatment. Smellie (1949), in discussing the pathogenesis of the condition, stated that nocturnal polyuria had not been sufficiently emphasized, and that it was an outstanding feature of most cases. Holman (1954) seems to have been of the same opinion, for her book on bedwetting contains the following reference to the matter:

> 'For the child "night" is at least as long as day; if, as many do, he also has the unfortunate idiosyncrasy of a greater rate of excretion by night than by day, there will be a correspondingly greater volume of urine accumulating.'

Braithwaite (1956) mentioned it in his presidential address to the Royal Society of Medicine, though his own investigations did not cover this aspect of the subject. Poulton and Hinden (1953) put the matter to the test and measured the diurnal and nocturnal output of 200 enuretics in hospital. They found that no less than three-quarters of them were excreting an abnormally large volume at night and they concluded that enuresis is commonly due to anomalous renal secretion.

It therefore seemed worth while to try to confirm the observation with strict control of some of the variable factors which influence urine volume, and if nocturnal polyuria was indeed significant, to investigate the cause thereof.

Method

Two groups of children were studied in hospital, namely, (1) enuretics and (2) children of similar age who were in hospital for other reasons but were not enuretic. Boys were chosen for the enuretic group in preference to girls because of the necessity for using a collection apparatus at night without undue restriction or sedation. None were included if it was thought that psychological disturbance was severe nor in whom any clear organic cause was demonstrable. Two enuretic girls were included and for these no collecting apparatus was used but they were roused sufficiently to pass urine at approximately three-hourly intervals during the night. From the experimental work of others it is clear that the diurnal-nocturnal rhythm is not likely to have been influenced by such small variations in the depth of sleep (Simpson, 1924). Standardization of the fluid intake and diet reduced the day-to-day variation in urine output to some extent but there were inevitable differences in the amount of activity and in the environmental temperature.

The day was taken as 6 a.m. to 6 p.m. and the night as 6 p.m. to 6 a.m. Fluid intake apart from that in food was as follows:

Age 4-5 years	900 ml.
6-8 years	1,050 ml.
9-12 years	1,200 ml.

The first drink each day was given at 6 a.m. and the last drink at 6 p.m. Diet was standardized as far as possible for the three age groups, the sodium and potassium intake being measured in most cases with a view to comparing the relative day and night output of these electrolytes in enuretics and controls. Variations in diet did occur but they were such as would make no significant difference to the volume of urine excreted.

The 'day' collection consisted of all urine passed after 6 a.m. up to and including a 6 p.m. specimen. The 'night' collection consisted of all urine passed after 6 p.m., up to and including a 6 a.m. specimen. Night urine from the enuretics was obtained by means of Paul's tubing fixed over the penis, and, provided that there was supervision at frequent intervals during the night, this was found to be a satisfactory method. If any leakage did occur, the results for that 24 hours were discounted. The bladder was emptied voluntarily at 6 a.m. after the collecting apparatus was removed.

Regulation of fluid intake and diet was begun two days before the collection was started and this continued over an average period of five days and nights for each child. Sodium and potassium output was also measured because it was hoped that this would assist in elucidating the cause of the anticipated nocturnal polyuria. Day-to-day variations did occur but were no more marked in the enuretic group than in the controls. It was therefore decided (after obtaining statistical advice) that no error would be introduced by basing conclusions on the average daily output for the period.

Results

The accompanying table shows the average daily fluid intake and the day and night urine output in each case, together with the ratio of day: night volumes. Fig. 1 shows the night urine volume plotted by age for both groups in the form of a scattergram It can be seen from these that most children passed a volume of urine at night between 150 ml. and 400 ml. varying to some extent with age. There was no significant difference between the night urine volume of the enuretics and that of the controls. There were, however, four subjects whose night urine volume lay well outside these limits and who may be said to have had nocturnal polyuria. Two were enuretics (13E and 14E) and two were controls (10C and 16C). Case 13E (enuretic) gave a history of thirst and polyuria both by day and night and was accustomed to living in a sub-tropical climate. He was admitted with a tentative diagnosis of diabetes insipidus but investigations showed that there was no impairment of his ability to concentrate urine and it was considered that his thirst was in the nature of a habit. Prolonged observation was not possible because of his return abroad. Case 10C (control) had mild bronchiectasis and no explanation for his nocturnal polyuria can be given. Cases 14E (enuretic) and 16C (control) were both cases of coeliac disease, the significance of which is discussed below.

In Fig. 2 the day output of urine in each case is plotted against the night output giving the day: night ratio. There is a tendency for the values to cluster around the 2: 1 line with few exceptions and no

TABLE

Enuretics						Controls					
Subject	Age (yr.)	24-Hour Fluid Intake (ml.)	Urine Output 6 a.m.–6 p.m. (ml.)	Urine Output 6 p.m.–6 a.m. (ml.)	Ratio of Day Urine / Night Urine	Subject	Age (yr.)	24-Hour Fluid Intake (ml.)	Urine Output 6 a.m.–6 p.m. (ml.)	Urine Output 6 p.m.–6 a.m. (ml.)	Ratio of Day Urine / Night Urine
1E	5	900	396	108	3·66	1C	4	900	192	200	0·96
2E	5	900	468	324	1·44	2C	4	900	312	252	1·24
3E	6	1,050	514	255	2·08	3C	4	900	540	188	2·87
4E	7	1,050	600	204	2·94	4C	5	900	477	216	2·20
5E	7	1,050	540	252	2·14	5C	5	900	516	324	1·60
6E	7	1,050	408	164	2·50	6C	6	1,050	528	252	2·10
7E	7	1,050	619	403	1·53	7C	6	1,050	471	285	1·65
8E	7	1,050	579	337	1·71	8C	7	1,050	528	216	2·45
9E	7	1,050	552	208	2·66	9C	7	1,050	492	360	1·36
10E	8	1,050	540	380	1·42	10C	7	1,050	490	568	0·88
11E	8	1,050	564	216	2·60	11C	7	1,050	759	239	3·17
12E	8	1,050	660	240	2·75	12C	8	1,050	696	436	1·60
13E	9	1,200	672	608	1·10	13C	8	1,050	612	284	2·15
14E	9	1,200	564	804	0·70	14C	8	1,050	595	302	1·97
15E	9	1,200	708	348	2·02	15C	8	1,050	540	224	2·40
16E	9	1,200	552	312	1·77	16C	8	1,050	360	804	0·45
17E	10	1,200	456	372	1·23	17C	10	1,200	456	264	1·73
18E	10	1,200	622	302	2·06	18C	10	1,200	660	364	1·81
19E	11	1,200	396	332	1·20	19C	11	1,200	733	251	2·91
20E	11	1,200	540	348	1·55	20C	11	1,200	602	302	2·00
21E	11	1,200	612	436	1·40	21C	11	1,200	588	264	2·22
22E	12	1,200	600	300	2·00	22C	11	1,200	588	336	1·75
						23C	11	1,200	552	408	1·35
						24C	12	1,200	864	312	2·77

Average ratio of $\frac{\text{Day urine}}{\text{Night Urine}} = 1\cdot93$ Average ratio of $\frac{\text{Day urine}}{\text{Night Urine}} = 1\cdot90$

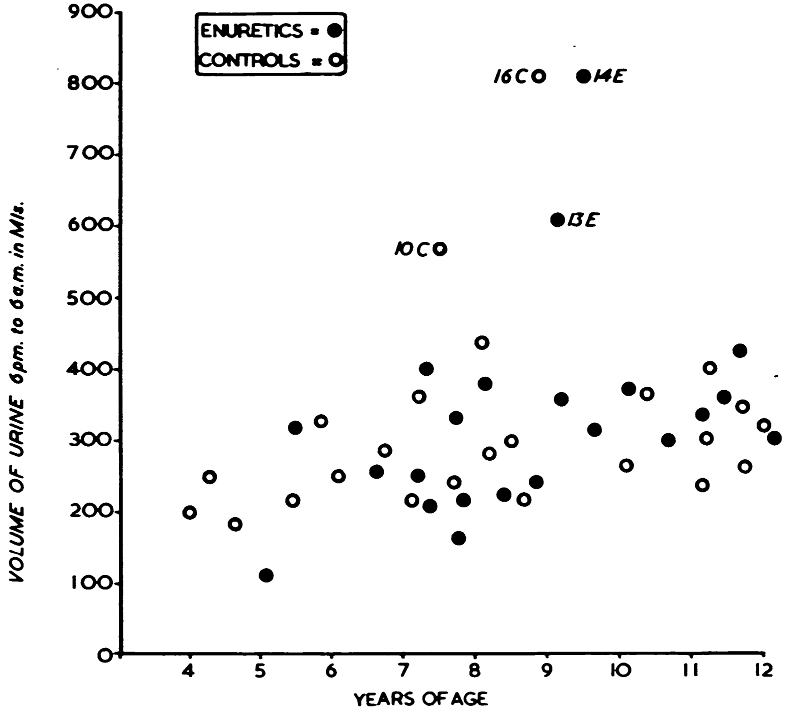

FIG. 1.—Night urine volume for both groups of children.

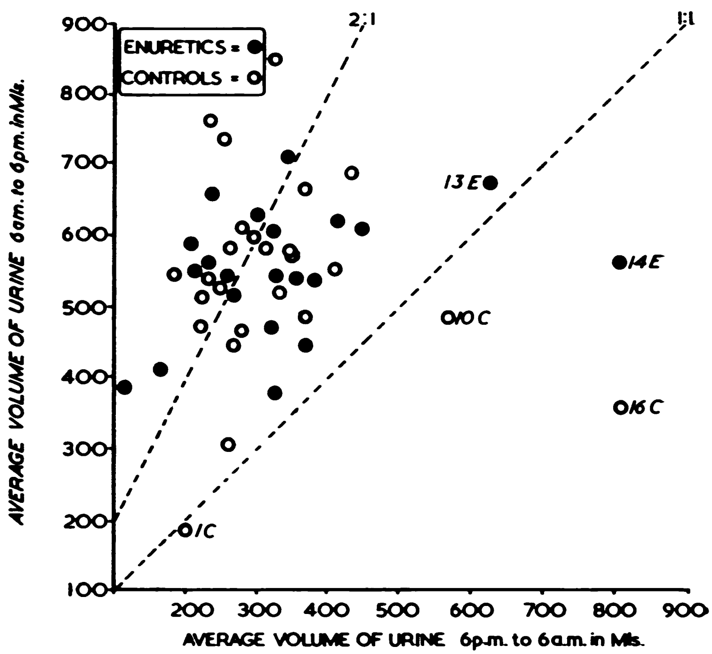

FIG. 2.—Rates of day to night output of urine.

significant difference between enuretics and controls. The main exceptions were again the subjects 14E, 10C and 16C whilst 13E tended to conform more closely to the average since he had both diurnal and nocturnal polyuria. The subject 1C whose day:night ratio was approximately 1 was a case of fibrocystic disease of the pancreas (*vide infra*).

The average day: night ratio of urine output for the enuretic group was 1·93 whilst that of the control group was 1·90.

Since the figures for sodium and potassium excretion do not add any useful information relevant to the present problem, they have not been tabulated in detail. It is interesting to note, however, that the average day: night ratio of both sodium and potassium output scarcely differed from that of the urine volume, i.e.,

		Enuretics	*Controls*
Average day output of sodium / Average night output of sodium	=	1·90	1·97
Average day output of potassium / Average night output of potassium	=	1·92	1·92

Bladder Capacity

Apart from the collections of urine at 6 a.m., 6 p.m. and 10 p.m., the children passed urine when they felt the need to do so. The largest volume of urine passed in one act of micturition during the stay in hospital therefore represented approximately the amount the bladder could hold without stress.

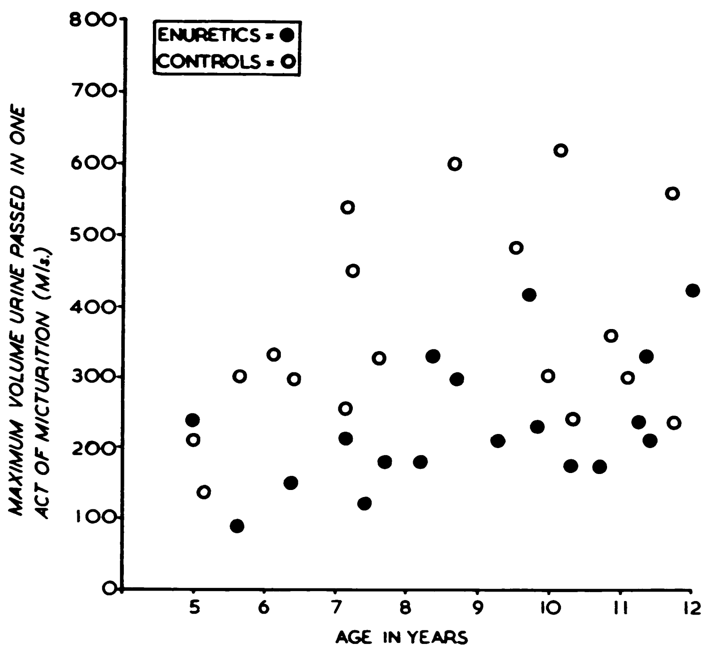

FIG. 3.—Maximum bladder capacity compared in some members of both groups of children.

This maximum volume was compared in some of the members of the two groups and is charted according to age (Fig. 3). It can be seen that the bladders of most of the enuretics held a relatively small quantity compared with those of most of the controls.

Discussion

It is disappointing to find that a clinical impression cannot be confirmed when put to the test. When questioned, the mother of the enuretic child will often readily support the notion of nocturnal polyuria in terms which are illustrative rather than factual; for example, 'You could float a battleship in the bed'. Under the conditions of the present investigation, it seems probable that if relative nocturnal polyuria does cause enuresis, it is likely to be due to some well defined disease, renal or otherwise. The observation that it may accompany steatorrhoea, as in the two instances mentioned here, is not a new one, though I can find no previous record of it happening in childhood. Wollaeger and Scribner (1951) gave a very clear account of it occurring in adults with idiopathic steatorrhoea and they showed that it was almost certainly due to retention of fluid in the small gut during the day with delayed absorption and hence excretion at night.

The fact that even when polyuria at night is marked, bedwetting does not necessarily follow, is well illustrated by the patient with coeliac disease (16C) who was never enuretic in spite of an output of about 800 ml. urine. His bladder capacity had adjusted itself to the increased flow, an achievement which is sometimes seen to a remarkable extent in children with diabetes insipidus.

It is sometimes said that enuretic children have a tendency to excrete a large volume of urine in the first few hours after going to sleep and this would not have been revealed by measurement only of total night volume. However, a specimen was always taken at 10 p.m. and the quantity passed between 6 p.m. and 10 p.m. was measured. No significant difference between enuretics and controls was found in this respect.

Renal function is to some extent influenced by emotional factors, and it might be that admission to hospital alone caused the nocturnal output of urine to return to normal. While this is difficult to disprove, it is unlikely that a nocturnal polyuria sufficiently great to be the cause of bed-wetting would suddenly cease in so large a proportion of cases. Although it is well known that enuretics may have dry beds when first admitted to hospital, it is by no means a constant occurrence and is probably often accounted for by lighter sleep.

The tendency to a small bladder capacity in the enuretics as compared with the controls is not unexpected. It is a well known clinical observation that even if there is no incontinence of urine in the day time, enuretic children almost always have some increased frequency of micturition. Cystometric studies have confirmed it.

The results of this investigation do not point the way to any new line of research into the causes of this distressing condition but if they have helped to put one suggested 'organic' cause into its right proportion, a small knot will have been unravelled from the tangle.

Summary

The theory that nocturnal polyuria is a common contributory cause of enuresis has been tested by measurement of the day and night output of urine from 22 enuretic children and 24 children who were not enuretic, under standardized conditions of diet and fluid intake.

No significant difference was found between the two groups.

The association of relative nocturnal polyuria with steatorrhoea was noted but enuresis did not always accompany it.

The tendency for most enuretics to have a relatively small bladder capacity as judged by the maximum volume passed in one act of micturition was confirmed.

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References

Beyer, P. and Kayser, C. (1949). *C.R. Soc. Biol. (Paris)*, **143**, 1231.
Braithwaite, J. V. (1956). *Proc. roy. Soc. Med.*, **49**, 33.
Friedell, A. (1927). *Amer. J. Dis. Child.*, 33, 717.
Holman, P. (1954). *Bedwetting*, p. 19. London.
Mills, J. N. (1951). *J. Physiol. (Lond.)*, **113**, 528.
Poulton, E. M. and Hinden, E. (1953). *Archives of Disease in Childhood*, **28**, 392.
Simpson, G. E. (1924). *J. biol. Chem.*, **59**, 107.
Smellie, J. M. (1949). *Bgham. med. Rev.*, **16**, 55.
Wollaeger, E. E. and Scribner, B. H. (1951), *Gastroenterology*, **19**, 224.