Sodium Orthophosphate Hydrate (Na₃PO₄ · 12H₂O): A New Type of Human Urinary Stone

K. M. Kim¹, H. B. Alpaugh², and F. B. Johnson²

¹ V. A. Medical Center and University of Maryland, Baltimore, and ² Armed Forces Institute of Pathology, Washington, DC, USA

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Summary. In a series of electron microscopic studies of human urinary stones, a stone composed of sodium orthophosphate hydrate was identified. The stone was recovered from a patient who succumbed to advanced renal failure. A massive failure of the sodium pump, which cotransports phosphate across the brush border membrane of the proximal tubules is thought to be responsible for such an exceptional stone. This appears to be the first description of sodium phosphate crystal in a human urinary stone. Electron microscopy is a useful tool for stone analysis.

Key words: Electron microscopy, Urolith, Sodium phosphate, New stone component.

Introduction

Phosphate crystal deposition in humans, either physiological or pathological, occurs mainly as calcium salts with the exceptions of magnesium and ammonium magnesium phosphates in urinary stones [5]. In view of the high solubility, sodium phosphate crystals in human urine have been virtually unknown. In a series of electron microscopic studies of human urinary stones, a stone which consisted solely of sodium orthophosphate hydrate was encountered.

Materials and Methods

The patient was a 91-year-old black male who suffered from chronic renal failure due to severe arteriolar nephrosclerosis associated with secondary hyperparathyroidism and hyperkalemia. He also had aortic stenosis, gout, adrenal cortical insufficiency and essential thrombocytosis. The patient remained comatose during his last hospital admission of 8 days duration. His blood urea nitrogen ranged from 85 to 175 mg/dl; potassium 6.5 to 8 mEq/l; calcium 8.6 to 6.5 mg/dl; inorganic phosphorus 7.1 to 7.9 mg/dl; HCO₃ 10 to 17 mEq/l; and blood pH was 7.15. His urine electrolytes were measured once, revealing osmolality of 264 mOsm/kg H₂O, Na 57 mEq/l, K 11 mEq/l and Mg 2.3 mEq/l. Urine calcium and phosphate were not recorded. Despite vigorous treatment, the patient developed anuria 3 days after admission which improved only slightly with dopamine infusion. The patient expired from Klebsiella pneumonia following an episode of pulmonary edema. An oval grayish white stone measuring 1 x 0.5 cm in diameter was found in a mildly distended renal pelvis on autopsy.

The stone crumbled into pieces when it was cracked with a razor blade and a hammer. Larger pieces were mounted on an aluminum stub with the fractured surface up, using carbon conductive glue. The mounted specimens were coated with either carbon or gold in a sputter coater and examined with an ETEC Autoscan scanning electron microscope (SEM) and energy dispersive x-ray microanalysis (XA). Representative portions of the stone were ground with a mortar and a pestle, mounted on formvar coated grids and an additional carbon coating was applied to stabilize the particles in an evaporator. Selected area electron diffraction was performed on the powdered stone using gold coated grid as a standard in a JEOL 100CX Analytic Electron Microscope. All the particles demonstrating unique morphology by transmission electron microscopy were subjected to electron diffraction at 80 KeV and camera length of 76 cm. X-ray diffraction was performed using a Debye-Scherrer diffraction camera. Infrared spectra were obtained with a Perkin-Elmer 727 Infrared Spectrometer using the KBr pellet technique.

Results

SEM of the stone revealed an aggregate of spheroidal shells with empty centers (Fig. 1). The inner surface of the shell was smooth. The outer surface appeared granular with nodular protuberances. The fractured surface of the shell was conchoidal (smoothly curved) and the shell wall appeared to be formed by multiple layers of thin lamellar crystals. Amid the aggregate of the shells, there were occasional clusters of oval plates or spindle shaped particles (Fig. 2). XA of both the shells and the plates yielded exclusively the peaks of Na and P, which were similar in heights to those of the authentic Na₃PO₄ · 12H₂O (Fischer Scientific Co., Pittsburgh, Pa.) (Fig. 3). Electron and x-ray diffractions of both the shells and the plates produced the powder pattern most consistent with sodium ortho-
Fig. 1. The stone consisted mainly of an aggregate of spherical shells with empty centers.

Fig. 2. A small amount of oval plate shaped crystals were seen in areas.

Fig. 3. X-ray analysis of both the shells and the plates yielded Na and P (*upper spectrum*). The peaks are very similar to an authentic Na$_3$PO$_4$ $\cdot$ 12H$_2$O (*lower spectrum*) in heights.

Fig. 4. Electron diffraction pattern of the stone (*left*) and the authentic Na$_3$PO$_4$ $\cdot$ 12H$_2$O (*right*) which show identical powder patterns. X-ray diffraction yielded similar patterns. Both patterns contain an extra d spacing (*arrow*) which is not listed in the JCPDS Powder Diffraction file (see Table 1).

Fig. 5. Infrared spectrum of the stone (*upper*) and the reference Na$_3$PO$_4$ $\cdot$ 12H$_2$O (*lower spectrum*).