Endoscopic Evidence of Calculus Attachment to Randall's Plaque

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Purpose: It has been proposed that calcium oxalate calculi begin as small stones attached to the renal papillae at sites of Randall's plaque. However, no study has investigated the prevalence of attached stones in calcium oxalate stone formers or the relationship between stone attachment site and Randall's plaque. In this study we used endoscopic examination of renal papillae in stone formers undergoing percutaneous nephrolithotomy to investigate both issues.

Materials and Methods: Idiopathic calcium oxalate stone formers undergoing PNL for stone removal were enrolled in this study. Multiple papillae were examined and images were recorded by digital video. The presence or absence of papillary plaque and attached stones was noted, as was the site of stone attachment.

Results: In 23 patients, 24 kidneys and 172 renal papillae were examined. All kidneys were found to have papillary plaque and 11 of the patients had attached stones. Most papillae (91%) contained plaque.

Conclusions: The prevalence of attached stones in calcium oxalate stone formers (48%) is greater than that previously reported for the general population. Attachment appears to be on Randall's plaque. The high prevalence of attached stones and the appearance of the attachment site are consistent with a mechanism of calcium oxalate stone formation in which stones begin as plaque overgrowth.

Key Words: kidney; kidney calculi; nephrostomy, percutaneous

The exact mechanisms of the crystallization processes that occur in kidney stone formation are controversial. One of the critical elements of this process is particle retention, which allows the forming stone to develop into a clinically significant calculus.[1] More than 6 decades ago Alexander Randall addressed this issue when he conducted a detailed examination of the papillae of more than 1,000 nonselected cadaveric renal units.[2] He observed calcium salt deposits in the tip of the renal papilla in 19.6% of individuals studied. These deposits, which he termed plaque, were interstitial in location, composed of calcium, and not observed in the tubular lumen. Randall noted that these areas of plaque would be an ideal site for an overgrowth of calcium oxalate to develop into a calculus.

In fact, Randall reported that in a number of kidneys, small stones were fixed to the surface of the renal papillae, anchored at the location of plaque. The frequency with which stones are attached to plaque remains unknown. It could be that every calcium oxalate stone begins as a papilla attached stone, or it could be that only a minority of stones form in this way. However, data are lacking on the true incidence of attached stones in any population of stone formers. Randall's studies were confined to a population of nonselected cadavers, and there have been no subsequent studies directly addressing the attached renal calculus.

The finding of stone attached to Randall's plaque was first reported in vivo with endoscopic techniques by Low and Stoller, although the exact nature of the papilla stone relationship is somewhat difficult to interpret from the published images.[3] Using more advanced visualization techniques permitted by the PNL approach, we have been able to visualize with much greater resolution the attachment of calcium oxalate stones to Randall's plaque.[4,5] To more completely define the attached stone phenomenon, we assessed the prevalence of attached renal calculi in a well characterized population of common calcium oxalate stone formers. A secondary purpose of this study is to present the first images of attached calculi captured with modern digital endoscopic equipment.

MATERIALS AND METHODS

A total of 23 patients undergoing PNL were enrolled in this Institutional Review Board approved study. All patients fulfilled the criteria for common, idiopathic calcium oxalate

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TABLE 1. *Anatomical distribution of stones and plaque*

Location of Papillae	No. Papillae Observed	No. Papillae With Plaque (%)*	No. Papillae With Stones (%)*
Upper pole	75	67 (89)	26 (35)
Middle kidney	50	46 (92)	15 (30)
Lower pole	47	43 (91)	8 (17)
Totals	172	156 (91)	49 (28)

* Papillae with stone and papillae with plaque numbers do not differ by papilla location (nominal logistic fit test $p > 0.28$).

stone formers.[6] In all patients at least 1 stone was analyzed and shown to be composed of calcium oxalate, and no stones contained uric acid, struvite, cystine, or more than 50% calcium phosphate. None of the patients had systemic disorders such as primary hyperparathyroidism, sarcoidosis, vitamin D excess, hyperthyroidism, or renal tubular acidosis.

PNL was performed as previously described.[7] Following evacuation of the unattached calculous debris, all accessible papillae were sequentially visualized. Those papillae immediately accessible to the calix of entry were visualized with a 27Fr offset rigid nephroscope, and more peripherally located papillae were visualized with a 15Fr digital flexible nephroscope (Pentax, Orangeburg, New York). Locations of papillae were identified using fluoroscopy. Video footage of the endoscopic mapping procedure was recorded digitally on tape. The video footage for each patient was then reviewed using the retrograde pyelogram as a reference to confirm the location of each papilla. Representative color and black and white still images of each papilla were also captured from the video. A single investigator (JEL) reviewed the video and still images to identify the location of all calculi attached to the renal papillae, as well as the presence of any papillary plaques.

RESULTS

A total of 172 renal papillae were endoscopically identified and inspected in 24 kidneys of 23 patients (table 1). A mean of 7.2 papillae per kidney were inspected. There were 156 papillae (91%) that had plaque, and all renal units in the study had plaque on at least 1 papilla. Of these papillae 49 (28.5%) had attached calculi and 44 of those papillae were observed to have plaque. In the 5 papillae upon which plaque was not observed it is possible that the plaque was removed along with the attached stone.

The quality of digital imaging provides strong evidence of stone attachment to plaque. Figure 1 demonstrates a typical single calcium oxalate stone attached at the papillary tip (fig. 1, *A*). After stone removal plaque is clearly evident at the site of stone attachment (fig. 1, *B*). Figure 2 demonstrates another example of a single calcium oxalate stone attached to a region of plaque on a renal papilla (fig. 2, *A*). Exposed openings of inner medullary collecting ducts are evident following stone detachment (fig. 2, *B*). Removal of multiple attached stones on a compound papilla (fig. 3, *A*) reveals (fig. 3, *B*) underlying plaque with residual stone material. Removal of 1 of 2 attached stones (fig. 4, *A*) on a simple papilla, with a nitinol basket (fig. 4, *B*), reveals plaque at the site of prior stone attachment (fig. 4, *C*).

Attached calculi were observed in 11 of 23 patients (48%) and 12 of 24 kidneys (50%). This far exceeds the prevalence found by Randall (table 2) in an unselected cadaveric population. The distribution of plaque and calculi did not differ significantly with location (upper pole, middle region, lower pole) within the kidneys (table 1).

DISCUSSION

We have noted that when endoscopically examining the renal papillae of patients, stones attached to the papillae are often encountered. Low and Stoller have also reported this phenomenon.[3] Our present data suggest that attached stones are encountered more frequently than Randall initially reported.[2] Randall's studies were of nonselected kidneys, in which he examined both stone formers and nonstone formers. It is likely that the prevalence of attached renal calculi in an exclusively stone forming population such as

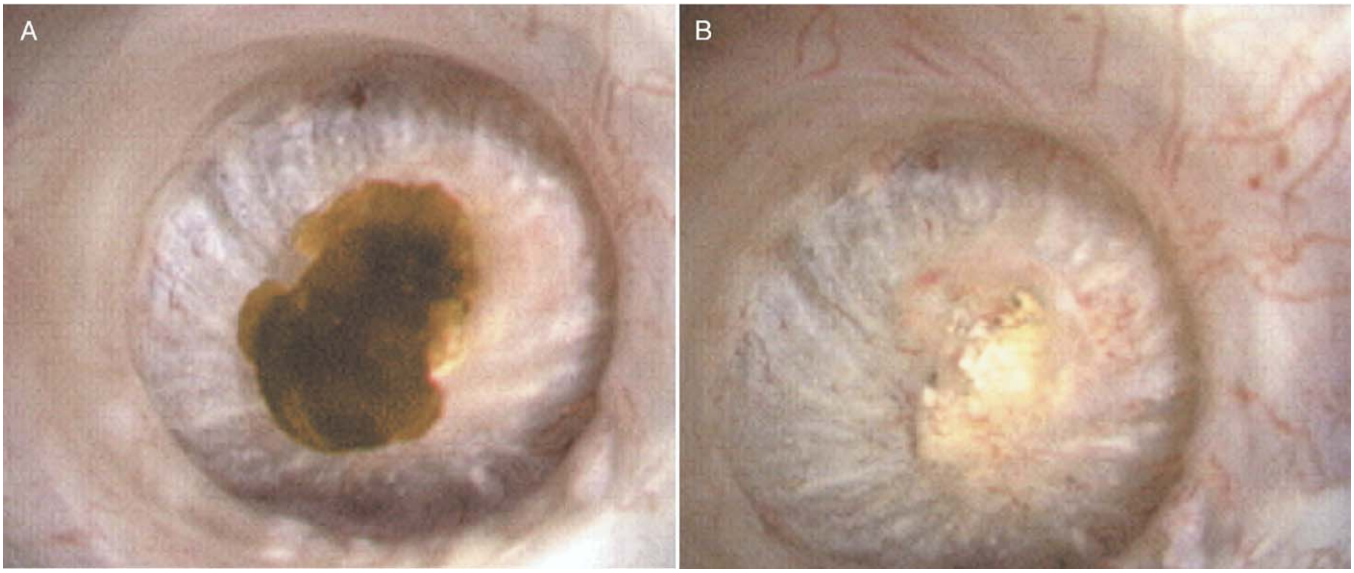

FIG. 1. *A*, digital photograph of calcium oxalate monohydrate stone attached to tip of renal papilla. *B*, papilla from part *A* after stone removal demonstrates extensive plaque at site of stone attachment.