CHAPTER II

GENERAL STRUCTURE
OF CALCULI
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Normally renal calculi are composed of one or more crystalline substances admixed with a colloidal matrix. The stone is at first small usually solitary (but occasionally multiple), hard, flat, pyramidal or concavo-convex and often attached to a renal papilla and gradually enlarging to fill a calyx. A stone in renal pelvis often takes the shape of pelvis. The 'Staghorn' calculus has prolongation in the calyces. The colour of the stone varies according to chemical composition and may be modified by a superficial coating of blood pigment, pus or fibrin.

1. Crystalline content

There are 11 different crystalloid substances found in stones. Sometimes adventitious substances including drugs like sulphonamides, tetracycline, methylene blue or porphyrin are also found. The stone usually has an identifiable nucleus which differs in its composition from the remainder of the stone. When cut across, some stones show radial striation and also concentric lamination. Sometimes with crystalloid and colloidal laminae alternating (Pyrah, 1979).

2. Colloidal content

The colloidal matrix of a stone is the non-dialysable remainder after the crystalline component has been dissolved. It is a mucoprotein
complex. The composition of stone matrix seems to be constant. It consists of about 2/3 protein and various sugars including glucose and mannose and also hexosamine and glucosamine, and inorganic substances like calcium and phosphate. These substances combine together to form matrix, having been derived from urine, the blood plasma and possibly the kidney (Stanton et al, 1963). Matrix substance 'A' has been demonstrated to be present in the matrix of all types of stone. It originates in the renal parenchyma. It is a mucoprotein present in the urine of stone forming patients.

Stone can be amorphous or crystalloid. According to its major chemical content, it is usually classified as:

a) oxalate calculi
b) phosphate calculi
c) uric acid or urate calculi
d) cystine calculi.

The rare constituents are xanthine, indigo, fibrin or albumin. The calcium is the main element to which phosphate, oxalate or other negative ions bind and form the crystals. The common kidney stone is made predominantly of calcium oxalate. Many other stones are made up of calcium phosphate and carbonate. Calcium is a major constituent in 90 per cent of cases and oxalate is present in 66 per cent of stones. The calcium-oxalate stones are usually found in sterile acid urine and may contain varying amount of apatite. The calcium-oxalate occurs in
Two forms. The first form is calcium oxalate monohydrate (Whewellite \( \text{CaC}_2\text{O}_4\cdot\text{H}_2\text{O} \)) which has monoclinic crystals and second form is calcium oxalate dihydrate (Weddellite \( \text{CaC}_2\text{O}_4\cdot2\text{H}_2\text{O} \)) which has tetragonal crystals. Calcium oxalate trihydrate (\( \text{CaC}_2\text{OH}3\text{H}_2\text{O} \)) is very rare.

Four different types of phosphates found in calculi:

1. Apatite is the commonest constituent of urinary calculi. It is found in two varieties: (a) hydroxyapatite \( \text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2 \) and carbonate apatite \( \text{Ca}_{10}(\text{PO}_4\text{CO}_3\cdot\text{OH})_6\text{OH}_2 \).

2. Struvite or magnesium ammonium phosphate hexahydrate \( \text{MgNH}_4\text{PO}_4\cdot6\text{H}_2\text{O} \) found in stones with alkaline infected urine. The crystals are short and prismatic and are formed as "Kniferest" or "Coffin-lid" crystals. It gives creamy white appearance to the stone.

3. Brushite or calcium hydrogen phosphate dihydrate \( \text{CaHPO}_4\cdot2\text{H}_2\text{O} \). It occurs in acid urine, light yellow in colour usually associated with oxalate and sometimes with apatite.

4. Whitlockite or Beta-tricalcium phosphate \( \text{Ca}_3(\text{PO}_4)_2 \) are long, colourless, rhombohedral crystals appearing as bristle like structures radiating from a nucleus of apatite or calcium oxalate.

Octocalcium phosphate or tetracalcium hydrogen triphosphate trihydrate \( \text{Ca}_4\text{H}2\text{PO}_4\cdot2.5\text{H}_2\text{O} \) was first detected by X-ray diffraction studies. It has been suggested that it may be the first of the phosphates to be precipitated during renal stone formation. There are
other rare phosphate calculi including newberyite (magnesium hydrogen phosphate - MgHPO₄.3H₂O).

The calcium-oxalate stones show different varieties of external appearance:

1. **Hempseed calculi** are small, round or ovoid, multiple grey or brown with varnished surfaces and concentrically laminated structures.

2. **Nodular or Mulberry stones** are rounded or ovoid, amber to dark brown with many rounded bosses or mamillary processes.

3. **Jack stone** is a variant of the nodular stone. It has longish solid processes radiating from the centre.

These calculi are usually composed of calcium-oxalate monohydrate and may have nuclei of uric acid or apatite.

4. **Crystalline stone**: The surface is covered with well formed large 'envelope' crystals of calcium-oxalate dihydrate. The interior may be composed of monohydrate or apatite and only coarse lamination but no radial striations.

**Infection stones**

The term 'infection' stones refers to calculi composed of magnesium ammonium phosphate and carbonate apatite and it is synonymous with "struvite stones", "urease stones" and "triple-phosphate stones" which account for 10-15 per cent of urinary calculi.
In the general population, female subjects are affected more commonly than male subjects by 2:1 (Resnick, 1981) presumably because of their increased susceptibility to urinary infection.

Rendering the urine free of infection, the source of urease, is the benchmark of prevention.

The biochemistry and stoichiometry of calculogenesis are well recognized (Griffith, 1978). Human urine is replete with substrate - calcium, magnesium, phosphate and urea. The presence of urea and urease is essential. The protein urease comes only from bacteria. Thus, infection with a urease producing organism is a critical ingredient. More than 45 different microorganisms produce urease (Finegold, 1986). Proteus species are identified in 72 per cent of bacterial isolates (Silverman and Stamey, 1983). Klebsiella, Pseudomonas and Staphylococcus species produce urease and they frequently are identified in culture of infection stones. Escheria coli rarely produce urease.

Most renal infection results from bacteria ascending from the lower urinary tract via vesicoureteral reflux or lymphatics. A glycocalix secreted by the bacteria promotes their adherence and a bacterial biofilm develops on the urothelial surface (Nickel et al, 1985). Elevated urinary ammonia via urea hydrolysis damages the protective glycosaminoglycan layer, further facilitating bacterial adherence and tissue invasion (Parsons et al, 1984). The glycocalix further serves
to protect the bacteria and binds crystals of struvite and apatite that form as a result of elevated pH (Nickel, 1987). Organic compounds increased by tissue inflammation and urinary microproteins are incorporated as continued bacterial growth promotes crystal deposition and formation of a gelatinous or matrix stone. With time, this immature, low density amalgam is progressively mineralized via ongoing ureolysis by bacteria within the matrix. Struvite and carbonate apatite ultimately replace the matrix and the concretion evolves into a dense, radiopaque stone (Griffith and Osborne, 1987).