Seasonal variations in the composition of urine in relation to calcium stone-formation

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Summary

1. A retrospective cross-sectional study was carried out on data derived from single 24 h urine collections from 246 male idiopathic calcium stone-formers.

2. The daily urine volume and pH and the excretions of calcium, oxalate, phosphate, creatinine and magnesium were related to the time of year when the urine was collected, and the saturation of urine with calcium oxalate and octocalcium phosphate calculated for each month.

3. There were significant seasonal variations in the urinary excretion of calcium and oxalate, each showing a maximum during the summer months and a minimum in the winter. There was no significant seasonal variation in urinary pH, volume, creatinine, phosphate or magnesium.

4. There was a significant increase in the saturation of urine with calcium oxalate and a trend towards higher saturation levels of octo-calcium phosphate in the summer. These changes were dependent only on the seasonal variation in urinary calcium and oxalate and not on urine volume.

5. A retrospective study of the seasonal incidence of stone episodes among these 246 stone-formers showed that the rate of stone passage per month was 50% higher in the summer than in the winter. There was no significant seasonal variation in the incidence of stones removed surgically.

Key words: calcium, oxalate, phosphate, seasons, urinary calculi.

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Introduction

A marked seasonal variation in the daily urinary excretion of calcium has been reported both in patients with calcium stones and in healthy normal subjects (Morgan, Rivlin & Davis, 1972; Robertson, Gallagher, Marshall, Peacock & Nordin, 1974). Urinary calcium reaches a maximum in July and August and a minimum in December and January. There is a parallel seasonal fluctuation in the occurrence of urinary stones in the so-called ‘Stone-Belt’ of the U.S.A. (Prince & Scardino, 1960; Leonard, 1961). A retrospective study has therefore been carried out to determine whether there is a seasonal fluctuation in the occurrence of stones in Britain, and, if so, whether this may be explained by seasonal variations in the composition of urine and its degree of saturation with calcium salts.

Materials and methods

The study is based on an analysis of single 24 h urine samples collected with preservative (1 ml of 20%, v/v, hibitane) from 246 male idiopathic stone-formers (as defined by Robertson, Peacock & Nordin, 1968) who attended a renal stone clinic in Leeds, England, over a period of 3 years from 1966 to 1969. The patients were part of a larger series of 385 stone-formers whose urinary calcium excretions were reported in a previous communication (Robertson et al., 1974), but the other 139 patients of that study were excluded from the present study as the urinary data on those patients was insufficient. All had a
history of forming calcium-containing stones. They were otherwise healthy and had no known metabolic disorder such as primary hyperparathyroidism, renal tubular acidosis or urinary tract infection. All had normal renal function. The patients were on a free diet at the time of study.

Urinary volume, pH, creatinine, calcium, magnesium, sodium, potassium, ammonium, phosphate, oxalate, citrate and sulphate were measured at the time of collection as previously described, and the saturation of urine with calcium oxalate and octocalcium phosphate was calculated from the relevant ion concentrations (Robertson et al., 1968; Robertson, 1969). The mean daily urinary excretions of calcium, oxalate, phosphate, magnesium, volume, pH and creatinine were calculated for each month of the year. The corresponding saturation levels of urine with calcium and octocalcium phosphate were compared with the known levels of spontaneous precipitation of these salts (formation products).

To determine whether there was a seasonal variation in stone episodes we examined the case records of these 246 stone-formers. A stone episode was defined as either the spontaneous passage or the surgical removal of a stone. There was a total of 416 such episodes of stones (337 passed, seventy-nine removed surgically) recorded in the 246 cases. The stone episodes were grouped in 2-monthly periods. Attacks of renal colic without the definite passage of a stone were excluded on the basis that there was no conclusive evidence of a stone being formed.

Seasonal changes in climate in the Leeds area during the study period were assessed from the average daily temperatures and hours of sunlight, as supplied by the Meteorological Office.

Results

Urinary composition

The mean daily urinary excretions of calcium, oxalate and inorganic phosphate for each month of the year are shown in Fig. 1. In addition to the marked seasonal variation in the daily excretion of calcium, as shown previously, there is also a higher excretion of oxalate during the summer months. On the other hand, there is no significant seasonal variation in either urinary pH or urinary volume, nor in the daily excretion of creatinine, phosphate or magnesium (Fig. 1 and Fig. 2).

The mean saturation levels of calcium oxalate and octocalcium phosphate for each month are shown in Fig. 3 in relation to the formation products of these salts. This shows that as a consequence of the summer increase in urinary calcium and oxalate there is a significant increase in the saturation of urine with calcium oxalate during the summer months. There is, however, only a trend towards higher saturation levels of octocalcium phosphate at this time. The general level of saturation of urine with this salt is lower than that with calcium oxalate.

During the summer months the urine samples of the stone-formers become so highly supersaturated
that many of them exceed the level at which spontaneous precipitation of calcium oxalate takes place (Fig. 4). Few urine samples, however, exceed the formation product of octocalcium phosphate at this time of year (Fig. 4).

**Stone incidence**

Fig. 5 shows the seasonal variation in stone episode rate among idiopathic stone-formers, where a stone episode is defined (a) as the passage or (b) the surgical removal of a stone. This demonstrates that there is about a 50% increase in the number of episodes of stones passed per month during the summer relative to that in the winter. In contrast, the number of episodes of stones removed surgically each month is fairly constant throughout the year.
FIG. 5. Number of stone episodes per month among the 246 male idiopathic stone-formers, plotted at 2-monthly intervals throughout the year: ○, episodes of stones passed spontaneously; ●, episodes of stones removed surgically.

Climatic conditions

The average daily temperature and hours of sunlight in the Leeds area for each month during the period of this study are shown in Fig. 6.

Discussion

It has been known for many years that there is a seasonal fluctuation in the incidence of urinary calculi in the U.S.A. (Prince & Scardino, 1960; Leonard, 1961). It has been generally assumed that this is attributable to an effect of the seasonal variation in temperature on urinary volume (Prince & Scardino, 1960; Blacklock, 1969), it being supposed that the higher temperatures of summer will produce more concentrated urine than in winter and consequently an increased risk of crystalluria. In apparent support of this assumption it is often said that there is a higher incidence of stones among populations living in hot climates and an increased incidence among groups of people, such as troops or sailors, when they move from temperate to hotter climates (Pierce & Bloom, 1945; Blacklock, 1969). However, it has never been established that a reduction in urinary volume is the major cause of any increase in the urinary concentration of stone-forming salts either during the summer months or in hot climates.

In this study it is clear that, during the summer in Leeds, there is a marked increase both in the incidence of stones and in the concentration of calcium salts in urine, particularly calcium oxalate. This increase in the saturation of urine with calcium oxalate is entirely attributable to an increase in urinary calcium and oxalate (Fig. 1) and not to a decrease in urinary volume. In Leeds, where the climate is temperate (Fig. 1) and not to a decrease in urinary volume. In Leeds, where the climate is temperate (Fig. 1), there does not appear to be a significant seasonal variation in urinary volume (Fig. 2). Of course, this does not prove that changes in urinary volume may not be of some importance in climates hotter than that of Britain.

The possible causes of the increased urinary excretion of calcium during the summer months have
already been discussed (Robertson et al., 1974), when it was suggested that at least part of the increase may be attributed to the effect of sunlight on the production of vitamin D (McLaughlin, Raggatt, Fairney, Brown, Lester & Wills, 1974; Stamp & Round, 1974) and the subsequent stimulation by vitamin D of the intestinal absorption of calcium (Kodicek, Lawson & Wilson, 1970; Omdahl, Holick, Suda, Tanaka & DeLuca, 1971). In support of this thesis Parry & Lister (1975) have reported that there is a marked increase in the urinary calcium of troops moving from Chatham in summer (mean daily sunlight = 6·13 h) to the Persian Gulf during the 'hot season' (mean daily sunlight = 11·35 h), where the production of vitamin D would be predictably higher (Haddad & Chyu, 1971). In the present study, too, there is a good correspondence between the seasonal variation in urinary calcium and the mean daily hours of sunlight (Fig. 1 and Fig. 6).

The cause of the increased urinary excretion of oxalate during the summer is not clear. It may be that it is secondary to the increase in urinary calcium, since a positive relationship has been established between the two variables (Zarembski & Hodgkinson, 1969; Hodgkinson, 1974). One possible mechanism by which this may come about depends on the interrelation between the intestinal absorption of calcium and that of oxalate. Most ingested oxalate is thought to form a complex or be precipitated with calcium in the intestine and only a small fraction is absorbed (Archer, Dormer, Scowen & Watts, 1957; Zarembski & Hodgkinson, 1969). If, however, the percentage absorption of calcium, from a given intake, is increased during the summer months as a result of increased production of vitamin D, then less oxalate may be in complex in the intestine and more will become available for absorption. Thus the observed increase in urine oxalate may, in fact, derive from increased intestinal absorption of oxalate. An alternative possibility is that in the summer there may be an increased intake of oxalate or of oxalate precursors, such as vitamin C (Lambden & Chrystowski, 1954), from certain fresh fruit and vegetables, and that this may result in more oxalate being absorbed or being produced by metabolism.

Whatever the reasons for the seasonal variation in urinary calcium and oxalate, there is clearly a marked increase in the summer in the number of patients who exceed the level of spontaneous precipitation and who are at risk of periods of persistent crystalluria (Fig. 4). Moreover, there are many more patients, with 24 h saturation levels just below the formation product of calcium oxalate, who will have periods of crystalluria at some time during the day because of diurnal fluctuations in the saturation of urine (Marshall, Cochran, Robertson, Hodgkinson & Nordin, 1972) superimposed on the seasonal variations. Since the size of crystals excreted is normally dependent on the balance between the level of supersaturation and the concentration of inhibitors of crystallization (unpublished work), then frequent periods of excessive supersaturation and crystalluria may overwhelm the protective effect of the inhibitor(s). This will increase the risk of formation of abnormally large crystals and aggregates, which, if retained in the urinary tract, may act as nuclei for stone-formation (Robertson, Peacock & Nordin, 1969, 1971; Robertson & Peacock, 1972). This increased risk of abnormal crystalluria appears to be reflected in the increase in the number of stones passed during the summer months.

It is noteworthy that whereas there is a seasonal variation in the incidence of stones passed spontaneously, the number of stones removed surgically each month appears to be fairly constant throughout the year. One possible explanation for this difference is that stones which are passed spontaneously are generally small and in many cases may be freshly formed. It is therefore likely that the date of passage may be close to the time of initiation of the stone. On the other hand, stones removed surgically are more variable in size and may have been in situ for variable periods of time after the actual initiation of the stone. If this is so then any seasonal variation in the initiation of such stones would be masked by the variability of the period between the initiation of the stone and its removal at operation.

References


