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Encrusted Urinary Stents: Evaluation and Endourologic Management

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ABSTRACT

Ureteral stents and nephrostomy tubes have been used extensively in urology. Attendant to their use are their associated morbidities, such as pain, infection, and encrustation. We review the literature on the subject of the encrusted stents and drainage catheters, discuss the risk factors for encrustation, and describe the endourologic evaluation and management of these encrusted and retained urinary drainage devices. A variety of factors contribute to the rate at which this process occurs, including the material of the stent or catheter, urine composition, and duration of use. The risk of stent encrustation is increased in patients with a history of urolithiasis and with progressively longer indwelling times. Novel stent designs incorporating antimicrobial eluting stents and stents with enzymes to degrade urinary oxalate have shown promise *in vitro* to minimize stent morbidity. Imaging plays a pivotal role in determining the appropriate surgical management of the encrusted and retained stent. In cases in which encrustation is minimal, extracorporeal shock wave lithotripsy has been used with high success rate. Calcifications along the ureteral component of the stent can be treated with retrograde ureteroscopy and laser lithotripsy while the percutaneous route is the preferred primary approach when stone size is greater than 2 cm and/or if there is associated significant encrustation on the proximal ureteral end of the stent. It is not unusual to need multiple sessions to successfully render the patient stent and stone free, depending on which modalities are used. A computerized tracking system for patients with indwelling ureteral stents has been advocated to reduce the number of "forgotten" stents. Finally, it is of paramount importance that the treating urologist communicates clearly to the patient the presence of any internal urologic stents, the temporary intent of their use, risks with prolonged indwelling times, and the need for appropriate follow-up to avoid complications of encrustation.

INTRODUCTION

ENCRUSTATION is a clinical problem occurring with indwelling urinary drainage devices both external and internal. The chemical constituents of the urine combine with the tubing to form a matrix on which further calcification occurs; the end result is encrustation (Fig. 1). A variety of factors contribute to the rate at which this process occurs, including the material of the stent or catheter, urine composition, and duration of contact of the drain with urine. This phenomenon can be observed with urethral catheters, suprapubic and nephrostomy tubes, and ureteral stents.

Ureteral stents have been used extensively in urology since their first description in 1967.[1] Their main application is toward preventing or managing obstruction within the urinary tract secondary to a variety of causes: Calculus disease, malignancy, and edema after reconstructive surgeries. Attendant to their use are their associated morbidities, such as pain, infection, and encrustation.[2] The encrusted stent has many names throughout the literature: The retained stent, "forgotten stent," and overlooked stent.[3,4] The forgotten stent may be asymptomatic and "remembered" only when its presence is incidentally revealed by abdominal imaging. Conversely, a patient with ureteral obstruction from an encrusted stent can present with life-threatening urosepsis, which may be lethal in some cases.[5]

We conducted a nonstructured review of the English literature published before 2007 using the Internet search databases including PubMed® or Ovid Medline.® A combination of the

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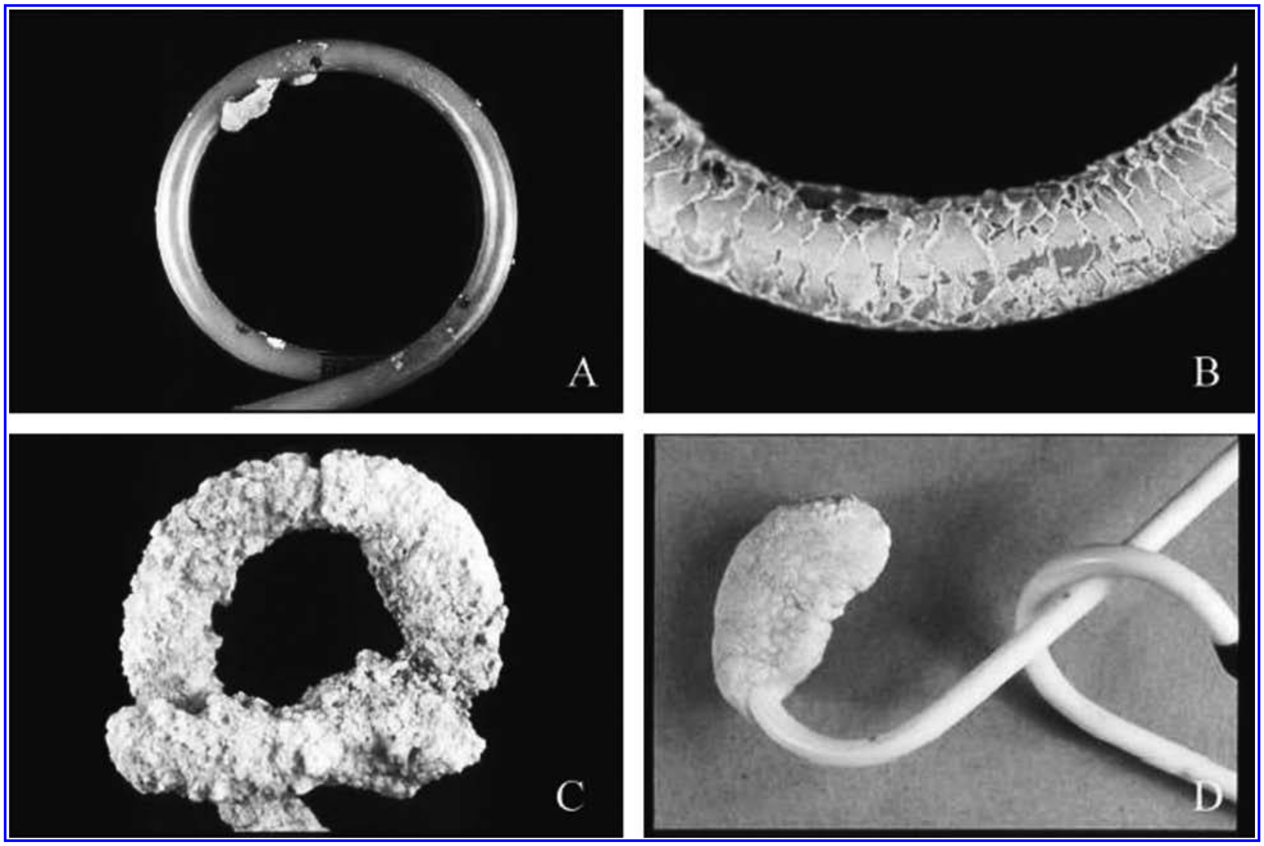

FIG. 1. Encrustation of varying composition and severity develops on ureteral stents. (From Roupret M, et al. Urology 2005;66:246–251.)

search words "ureteral stent" or "nephrostomy" or "urinary drain" and "encrustation" or "retained" were typed into these databases. Clinical case reports and case series, as well as investigative basic science publications, served as the basis of this review.

This manuscript is intended to review the literature on the subject of the encrusted stents and drainage catheters, discuss the risk factors for encrustation, and describe the endourologic evaluation and management of these encrusted and retained urinary drainage devices.

RISK FACTORS FOR ENCRUSTATION

While no formal consensus exists as to the maximum indwelling time for internal ureteral stents, previous studies have shown increasing rates of encrustation with increasing indwelling time. El-Faqih and colleagues,[6] in a series of 290 stone patients with 141 stents retrieved and examined, discovered that encrustation occurred in 9.2% of the stents retrieved before 6 weeks, 47.5% when stents were indwelling for 6 to 12 weeks, and rose to 76.3% when stents were indwelling longer than 12 weeks. Clinical obstruction, however, as evidenced by urography or isotope studies, was recorded in only 5% of the patient population and was absent with indwelling periods of less than 6 weeks. Most case reports and patient series of encrusted stents consistently show that the stent had been in place for more than 3 months.

There are conflicting reports about whether the composition of the stent is a factor in the degree of encrustation. *In vitro* studies have shown that hydrophilic-coated polyurethane stents encrust faster and to a larger extent than silicone or nonhydrophilic-coated polyurethane stents.[7] The hydrophilic coating is used to reduce the coefficient of friction of the stent during endourologic placement; however, this same hydrogel coating is permeable to inorganic salts and may account for the enhanced risk of encrustation. In a separate study, however, Wollin and coworkers[8] demonstrated that stent type and duration of insertion did not correlate significantly with the amount of encrustation observed from stents retrieved from humans after 11 to 17 days.

A history of urolithiasis also predisposes to development of encrustations. In a clinical study of 40 patients, Robert and colleagues[9] found that patients with a history of urolithiasis had a nearly three times increased risk of encrustation of ureteral stents compared to non-stone-formers. Formation of encrustations is also dependent on both the urinary constituents and bacterial colonization.[10] When in contact with urine, the stents are rapidly covered by a bacterial biofilm and with continued growth can lead to obstruction of the

FIG. 2. Scanning electron microscopy of a polyurethane ureteral stent after use demonstrates biofilm and surface irregularities from encrustations.

urine flow and possibly urinary tract sepsis[8] (Fig. 2). In the presence of urease-producing organisms, especially *Proteus* species, hydrolysis of urea occurs, and the corresponding elevation of pH induces the deposition of calcium and magnesium phosphate crystals along this biofilm. In noninfected urine, the encrustations often result from accumulation of calcium oxalate on the surface.[11]

An additional risk factor for stent encrustation can be pregnancy (Table 1). Pregnancy is accompanied by a number of physiologic changes to the urinary tract that may predispose the gravid woman with an indwelling urinary drain to encrustation. Important metabolic changes during pregnancy include an absorptive calciuria from placental production of 1,25-dihydroxyvitamin D_3 and a resultant decrease in parathyroid hormone secretion.[12] Further, the increase in the glomerular filtration rate during pregnancy increases the filtered load of calcium. Hyperuricosuria and an increased filtered load of sodium are also observed in pregnant women; however, the observed increases in urinary output and urinary inhibitors excreted during pregnancy may mitigate these risk factors.[13]

While the incidence of symptomatic urolithiasis is similar in nonpregnant and pregnant women, reports of rapid ureteral stent and nephrostomy tube encrustation exist in pregnant women. Kavoussi and associates[14] reported nephrostomy tube encrustation as early as 2 weeks after placement in a series of pregnant women who needed urgent decompression of the kidney.[1] The investigators in that study advocated that, because of the risk of calcification with ensuing obstruction, stents should be changed every 6 to 8 weeks.

EVALUATION OF ENCRUSTED STENT AND SELECTION OF EXTRACTION TECHNIQUE

Imaging plays a pivotal role in evaluating the patient and determining the appropriate surgical management of the encrusted and retained stent (Table 2). The principal chemical composition of the encrustation surrounding the stent is typically calcium based, and a plain film, such as of kidneys, ureters, and bladder, should suffice to assess the degree of encrustation along with any associated stone burdens on the proximal or distal coils (Fig. 3). Quantifying the stone burden associated with encrustation by multiplying the width of encrustation around the stent times the length expressed in millimeters squared (mm^2) or direct measurement can have some prognostic significance. Some investigators have suggested that a severe stone burden (> 400 mm^2) or calcifications > 3 mm over one-third of the stent are more likely to necessitate a multimodal or percutaneous therapeutic approach to render the patient stone free.[15–17]

CT or ultrasonography can also help assess stone burden, especially in the uric acid stone former when the stones are radiolucent and the extent possibly underestimated by plain radiography (Fig. 4). If the stone burden is large, assessment of differential renal function with radionucleotide studies is prudent. This test serves a two-fold purpose: To determine preprocedural renal function in what may be potentially a litigious situation and to evaluate the function of the affected renal unit. A poorly functioning kidney with significant stone burden may be better suited for a nephrectomy rather than multiple procedures to eliminate all stones. Case series, however, have reported significant recovery of renal function after endourologic management of severely encrusted ureteral stents.[18]

If there is no encrustation visible on plain radiography, removal of the stent in a retrograde fashion may be attempted. Ideally, fluoroscopy should be available to see if there is uncoiling of the proximal curl during removal, because this may be a site of resistance. If there is any resistance or if the patient complains of significant pain during attempts at cystoscopic removal, one should stop immediately, because the risk of stent fracture or ureteral injury cannot be ignored.

At times it may be possible to remove the stent outside the urethral meatus before meeting resistance. If this occurs, a guidewire can be passed retrograde through the lumen of the stent in an attempt to determine its patency or to straighten the proximal curl. If these measures prove unsuccessful, then a procedure to address likely encrustation of the proximal curls will be necessary. In cases in which encrustation is minimal, extracorporeal shock wave lithotripsy (SWL) has been used with a high success rate.[19–22] After adequate treatment, repeat cys-

Table 1. Risk Factors for Urinary Stent Encrustation

Increasing indwelling time
Stent composition
Bacterial colonization
Biofilm on stent
History of urolithiasis
Pregnancy

TABLE 2. SEQUENCE OF EVALUATION OF PRESUMED ENCRUSTED URINARY STENT

Patient history
(Reason for initial stent placement, length of time stent has been in place)
Imaging
(Plain film initially and CT if necessary, depending on stone burden and history of uric acid stone)
Cystoscopic removal under fluoroscopy if no encrustation seen on imaging
If no success, can consider shockwave lithotripsy along stent for minimal encrustation
If encrustation of ureteral stent is significant on imaging:
Ureteroscopy for encrustation along distal end of stent
Antegrade nephroscopy for proximal coil/proximal ureteral encrustation

toscopy can be performed and retrieval of the stent attempted in the same setting.

Significant stone encrustation of the vesical portion of the stent can be addressed by performing transurethral cystolitholapaxy using either laser, electrohydraulic, or pneumatic lithotripsy. Calcifications along the ureteral component of the stent can be managed with retrograde ureteroscopy and laser lithotripsy.[23,24] In certain cases, it can be difficult for the ureter to accommodate both the ureteroscope and stent. When this occurs, placing a new ureteral stent alongside the encrusted stent, waiting for the ureter to passively dilate, and performing interval ureteroscopy may be beneficial.[25] Some investigators have reported high success rates in managing calcified stents using endourologic techniques in a single anesthetic setting[24,26,27]; however, it is not unusual to need multiple sessions to successfully render the patient stent and stone free, depending on which modalities are used.[15,17,28]

FIG. 3. Plain radiograph shows a retained ureteral stent and bladder stones. (From Lam JS, et al. J Endourol 2002;16: 733–741.)

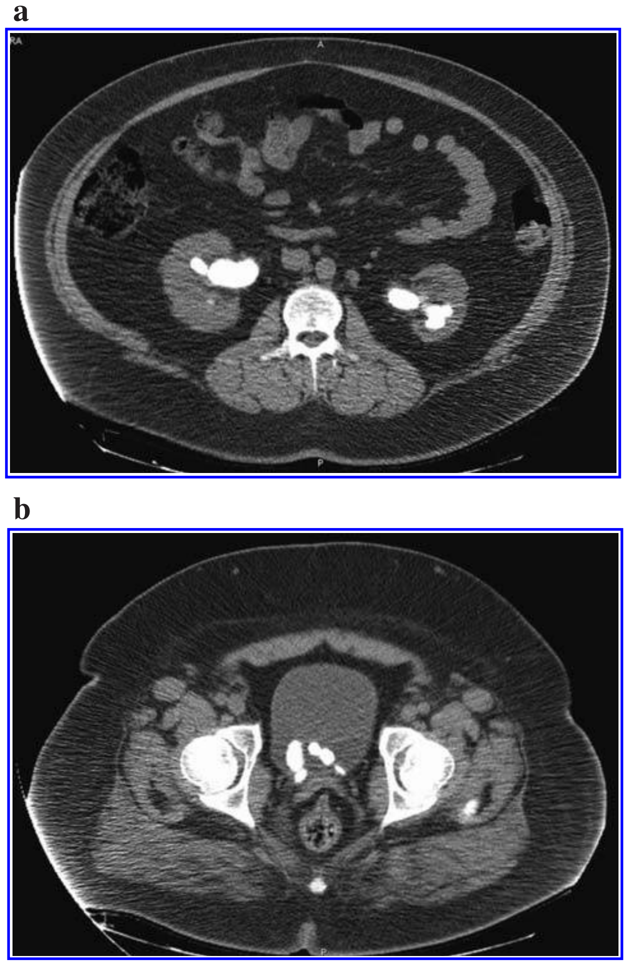

FIG. 4. CT (**a, b**) demonstrates the proximal and distal ends of a completely encrusted stent from a patient whose severity of encrustation was significantly underestimated by plain radiography. Stone composition on the stent was uric acid.

Antegrade nephroscopy and ureteroscopy can also serve as alternative means to access the proximal collecting system to perform lithotripsy on calcified ureteral stents.[16] The percutaneous route, as with uncomplicated nephrolithiasis, is the preferred primary approach when stone size is greater than 2 cm and/or if there is associated significant encrustation on the proximal ureteral end of the stent.[17,18,28] In the case of simultaneous large proximal and distal encrustations, the issue of which encrusted end to address first, proximal or distal, is a matter of preference and severity of stone burden. However, managing the lower coil first transurethrally, placing a ureteral catheter retrograde, and repositioning the patient to the prone position to obtain percutaneous access to manage the upper coil is an efficient and logical approach.

FIG. 5. Calcified nephrostomy is seen in a woman who had it placed for symptomatic nephrolithiasis during pregnancy.

An alternative nonsurgical option to managing the encrustation is the instillation of chemolytic agents via a nephrostomy tube. Case reports using hemiacidrin and Suby G solution to dissolve associated stones and encrustation, followed by successful cystoscopic retrieval of the stent, have been described.[29,30] These agents should be reserved for extreme cases, given their irritating effects on the lower urinary tract and the need for close monitoring secondary to potential electrolyte imbalances from systemic absorption.

EVALUATION AND MANAGEMENT OF AN ENCRUSTED AND RETAINED NEPHROSTOMY TUBE

Percutaneous nephrostomy and suprapubic tubes are also subject to the same complication of encrustation as ureteral stents with prolonged indwelling times precluding their removal (Fig. 5). Several reports in the literature detail the inability to remove the nephrostomy tubes and their respective management.[31–35] The type of drainage catheter can affect the cause of the entrapment. A common finding with a retained Malecot nephrostomy tube is that the flange of the Malecot catheter can become anchored to the urothelium by tissue bridges or adhesions. This can be caused by either prolonged use or from an unusual complication—perforation of the renal pelvis from the Malecot nephrostomy tube and the resulting inflammatory response to the injury to the renal pelvis entrapping the flange within the renal sinus (Fig. 6).

Tasca and Cacciola[31] describe an entrapped nephrostomy tube in a 61-year-old woman in whom a nephrostomy tract was created alongside the Malecot catheter and the overgrown tissue bridging the wings of the tube were incised with an urethrotome.[31] In a similar fashion, Koolpe and Lord[32] described the dilation of an eccentric nephrostomy tract alongside the existing nephrostomy tube with lysis of calcifications and tissue bridges using nephroscopy.

Less invasive methods have been described using the tube as the conduit for passing instruments. Bellman and colleagues[33] reported a novel method of managing a retained nephrostomy tube that had been in place for a 9-week period for bacillus Calmette-Guérin instillation.[33] The investigators passed a stone-grasping forceps through the Malecot under fluoroscopic guidance to straighten the flanges and applied electrocautery to incise tissue enabling easy removal (Fig. 7). Sardina and coworkers[34] described a similar minimally invasive approach by placing a 9F pediatric cystoscope through the lumen and using a Bugbee electrode to incise a tissue bridge in three patients.

Once again during the evaluation, imaging helps to determine the extent of calcification and the operative approach. Large stone burdens on the proximal end of the nephrostomy tube may necessitate SWL, ureteroscopic lithotripsy, percutaneous nephrolithotomy, or a combined approach. Percutaneous

FIG. 6. Malecot nephrostomy tube was placed with unrecognized renal pelvis perforation. Attempts to remove it were met with resistance, and the incorrect positioning revealed with nephrostography. The tube was removed percutaneously after elimination of the adhesions from the tube and the renal sinus.

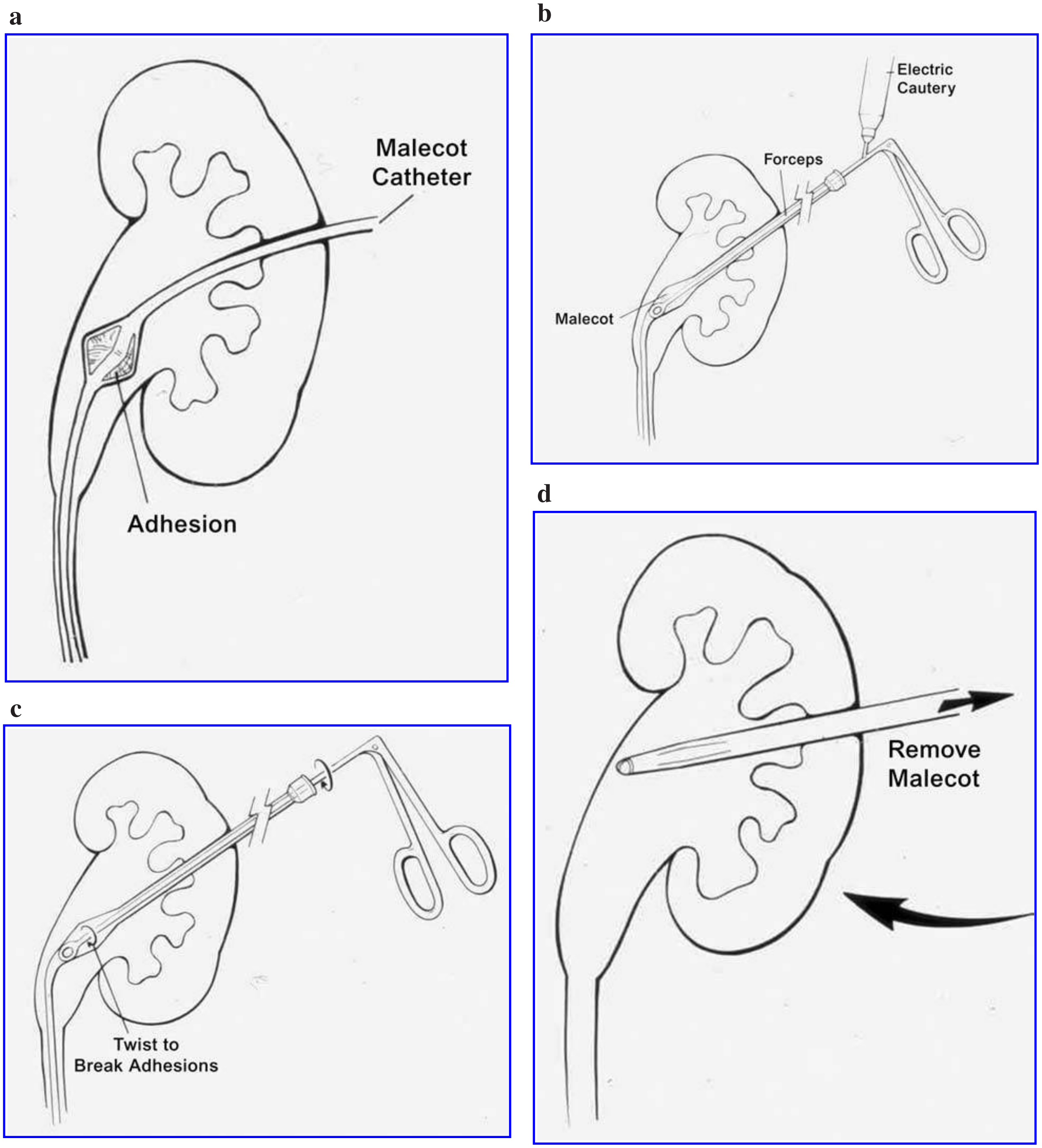

FIG. 7. Nephrostomy tube removal is diagrammed. Malecot tip of the nephrostomy tube is entrapped in the renal pelvis by adhesions (**a**). Stone-grasping forceps straighten Malecot flanges and position for incision of tissue with electrocautery (**b**). Forceps are rotated in both directions to free the nephrostomy tube (**c**). Catheter is removed (**d**). (From Bellman GC et al. *J Endourol* 1994; 8:115–117.)

access through an adjacent calix may be necessary to perform lithotripsy on the calcified portion of the nephrostomy tube to allow for removal. Intraluminal pneumatic lithotripsy within the encrusted nephrostomy tube under fluoroscopic guidance in concert with ureteroscopic lithotripsy has been described to straighten and remove a nephrostomy tube.[35]

PREVENTION OF ENCRUSTATION

The combination of potential significant morbidity associated with neglected internal stents and the increased mobility of our society and patients has provided the impetus for the pursuit of novel methods to limit such complications (Table 3). A

Table 3. Prevention of Urinary Stent Encrustation

Educating patient about temporary nature of and need for follow-up/maintenance of internal ureteral stent/nephrostomy tube
Frequent stent/nephrostomy tube exchange in pregnant population with existing stent/nephrostomy tube
Exteriorized ureteral stents connected to a urethral catheter after urteroscopy in presumably noncompliant patients
Biodegradable stent

computerized tracking system for patients with indwelling ureteral stents has been advocated to reduce the number of forgotten stents.[36,37] Ather and associates[36] noted the incidence of long-term indwelling stents decreased from 12.5% to 1.2% with the use of a software program that alerted the urologist that the stent needed to be addressed.

Altering the manner in which ureteral drainage is achieved is another way to reduce the number of patients lost to follow-up. Mydlo and colleagues[38] used straight ureteral stents exteriorized through the urethral meatus and connected to a urethral catheter after ureteroscopy in presumably noncompliant patients. In this study, all patients with straight ureteral stents returned for follow-up, whereas only 45% of those with internal stents did. Of course this increased compliance comes at the expense of the added morbidity of an exteriorized stent and catheter.

Investigators have recently developed a novel method to specifically target the chemical reaction that results in calcium deposition. Watterson and colleagues[39] coated circular silicone disks with an oxalate-degrading enzyme and implanted these disks in a rabbit model for 30 days. There was a 21% and 40% reduction in dry weight of encrustation and calcium within the encrustation, respectively, in the experimental group compared with the control group. The same laboratory evaluated the use of a triclosan eluting stent in a rabbit model to decrease bacterial growth in urine and lower bacterial deposition on the device with the hypothesis of less stent encrustation resulting.[40]

Triclosan is a potent, broad-spectrum antimicrobial and anti-inflammatory agent. In a rabbit model, Cadieux and coworkers[40] isolated urine from the triclosan group and discovered that it contained significantly fewer *Proteus* organisms than controls. Although there was no significant difference in stent encrustation among the groups after 7 days, bladders harvested from the triclosan group demonstrated significantly less inflammation on histopathology. Much like drug-eluting cardiac stents have demonstrated improved outcomes compared with non–drug-eluting stents for the management of coronary artery disease,[41] the drug-eluting ureteral stent may well follow the same clinical course; however, its use remains experimental at the present time.

Additional attempts to eliminate or reduce encrustation of urinary drainage devices have been pursued using a variety of techniques. Hyaluronic acid, heparin, and pentosanpolysulfate are types of glycosaminoglycans, which are compounds that are extremely potent inhibitors of nucleation, crystal growth, and aggregation.[42–44] Glycosaminoglycan-coated stents and catheters have demonstrated increased resistance to encrustations in experimental studies.[45,46] In *in vitro* demonstrations, other methods to reduce encrustations in urinary catheters include electrified catheters,[47] inflation of balloon retention devices with triclosan,[48] intermittent rather than continuous drainage through the catheter,[49] and irrigations with Suby G solution. [50]

Absorbable and biodegradable ureteral stents have been proposed as the ideal way to accomplish temporary drainage without the need for removal or follow-up.[51] Unfortunately, these stents have not been without problems. In a phase II multi-institutional clinical trial of a temporary biodegradable ureteral drainage stent, 4.5% of patients had a severe adverse event related to the stent resulting from stent **migration of** problems with stent fragment passage.[52] Fortunately, all patients were treated endoscopically with no adverse sequelae. Nonuniform and incomplete dissolution are technical hurdles still needing to be overcome before widespread applicability of this technology.

Finally, it is important that the treating urologist communicates clearly to the patient the presence of any internal urologic stents, the temporary intent of their use, risks with prolonged indwelling times, and the need for appropriate follow-up. While external draining catheters, such as nephrostomy or suprapubic tubes, are not hidden, these patients must also be educated about the need for regular maintenance and follow-up if they are to be kept *in situ* for prolonged periods. Unfortunately, with all of these precautions exercised, stenting and draining of the urinary tract will continue to be an essential part of the practice of urology and until an improved way to accomplish this task evolves, there will be patients who will inevitably encounter complications from their use.

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ABBREVIATIONS USED

CT = computed tomography
SWL = shockwave lithotripsy

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