Endourological Management of Encrusted Ureteral Stents

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1 Introduction

Ureteral stents are a minimally invasive method to secure urinary drainage from the upper urinary tract(s). Since the first description of the double 'pigtail' stent in 1978 by Finney et al., they have become established as a fundamental part of the endourologist's toolkit [1]. Indeed, valuation for the global stent market is estimated to exceed $560 million by 2026 [2]. Despite an evolution in stent technology which has seen a plethora of developments related to material, design and surface coating, a number of limitations persist [3]. This includes complications such as bleeding, pain and bothersome urinary symptoms. Up to 80% of patients experience negative effect on their quality of life [4]. Stent encrustation (SE) is a further possible adverse sequela, which occurs as a result of crystal deposition (Fig. 1) [5, 6]. These crystals form due a change in the pH of the urine due to bacterial activity e.g. *Proteus mirabilis*. The latter are associated with urease production and therefore accumulation of ammonia resulting in a pH rise accordingly [7, 8]. A degree of SE is reported to occur in up to 47% of patients according to some studies [9, 10]. In severe cases, SE renders standard cystoscopic removal impossible. Management of such cases can be a complex problem, which requires a step wise approach to ensure safe removal and secure the best possible outcome for the patient [11].

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Fig. 1 Encrusted stent removed from patient

Left undiagnosed and or untreated, SE that occurs both intra and extra luminally, can lead to a host of serious complications including infection (and potentially life-threatening sepsis), stent fracture (Fig. 2), obstruction and deterioration in renal function [12].

Furthermore, over 50% of lawsuits arising from endourological surgery are stent related e.g. lost to follow up or forgotten stents [13]. Given the rise in the prevalence of kidney stone disease (KSD) and the worldwide trend for minimally invasive interventions which often employ ureteral stent insertion, the volume of stent encrustations may also be set to rise [14]. Awareness and understanding of the endourological management is therefore of paramount importance.

Fig. 2 Plain radiograph showing fractured stent at lower end

2 Risk Factors

The temporal relationship between stent indwelling time and morbidity is now well recognised [15]. Moreover, stent duration is generally considered the greatest risk factor for SE [5]. The relevance of this is now arguably greater than ever before given the near universal delays in operating as a result of the Covod-19 global pandemic [16, 17]. Many cases of SE may be related to a 'forgotten' stent which Molina et al. found to take place in up to 12% of stent placements. This can be a result of poor patient compliance [18]. Previous studies have revealed the correlation between forgotten stents and socio-economic background as well as lack of health insurance [19]. A history of prior and concurrent KSD predispose the patient to a higher chance of SE. Risk of SE is also heightened further in the context of pregnancy due to metabolic changes such as reduced secretion of parathyroid hormone and the rise in filtered calcium associated with the rise in glomerular filtration rate during pregnancy [2]. Kavoussi et al. found that pregnant women with nephrostomy tubes in situ required exchange as often as every 2 weeks in selected cases due to SE [20]. Malabsorptive states and malignant processes are also catalysts for pro-encrustation. As well as patient factors, the properties of the stent e.g. material and caliber will also play a role. Kawahara et al. found the rate of SE to be significantly lower when ≥7 Fr stents were used [9]. Unfortunately, even newer modifications such as metallic stents are not exempt from SE.

3 Clinical Assessment and Treatment Planning

While the clinical history can highlight the group of patients with greater likelihood of SE, an important pre-operative step is imaging. The first line modality is plain X-Ray (Fig. 3), but a low threshold should be maintained for expediting a computed tomography (CT) scan with a stone protocol applied. This may be selected in the first instance if the person has a history of uric acid stones. Although it holds the advantage of no radiation exposure, the role of ultrasound in the assessment of SE is very limited and is not routinely practiced in most centres.

Imaging can be complemented through use of grading system for SE. The two most commonly used nomograms are Kidney, Ureter, Bladder (KUB) and the Forgotten encrusted, calcified (FECal) Double J classification [12, 21]. These validated tools allow the surgeon to better predict those cases which will warrant multiple procedures, a multi-modal intervention plan e.g. combined endourological approach and those cases with long operative time (e.g. >3 h). It further helps to counsel the patient and manage expectations. More recently, the Visual Grading for Ureteral Encrusted Stent (V-GUES) has been developed [22]. If a patient attends for routine removal of ureteral stent under local anaesthetic (LA) and resistance is encountered, it should be abandoned and an up-to-date imaging organised. Understanding the impact on quality of life caused by the stent is also a valuable

Fig. 3 Plain radiograph showing encrustation at distal coil

step and this can be assessed using a patient reported outcome measure (PROM) such as the ureteral stent symptom questionnaire (USSQ) [23].

If the CT scan reveals poor condition of the renal parenchyma, consideration for nuclear renal scan should be given. Should this reveal less than 15–20% renal function, a simple nephrectomy may represent an alternate treatment option for that patient [12]. However, if both the parenchymal appearances and renal function are satisfactory, a more minimally invasive treatment can be selected for removal of encrusted stent. It is now standard practice among many endourology centres to have regular stone multidisciplinary team (MDT) to discuss such complex cases. This not only allows for a shared treatment plan to be established but it also facilitates assessment by dietician and referral to metabolic clinic after the initial treatment [24].

Careful review of the patients imaging will allow to determine the severity of SE as well as whether it occupies both the proximal and distal ends of the ureteral stent or the whole length of the stent. Minimal linear encrustation at one end of the ureteral stent could permit standard removal of the stent by cystoscopy. However, if encrustations found are more than this then formal treatment of SE is warranted. Any planned procedure should be accompanied by collection of urine culture and antibiotic sensitivities prior to treatment. It is a further possibility that SE may only be discovered intra-operatively.

Retrospective and prospective studies have described different surgical approaches of stent retrieval related to the location and volume of encrustation.

In some cases, stent encrustation is an unexpected intraoperative finding and the surgeon has no choice than to abandon the procedure and repeat the treatment in after further planning. This allows strategic planning of staged stent removal with appropriate equipment and staff preventing further complications.

Mapping of SE can be done pre-operatively with imaging or can be described by the surgeon intra-operatively. The absence of standardisation in describing the location of encrustation(s) can make management planning and comparison of outcomes very difficult. It therefore highlights the need for dissemination and adoption of classifications systems in order to facilitate surgical planning. Use of a tool to grade severity of SE will also help guide a clinician as to whether they have the necessary expertise for the proposed treatment or whether onward referral to a specialist centre is warranted.

4 Minimally Invasive Approaches

Before the advancements in modern technologies, open surgery remained a go to option for difficult cases. Indeed, its role serves a purpose in less developed countries [5]. However, such is the expanded application of ureteroscopy and percutaneous nephrolithotomy (PCNL), that even highly complex cases of SE can be handled using these minimally invasive interventions. The surgeon must bear in mind the option of using a combined modality approach. At time of patient counselling, it should also be explained that multiple sessions can be warranted.

5 Cystolithotripsy and Cystolitholapaxy

In cases of encrustation to the distal or bladder portion of the stent, cystolitholapaxy using stone punch can be an effective method for fragmentation. If SE is limited to this site only, then it can be sufficient for then grasping and removing the stent. In certain cases, when the encrustation bulk around the distal coil of the stent is too large to be released with the stone punch, an alternative and less invasive method is laser cystolithotripsy (Fig. 4). This is particularly effective in cases where the calcification has formed a large bladder stone surrounding the stent. The focused effect of the Holmium laser is able to gradually fragment and dust the encrustation preserving the stent integrity. The technique can be accomplished with 550 μm laser fiber, high energy settings (1–2 J). Use of resectoscope rather than rigid cystoscope can help maintain low pressure bladder irrigation. When all encrustations are released, the stent can be finally removed with normal grasper and all the fragments evacuated with bladder washout. The disadvantages of these methods e.g. cystolithotripsy, is the requirement for general anaesthesia and laser training. Lam et al. carried out an institutional review of their cases and reported that on average 2.7 procedures (range 1–4) are required to clear heavily encrusted stents [25].

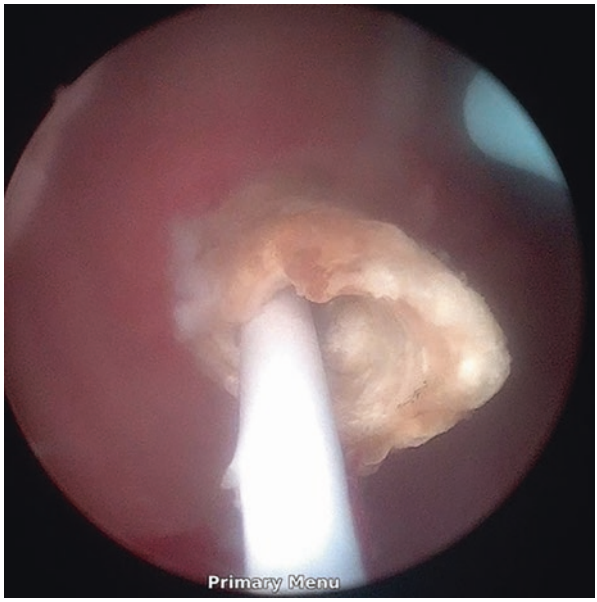

Fig. 4 Endoscopic view of encrusted distal coil at time of cystolithotripsy

6 Shockwave Lithotripsy (SWL)

SWL represents a minimally invasive intervention in endourology. While its clinical application for treatment of KSD is far reaching, in the setting of SE, it is more limited. Its role for SE is largely restricted to cases of low volume encrustations. Its application favours cases where the area of encrustation is localised to the proximal, intra-renal portion of the stent [26]. Use of SWL for this scenario is more suitable if in the setting of high volume centre with a fixed lithotripter. It can also be implemented before planned stent removal with grasper. SWL is a preferred modality in those patients with a high anaesthetic risk.

7 Ureteroscopy

Ureteroscopy can allow for use of laser to remove encrustations (recommended fragmentation settings 0.4–0.6 J, 5–20 Hz). This should be performed in standard lithotomy procedure under a general anaesthetic. Intravenous antibiotic prophylaxis should be administered at induction. After placement of a cystoscopically guided safety wire (0.035 in.), the semi-rigid ureteroscope can be inserted parallel to the stent. Holmium laser treatment of encrustation can allow gradual release of the encrustations around the stents in order to create space and proceed retrogradely towards the kidney. In many cases series, rigid and flexible ureteroscopy are described as the definitive treatment to completely remove encrustation with the aid of Holmium laser.

When this is not possible, because of heavy encrustation encasing the stent, it can be divided using the laser and 'piecemeal strategy' of retrograde removal of the stent can be carried out [27]. Cutting the distal portion of the stent with laser allows for creation of more space (recommended cutting settings 1–1.5 J, 5–10 Hz).

Although fluoroless endourological surgery has gained increased attention in the modern era, use of fluoroscopy is still advocated in these complex cases [28]. However, the principle of 'as low as reasonably achievable' (ALARA) should still be upheld [29]. Once sufficient space has been established, the scope can be advanced and a further section of the stent can be cut and removed using grasper or basket in a step wise fashion. This method has also been termed 'coil resection'. In cases where an additional operative session is determined to be required or where no initial entry with the semi rigid ureteroscope is possible, a small calibre stent (e.g. 4.8 Fr) can be inserted in parallel to allow passive dilatation of the ureter and the patient is booked to return at a later date. SWL can also be considered in these cases during the interval period. A smaller sized ureteroscope can also be used where there is limited space to

Fig. 5 Fluoroscopic view of flexible ureteroscope and cut proximal loop of stent

accommodate an instrument alongside the encrusted stent. Where the distal portion of the stent can be safely withdrawn to the urethral meatus, it can be secured (clamp or stitch) in order to fix its position and provide gentle traction.

Where proximal encrustation exists, treatment can be carried out using flexible ureteroscopy. Placement of ureteral access sheath (UAS) can facilitate this process. The cut proximal loop can then be removed via the UAS and hence reduce trauma on exit (Fig. 5). Once clearance has been achieved, a new ureteric stent should be temporarily inserted with a fixed date for removal supplied to the patient before discharge. Thomas et al. successfully treated over 90% of cases (n = 51) at their institution with use of ureteroscopy (semi-rigid and/or flexible) alone [30]. The advantages of newer generations of lasers e.g. high powered 100 W machine lend themselves well to these cases of heavy encrustation [31]. The introduction of the Holmium YAG (Ho:YAG) laser has heightened the reach of what can be achieved. High precision is enabled with reduced tissue trauma as a result [32, 33].

Smaller hospitals should consider a centralised process and onward referral of these cases for treatment in a high volume centre [34]. Furthermore, patients may require post-operative admission to high dependency unit (HDU) or intensive care units (ICU) given potential for septic shower and serious morbidity which could occur especially in multiple comorbidities [35].

8 Percutaneous Nephrolithotomy (PCNL)

In cases of heavy encrustation within the kidney, a percutaneous approach may be necessitated. This will allow for antegrade nephroscopy and fragmentation to be undertaken from above. Due to high stone burden of the renal encrustation around

the proximal coil of the stent, up to 20% of cases warrant PCNL and anterograde approach. Although universal consensus does not exist in regard to the optimal approach when there exists both distal and proximal SE, it is the opinion of the authors as well as most published reports, that the distal portion should be handled and released of SE first [5]. Patients should also be consented for proceeding to a combined antegrade approach at the same anaesthetic if retrograde surgery alone is not sufficient. The procedure can be indeed performed with combined retrograde and anterograde approach in the presence of the correct equipment, positioning and staff in order to grant the best expertise and outcome but also keeping in mind patients' preference and safety.

9 Open Approach

The majority of severely encrusted stents described in the literature can be removed with one endourological procedures or a combination of them. However, when these minimally invasive techniques fail to achieve a full stent clearance, open pyelolithotomy still serves as an option. Nephrectomy with removal of the encrusted stent is considered the last resort, especially in patients where the kidney function has been compromised from prolonged obstruction [5].

10 Encrusted Nephrostomy Tube

This represents another potential clinical scenario. The intra-renal portion can become heavily encrusted or a prolonged period in situ can lead to tissue bridges forming. The same principles of planning and treatment apply for this situation. As well lithotripsy down the established track and ureteroscopic treatment from below, another consideration is to establish an additional percutaneous calyx puncture to treat the large encrustation burden if it is present via a PCNL procedure.

11 Prevention

Patient and surgeon education are arguably the most effective treatment tool [36, 37].

Careful counselling and an ethos of shared responsibility between patient and surgeon is of paramount importance. Implementation of strategies such as stent registries and more recent adjuncts such as novel use of mobile based reminder systems are possible remedies for this widespread problem [38, 39]. Ather et al. implemented a modern software tracking system and this significantly reduced the incidence of overdue stents from 12.5% to 1.2% [40].

Preventative medical management and metabolic treatment can still play a role in encrustation treatment and prevention. Torrecilla et al. performed a randomised

trial between urine acidifier and crystallization inhibitor capsules vs placebo in patients with encrusted stents [41]. The outcomes showed decrease of overall encrustation in the experimental arm compared to placebo. It also delivered shorter removal time and higher success rate of stent removal at first attempt, which did not require additional surgical procedures. Medical management can especially be useful for SE related to prior treatment of uric acid stones and acidic urine, where the patients can have urinary alkalinization to dissolve the encrustations [37].

12 Conclusion

The development of SE is multifactorial, and a vigilant approach is required in order to help prevent it and this should be mirrored when treating this clinical problem as well. The evolution of minimally invasive endourology allows for virtually all cases to now be managed successfully without the need for open surgery. A tailored management strategy should be formulated and use of an algorithm such as FECal or V-GUES system is recommended as part of this work up. The need for a multi-modal treatment plan should be considered. Patients should be carefully counselled of additional procedures and made aware that multiple sittings may be warranted.

Conflict of Interests No relevant disclosures.

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