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The Influence of Calcium Content of Water, Intake of Vegetables and Fruit and of other Food Factors upon the Incidence of Renal Calculi

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Summary. An area of high incidence of renal calculi in Northern England and Scotland has been found to coincide with an area of soft water supply. However, in Wales and South West England the equation of soft water with high incidence of urolithiasis is lacking, and an enquiry into regional variations in diet reveals that a high intake of fruit and vegetables may protect against renal calculi.

Key words: Renal stones, calcium intake, drinking water, regional variation.

Introduction

The existence of regional differences in the incidence of urolithiasis, giving so-called "stone-belts", is a commonplace of the literature of renal calculi (12). In the USA, Boyce et al. (2) found that the incidence of renal stone varied from 9.47 persons per 10,000 population in the state of South Carolina to a corresponding figure of 4.31 per 10,000 in Missouri. Matés (9) reported that the incidence of renal stones in 1953-1959 was higher in the Western than in the Eastern areas of Czechoslovakia by a factor of 3.4. He attributed these differences to: -

1. Occupational and social factors, with a higher incidence of renal stones in the sedentary occupations
2. Diet, with high levels of beer and butter consumption predisposing against the disease
3. Drinking water, hard water being associated with a low incidence of stones.

This last finding seemed paradoxical: Thus most stones are largely calcium salts (Westbury,

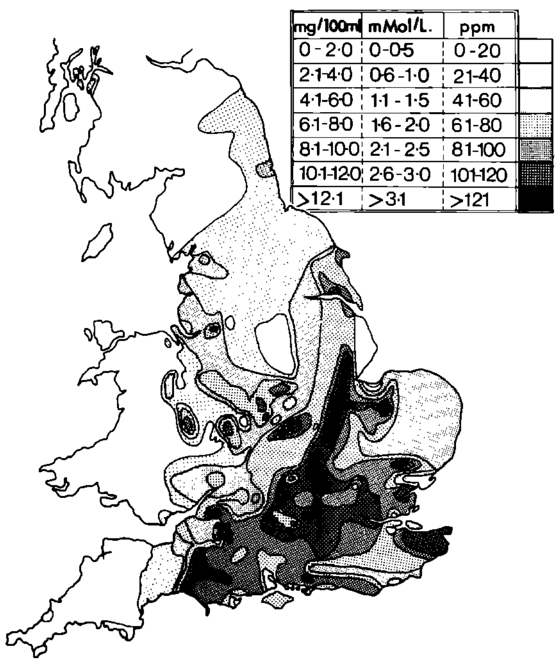

Fig. 1. A map to show the calcium content of tap waters in England, Scotland and Wales. Note that there are four main areas of very soft water, namely Scotland, Wales and Southwest England, and Northern England

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13), and yet high concentrations of this stone-forming material appeared to inhibit their formation. An opportunity arose to test the aetiological significance of hard water in a British context.

Methods

Samples of water were obtained from 2 sources. Firstly, patients attending the metabolic stone clinic at St. Peter's Hospital were asked to provide samples of drinking water from their local domestic supplies. Secondly, a nation-wide industrial group kindly sent us samples obtained from their local representatives. In all cases individuals were requested to allow water to run from the drinking water tap for several minutes prior to collecting the sample. Some 450 samples of drinking water were analysed for calcium content by the automated fluorimetric method of Rushton et al. (11), except for some of the earlier samples where the semi-automated procedure of Glatz and Rose (5) was used. It was then possible to prepare a map which indicated calcium content of water as drunk in various parts of the country. Magnesium concentrations from key

Table 1. Incidence of renal calculi cases presenting at selected hospitals

Hospital or hospital Group.	Year(s)	Total admissions	Cases of renal calculi	Calculi per thousand admissions
Birmingham (United)	1968-72	159,589	677	4.24
Brighton (Royal Sussex)	1972	24,123	63	2.61
Bristol (Royal)	1969-72	22,533	87	3.86
Caernarvon and Anglesey	1969-72	60,836	224	3.68
Cardiff (U. H. of Wales)	1972	57,366	157	2.74
Cumberland (West)	1970-72	13,207	93	7.04
Exeter (Royal Devon)	1969-72	39,216	128	3.26
Glasgow (Royal Infirmary)	1954-68	318,410	3539[a]	11.11
Leeds (United)	1970-71	41,238	321	7.78
Leicester (Royal Infirmary)	1972	19,290	55[b]	2.85
Liverpool (United)	1971-72	17,440	66	3.78
London: -				
Balham (St. James)	1968-72	70,402	265	3.76
Edgware	1972	14,731	35	2.38
Farnborough	1972 $\frac{9}{12}$ 1973	34,323	49	1.43
Greewich[c]	1972	6,832	38	5.56
Hillingdon	1968-72	93,399	199	2.13
Middlesex Central	1970-72	51,820	100	1.93
" North	1972	15,805	40	2.53
" West	1972	22,401	44	1.96
St. Helier	1972	16,730	43	2.57
Whittington	1972	19,191	64	3.33
Manchester (United)	1972	15,947	86	5.39
Newcastle (General)	1971-72	52,957	269	5.08
Plymouth (General)	1972	23,146	48	2.07

a This information was presented in graphic form
b Urolithiasis as primary and secondary diagnosis
c See comment in text

locations only were measured by a standard atomic absorption method.

Enquiries were sent to the records officers of 29 of the larger hospital groups in what were considered to represent key areas. Figures were requested for the annual total numbers of hospital admissions and the corresponding numbers of admissions for renal calculi. 24 hospital groups supplied figures which permitted the calculation of the incidence of "stone cases" per thousand admissions.

The figures for incidence of stone cases have been compared firstly with calcium content of water and secondly with the consumption of certain foods in various parts of the country. This latter information was obtained from the statistics of the Department of Agriculture (6). Indices of expenditure on beer and cider were taken from the Household and Expenditure report (1972) of the Department of Employment and Productivity (7).

Results

Magnesium content of water did not vary much in different areas and showed little correlation with stone incidence (Table 5) and is therefore not considered further.

Fig. 1 is the calcium "map" obtained. The minimal concentration range extended over the part of Scotland not shown with the exception of one location (Nairn) where the level was marginally higher.

Table 1 shows the raw figures of stone incidence and in table 2 these are related to average tap water calcium and magnesium levels in the supposed catchment areas. These incidence figures showed remarkable uniformity from year to year, and within the London conurbation the scatter from hospital to hospital was not unduly large, with one notable exception, which is in fact a hospital specialising in renal disease.

Table 2. The water environment in hospital catchment areas

Area	Mean tap water calcium mg/100 ml	Mean tap water magnesium mg/100 ml	Mean annual rainfall inches	Incidence of renal calculi cases/1000 admissions	Latitude °N
Birmingham	3. 1	0. 5	29. 87	4. 24	52. 4
Brighton	9. 1	1. 0	31. 52	2. 61	50. 8
Bristol	6. 9	1. 1	32. 20	3. 86	51. 2
Caernarvon	0. 1	0. 7	38. 65	3. 68	53. 5
Cardiff	1. 9	0. 6	42. 10	2. 74	51. 5
Cumberland	0. 7	0. 4	39. 00	7. 04	54. 4
Exeter	1. 8	1. 0	31. 90	3. 26	50. 6
Glasgow	0. 6	0. 2	41. 57	11. 11	55. 9
Leeds	1. 1	0. 4	29. 43	7. 78	53. 9
Leicester	7. 2	1. 1	26. 39	2. 85	53. 0
Liverpool	2. 4	0. 3	35. 06	3. 78	53. 6
London	10. 0	0. 5	23. 44	2. 54[a]	51. 4
Manchester	0. 5	0. 2	33. 79	5. 39	53. 7
Newcastle	4. 7	1. 7	27. 69	5. 08	54. 6
Plymouth	4. 0	0. 7	37. 76	2. 07	50. 8

a Aggregated value

For comparison, rainfall (mean annual values from 1916, supplied by the London Weather Centre) and latitude have been included in this table.

The National Food Survey findings are reported on the basis of 9 regions, which are described in table 3. For comparison with incidence data the assumption has been made that the incidence figures for centres in this area are representative of the entire region, and in table 4 the consumption of certain food items is shown in relation to the aggregated incidence thus calculated. The items selected are butter (as suggested by Matés), milk and cheese (rich in calcium), green vegetables and fresh fruit (rich in magnesium and alkaline ash), and meat (as a control). Beer is not included in the National Food Survey terms of reference, but expenditure on beer and cider is recorded in statistics measured on a different basis by another Ministry. In almost every case correlation seemed to follow an exponential pattern and the exponential correlation coefficients are shown in table 5.

Discussion

The epidemiological methods used are admittedly subject to certain errors. Criteria for admissions to hospitals may vary in different parts of the country and the composition of local populations may also vary. Methods of compiling hospital records may not be the same over the whole country. The figures given in the tables of the National Food Survey represent annual averages of many individuals and could mask big differences in minority groups of consumers. Nevertheless, the pattern of results does suggest that they have some significance, and an incidence of calculi in Glasgow 4 times the average in-

Table 3. The regions employed in the report of the national food survey committee

Region	Comprises	Incidence value aggregated from
Wales	Wales and Monmouthshire	Caernarvon and Anglesey; Cardiff
Scotland	Whole of Scotland	Glasgow
North	Cumberland, Durham, Northumberland, Westmorland and N. Riding of Yorkshire	Newcastle; W. Cumberland
Yorkshire	E. and W. Ridings, parts of Lincolnshire	Leeds
North-West	Cheshire, Lancashire and part of Derbyshire	Liverpool; Manchester
West Midlands	Hereford, Shropshire, Staffs Warwick and Worcester	Birmingham
East Midlands	Leicester, Northants, Notts, Rutland Parts of Derbyshire and Lincolnshire	Leicester
South-West	Cornwall, Devon, Gloucester Somerset, Wiltshire, most of Dorset	Bristol, Exeter Plymouth
South-East	Beds, Berks, Bucks, Essex, Hants, Herts, Kent, London, Oxford, Surrey, Sussex; Poole in Dorset All of East Anglia	Brighton, London

cidence in London does seem to call for an explanation.

The inspection of results in table 5 reveals that there is a higher incidence of renal stones in the soft water areas than in the hard water areas with a correlation coefficient of -0.58. This is in agreement with the findings of Matés (9) but nevertheless seems paradoxical and closer examination of the data shows that the situation is indeed somewhat more complicated. Thus, while there are 4 major areas of very soft water, only 2 of them, namely Scotland and Northern England, are characterised by the raised incidence of stones, while the other 2 areas, namely Wales and Southwest England, are not. It therefore seemed sensible to look for some other cause of these variations in incidence of renal calculi and we were struck by the re-

Table 4. Regional variations in diet and the incidence of renal calculi

Region	Consumption of butter oz/person/ week	Consumption of milk pints/person/ week	Consumption of cheese oz/person/ week	Consumption of green vegetables oz/ person/week	Consumption of fresh fruit oz/person week	Consumption of meat and meat products oz/ person/week	Expenditure on beer cider / household/ week	Estimated incidence of renal calculi cases/1000 admissions
Wales	8.22	5.15	3.53	16.00	26.74	40.40	1.04	3.21
Scotland	4.92	4.84	2.98	5.77	17.72	35.84	0.87	11.11
North	5.36	4.51	2.99	9.45	20.55	39.64	1.40	6.06
Yorkshire	5.18	4.85	3.16	14.98	23.90	38.49	1.17	7.78
North-West	4.85	5.03	3.62	10.32	23.52	38.05	1.23	4.58
East Midlands	5.22	5.24	3.91	18.06	22.92	36.37	1.26	2.85
West Midlands	5.38	5.37	3.88	16.37	21.96	38.02	1.09	4.24
South-West	5.71	5.20	3.48	17.82	23.09	38.01	0.69	3.06
South-East	5.88	5.46	4.05	18.87	28.11	40.41	0.85	2.58

Table 5. Exponential correlation of the factors investigated. y = aeb

x axis	y axis	Correlation coefficient
Stone incidence in hospital areas	Water calcium	-0.58
" " " "	Water magnesium	-0.39
" " " "	Total hardness	-0.59
" " " "	Latitude	+0.82
" " " "	Rainfall	+0.29
Stone incidence in regions	Butter consumption	-0.45
" " "	Milk "	-0.66
" " "	Cheese "	-0.81
" " "	Green vegetable consumption	-0.84
" " "	Fruit "	-0.76
" " "	Meat "	-0.47
" " "	Beer/cider "	+0.06

markable correlation coefficient of 0.82 between incidence of stones and latitude. The possible explanation for such a correlation could be differing dietary habits in different parts of the country. Intakes of the calcium-rich foods, namely milk and cheese, do not differ very greatly in the different regions, but in fact the correlation with stone incidence is still in the negative direction which therefore remains paradoxical. One might assume that high calcium intake would reduce absorption of dietary oxalate and so lower urinary oxalate, but this does not seem a very convincing explanation and another seems more likely. Table 5 shows that the greatest correlation of all was obtained by comparing intake of green vegetables with incidence of stones, although fruit intake also has a considerable effect. Intake of these foods does vary greatly with latitude being more readily available in the south where they are grown. Thus, table 4 shows the weekly mean vegetable intake per person (in ounces) is 5.77 for Scotland compared with 18.87 for Southeast England. Just how fruit and vegetables might protect against renal calculi cannot be definitely stated, but it should be noted that these foods are relatively rich in magnesium, an element which appears to have an important role in the aetiology of calcium oxalate renal calculi. Firstly, it was found by King et al. (8) and by Yendt (14) that urinary magnesium was reduced in stone formers, while Oreopoulos et al. (10) reported a reduced ratio of urinary magnesium to calcium in stone formers. Secondly, magnesium has been shown to protect against calcium oxalate stone formation experimentally in animals by Borden and Lyon (1) and in patients with primary hyperoxaluria by Dent and Stamp (3). It is therefore suggested that it could be the reduced intake of magnesium in fruit and vegetables which accounts for the raised incidence of stone formation in the Northern areas. This suggestion is, however, merely a working hypothesis and there might be some other quite different explanation of the facts.

There is little doubt that reduced urine volume raises the incidence of renal calculi (Frank and De Vries, 4) and the possibility must be considered that Northerners might have lower urinary volumes than Southerners. Such data cannot easily be directly obtained but table 5 does show that there is no correlation between expenditure on beer and cider and stone incidence. These results are not in conflict with Matés who reported a protective effect of beer in Czechoslovakia, since there was very little actual variation in expenditure in the different regions of this country.

Matés (9) noted that a high butter intake was associated with low incidence of renal calculi. In the results reported here, there is indeed a negative correlation between these factors (Table 5), but the correlation factor is only -0.45 and inspection of table 4 shows that this is attributable almost entirely to the results from Wales, where an unusually high butter intake was accompanied by a rather low incidence of renal calculi. This association cannot therefore be considered significant.

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