Post-percutaneous Nephrolithotomy Drainage

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Key Take Home Points

1. Post-PCNL drainage tubes have been steadily decreasing in size over the previous decade.
2. Tubeless PCNL is a reasonable modification in a properly selected patient and may help increase patient comfort, decrease hospital stay, and quicken time to recovery.
3. Several hemostatic agents are available for use during a tubeless procedure, but the potential benefits of these agents are not yet clear.

Introduction

The initial report of kidney stone removal through an operatively established nephrostomy tract was in 1941 by Rupel and Brown [1] for anuria from an obstructing calculus. It was over three decades later that the first formal percutaneous nephrolithotomy (PCNL) was performed in 1976 by Fernstrom and Johannson [2]. The benefit of PCNL is that it can clear large and complex stone burdens with great efficiency and it is significantly less invasive than open surgery. PCNL has been increasing in frequency since its introduction, and as surgical technology continues to advance its efficacy and safety profile have markedly increased [3]. Likely due to these factors, the utilization of PCNL has been increasing at a great rate [4].

Standardly, PCNL requires placement of a nephrostomy tube at the procedure's conclusion, which ensures adequate renal drainage. Additionally, the nephrostomy tube also simplifies reaccess to the kidney should there be residual stone requiring a second procedure. Although these advantages are clinically important, the nephrostomy drain can also cause some degree of morbidity and discomfort for the patient.

As PCNL has become more popular and more commonly performed over the recent decades, many modifications have been reported with the goals of minimizing morbidity and pain for the patient as well as shortening the time to full recovery. Among these have been placement of smaller tube sizes, mini-PCNL with smaller incisions and instruments, tubeless with various types of internal drainage, and the totally tubeless technique [5, 6]. Herein, we review the various techniques used to drain the kidney after PCNL.

The Size of Nephrostomy Tube

Traditionally a large-bore nephrostomy tube was left in place after the standard PCNL to allow for maximal drainage and tamponade bleeding while allowing for easy access if a second procedure

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was necessary. Commonly utilized nephrostomy tube sizes range from 5 French all the way up to 32 French. As the surgical technique of PCNL became mature, increasing interest was focused on improving the discomfort associated with the procedure—as a result, surgeons began to examine the use of different drain sizes, to assess for improved tolerance of smaller tubes.

Initially, studies evaluating PCNL performed with varying postoperative nephrostomy sizes were retrospective analyses. Maheshwari et al. [7] compared the use of a 28 French large-bore tube versus a 10 French pigtail catheter and found that those patients with the smaller tube had a significantly lower analgesia requirement and shorter duration of nephrostomy tract leakage after tube removal. Several other nonrandomized trials have compared small-bore tubes (9/10 French) with larger tubes (22 French) and showed that patients with smaller tubes placed had less pain, less analgesia requirement, and a decreased hospital stay [8].

Prospectively performed studies demonstrated similar findings. Liatsikos et al. [9] built on this study and in a prospective fashion evaluated placement of a 24 French reentry malecot tube versus an 18 French catheter with a 7/3 tail stent in a randomized fashion. Quality of life and urgency were similar between groups. The patients with the smaller tube had less pain but in this study there was no assessment of pain until 2 weeks postoperatively. Additionally because of the design of the study, it is unclear whether patient comfort is improved because of the smaller tube or because of bidirectional drainage with the tailless stent in place as well.

Ultimately, randomized controlled trials addressed the question and provided more definitive data. Pietrow et al. [8] evaluated the effect of using a smaller nephrostomy tube for percutaneous drainage after PCNL on postoperative pain in 30 patients in a randomized fashion. Half received a 10 French pigtail catheter while the others had a 22 French Councill-tip catheter placed. There was no difference in hematocrit change and the smaller tube group had significantly less pain by visual analog pain scale at 6 h postoperatively. Pain at 1 and 2 days postoperatively and narcotic usage were also assessed and while there was a trend for benefit with the smaller tube group it was not statistically significant. While there was no increased complication rate, there appeared to be limited usefulness based on this study; however, sample size was small and tube type was different so comparison was imperfect. Desai et al. [10] performed another prospective randomized controlled trial in 30 patients comparing large-bore drainage with a 20 French tube to a small 9 French pigtail tube to antegrade internal stenting. They had strict inclusion criteria with single subcostal access, no residual stones, normal renal function, and an uncomplicated procedure. Nephrostomy tubes were removed at 48 h while stents were removed at 4 weeks. Hospital stay and urinary leak was significantly shorter in the tubeless group but time to discharge was not different between the different tube groups. Analgesic requirement was greater in the larger bore group versus the small tube group and while it was the least in the tubeless group this was not statistically significant. The study group did not report on stent discomfort in the tubeless group.

Types of Drainage Tubes

In addition to different sizes of tubes there are also different types of tubes. Paul et al. [11] nicely reviews the different types of tubes available for post-PCNL drainage and suggests when each one should be placed. They suggest pigtail catheters (5–14 French) with or without a locking mechanism can be placed after a simple PCNL; if the system is delicate or if the procedure is complicated this may not be the ideal tube to use. Balloon retention catheters (12–32 French) can also be used and may allow for better drainage. Possible obstruction with balloon inflation can occur. Malecot tubes are a balloon-less alternative that allows for good drainage and eliminates the risk of obstruction from the self-retaining mechanism of other catheters. They suggest the use of a large-bore reentry tube in complicated renal surgery that allows for reinsertion of the tube after removal if bleeding occurs. Endopyelotomy tubes

when antegrade endopyelotomy is also performed and circle nephrostomy tube when prolonged drainage is anticipated as in a calyceal diverticulum are also discussed. Srinivasan et al. [12] also provide a nice review of tube types and their uses which are similar to the previous group's report.

A Brief History of the Evolution of Nephrostomy Drainage

The first report of tubeless PCNL was in 1984 where Wickham et al. [13] reported a totally tubeless procedure in 100 select patients. Two years later in 1986 Winfield et al. [14] reported significant complications in two patients with premature nephrostomy tube removal including serious hemorrhage and significant urinary extravasation requiring stent placement, transfusion, and prolonged hospitalization. Perhaps as a consequence of this report, the standard approach for PCNL became maintenance of the nephrostomy tube for at least 24–48 h [15].

It was a decade later, in 1997, that the tubeless procedure was reintroduced by Bellman et al. Their modification included internal drainage with a stent and their rationale was that with proper drainage of the renal unit, the controlled trauma of a PCNL tract should heal spontaneously [16]. A stent and a Councill catheter were placed in 30 patients with the nephrostomy tube being removed in 2–3 h while only a stent was placed in 20 patients. Those patients who did not have a nephrostomy tube had a decreased hospital stay, lower analgesia requirements, lower overall cost, and a quicker convalescence. Five years later they reported their experience with their first 112 patients undergoing the tubeless procedure for percutaneous renal surgery [17]. In 86 stone patients, over 90 % were stone free with a decreased hospital stay and no external drainage bag. The transfusion rate was 6 %. The disadvantages they noted were prolonged Foley catheter and need for a second procedure to remove the stent. It is important to note that the authors had strict inclusion criteria and only 28 % of their percutaneous procedures over a 5-year period were eligible for the tubeless procedure. Additionally 7 % of these patients did have residual stones though these were all treated successfully with shock wave lithotripsy.

The Tubeless Modifications

Randomized Controlled Trials

Since Bellman and associates reintroduced the tubeless procedure in 1997, a number of randomized control trials have been performed to evaluate it more thoroughly.

Feng et al. [18] looked at various PCNL techniques in 2001 in 30 patients. They evaluated the standard technique with a 22 French nephrostomy tube, the mini-PCNL with a 22 French tube, and the tubeless procedure. Pain scale results were similar but the tubeless group had a shorter hospitalization and less analgesia use. This study was not perfect because although stone burden was reported not to be significantly different it was twice as large (8 cm vs. 4 cm) in the standard tube group. This was also demonstrated in the fact that stone-free rate in this group was only 37.5 % (vs. 62.5 % in the mini-PCNL group and 71.4 % in the tubeless group). Although this study was biased with the standard cohort being more complex, the authors noted decreased cost in the tubeless group.

Desai et al. in 2004 evaluated the outcome of tube size and tubeless as discussed above in a randomized fashion [10]. The tubeless group had a shorter hospital stay and urinary leak was significantly shorter in the tubeless group. They also had less analgesic requirement but this was not statistically significant. This study was a small study of only 30 patients (only ten tubeless patients) with strict inclusion criteria but was one of the first randomized comparisons of tubeless to both large- and small-bore drainage tubes.

Marcovich et al. [19] also performed a randomized study in 2004 comparing different tube sizes with a tubeless procedure. They evaluated 60 patients and found no significant difference between patients with a 24 French reentry tube, an 8 French pigtail catheter, and those with a double J internalized stent. The main limitation

of their study was how they defined tubeless because those with an internal stent were still left with a large-bore drainage tube (20 French Councill-tip catheter) removed on the first postoperative day.

A number of investigators from India have investigated tubeless PCNL. There is a large amount of literature regarding post-percutaneous renal surgery drainage out of India. Three randomized controlled trials were all reported in 2008 evaluating the tubeless procedure.

One study included 202 patients using a moderate-sized tube of 16 French versus a 6 French stent [6]. They found a statistically significant difference in postoperative pain as measured by the visual analog scale pain score (59 vs. 31) and analgesia requirement. They also found a lower incidence of urinary leakage from the nephrostomy tube site and a shorter hospital duration (21.8 h vs. 54.2 h). Complete convalescence was 5–7 days for the tubeless group whereas it was 8–10 days for using the standard technique. They found no difference in infection or percent hemoglobin change. Total follow-up for the study was 18 months and CT scan at 1 month revealed all patients to be stone free. In this study location of puncture was not considered. They used suture to close the skin.

Another study out of India in 2008 randomly compared tubeless with stent placement to placement of a small-bore nephrostomy tube of 8 French in 65 patients [20]. They also noted less postoperative pain via the visual analog pain scale, less analgesia requirement, and patients were discharged 9 h earlier. Stone clearance was 87 % in both groups but they only used renal ultrasound and KUB to evaluate patients and considered less than 4 mm residual fragments to be stone free. They too noted no difference in complication rate or hemoglobin drop. One important outcome they evaluated that many groups do not discuss is stent discomfort. The tubeless group had bothersome stent-related symptoms in 39.4 % with 61.5 % of those patients requiring analgesics and/or antispasmodics. They did not measure these outpatient analgesic requirements for these stent symptoms. They also found the duration of perurethral catheter to be longer in the tube group but this was because they waited until urine leakage from the tract stopped (28 h vs. 36 h). Interestingly, one patient with the small-bore tube had pain and required stent placement. They used a pressure dressing at the skin.

One other randomized study from India in 2008 evaluated the difference between a large-bore catheter (22 French) and tubeless in 60 patients [21]. Analgesia requirement, hospital stay, and time to return to normal activity were all significantly less in the tubeless group. The tube group had a 30 min longer operative time suggesting that though the study was randomized the cases with tube placement were more complex. Also, the tubes were removed at 2.5 days but the stents were kept in place for 4.5 weeks. While stent symptoms were not evaluated in this study, one could imagine based on the previous study discussed that this could cause potentially significant distress in the stent group. CT scan was also not done postoperatively in this study.

Tefekli et al. [22] also performed a prospective randomized controlled trial in 2007 and reported benefit in the tubeless group.

Meta-analysis

With more data and literature emerging and many studies including small sample sizes, it can sometimes be difficult to interpret all of this information. For this reason a group from China performed a meta-analysis in 2010 with the existing randomized controlled trials evaluating the tubeless PCNL. This included 14 studies and 776 patients [5]. They subdivided the trials into three groups. There were three studies that compared small-bore tubes (4–10), eight studies that evaluated large-bore tubes (12–24) and two studies that included both sizes versus tubeless. One study included did not report size and was incorporated in with the larger tube group. One limitation of this meta-analysis was that not all of the studies reported all relevant parameters. The authors did find a significant difference in hospital stay but only 11/14 studies reported this information. Additionally the authors did not separate the data by small and large tube groups for this parameter. Postoperative analgesia use was significantly less in the tubeless groups but only four studies were

compared. Postoperative pain via the visual analog scale was less in the tubeless group but only five studies were included and there was no difference found between the tubeless and small tube groups. Urine leakage too was significant but also did not show a difference between the tubeless and small-bore groups and only four studies had these data available. In seven studies evaluated, operative time was significantly longer in the large-bore versus the tubeless group. With these operative time results, one has to speculate if there were intrinsic differences between the groups as nephrostomy tube placement should not really take longer than an antegrade stent placement. There were no differences found in stone-free rate (eight studies), postoperative fever (eight studies), or blood transfusion (nine studies). Also, between the small-bore and tubeless groups there were no significant differences found in operative time, postoperative pain, or urine leakage. Again, there were only four studies in the small-bore group.

While this study could not eliminate the intrinsic limitations of the individual studies the results are stronger than the individual studies alone and do support that tubeless PCNL could translate to a shorter hospital stay and less analgesia requirements which could potentially translate to decreased costs and improved quality of care. What most of these studies did not evaluate, however, are stent-related symptoms. Along the same lines, outpatient analgesics and pain was not measured and many studies left the stents in for 4–6 weeks. It is possible that the short inpatient benefits from the tubeless procedure could be reversed with the outpatient disadvantage of stent discomfort, a prolonged requirement for antispasmodics and/or narcotics, and a second procedure to remove the stent. Larger multi-institutional long-term randomized controlled trials that include outpatient evaluations, stent-related symptoms, and the need for an additional procedure are required before definitive conclusions can be made.

Nonrandomized Trials

In addition to randomized trials, many groups have reported their nonrandomized experience with the tubeless procedure [15, 23–25]. Lojananpiwat et al. [26] reported on 37 patients with externalized 6 French ureteral stents placed at the beginning of the procedure and removed at 48 h. Their patients had a significant reduction in length of hospitalization and postoperative analgesia but their average length of hospitalization was still 3.6 days and the majority of their patients (24/37) still required narcotics.

Karami et al. [27] reported on their 5-year experience in 201 patients and found the tubeless procedure to be safe, effective, and economical. Similarly, several other studies have shown good results [28, 29]. One review suggested that a double-J stent may theoretically facilitate small residual stone passage with passive dilation of the ureter [15].

Conservative Modification

While not leaving an externalized drain has been shown to be an effective means of managing post-PCNL drainage, some concerns remain, including adequate hemostasis and need for reaccess for a second-look procedure. One group compared tubeless with internal stenting versus internal stenting with tube placement but early removal on postoperative day 1 if CT imaging showed no complications or recurrent stone disease [30]. This comparison was performed in a prospective randomized controlled fashion and showed equivalent results with regard to analgesic requirement, hospital stay, and change in hemoglobin. They found that the group with early tube removal had a better stone-clearance rate and allowed for reentrance into the system if needed, concluding that it should be considered the standard of care and preserves the advantages offered by the tubeless modification.

Tubeless in Complex PCNL

While the tubeless PCNL has become more popular as many studies have demonstrated its safety and advantage in patient comfort, most surgeons are careful in their selection of patients. Many of the studies discussed had a strict inclusion limiting the tubeless procedure to straightforward, uncomplicated cases.

Recently, as surgeons have become more comfortable with the tubeless procedure and as technology has advanced, expanded criteria have

been reported and there is increasing literature of more complex cases being left with internal drainage alone. Some expanded criteria include solitary kidneys, large stone burden, renal insufficiency, multiple access tracts, and supracostal accesses and several groups have reported success in these populations [31–36]. Jou et al. retrospectively reviewed the tubeless procedure in 62 patients with stones greater than 3 cm and found no increase in morbidity as did Falahatkar et al. who achieved an 88 % stone-free rate in 42 staghorn calculi undergoing the tube-free PCNL [37, 38].

Shah et al. [33] retrospectively reported their experience in 72 patients with supracostal access. These patients also showed benefit with earlier discharge by 19 h, decreased postoperative pain via the visual analog pain scale, and less analgesia requirement. Complications and transfusions were comparable between groups. These patients also had their urethral catheter removed sooner, as in the control group they waited for leakage from the tract to stop. This is a limitation to their study because awaiting catheter removal prolonged the control group's hospitalization and also resulted in increased measurement of analgesia. Since these are the main outcome measurements the significance of the differences detected is questionable. They also had one major complication in each group both requiring exploratory surgery. The patient in the study group had a retroperitoneal hematoma and that in control group had a splenic rupture and hemoperitoneum.

Shoma and Elshal [39] performed a prospective randomized controlled trial comparing tubeless to standard PCNL without a strict inclusion criteria. They had negative results in patients with supracostal access and renal insufficiency. They suggest these should be considered contraindications to the tubeless procedure.

Tubeless PCNL has also been investigated in obese patients. Yang and Bellman in 2003 reported their experience in percutaneous renal surgery in 133 patients [40]. Subgroups for analysis consisted of 45 patients with BMI less than 25, 55 patients with BMI 25–30, 28 patients with BMI 30–40, and 5 morbidly obese patients with BMI over 40. Stone removal was the primary goal in 104 patients whereas 29 patients underwent percutaneous antegrade endopyelotomy. Two patients required readmission for low hematocrit and hematuria and one required embolization for a pseudo-aneurysm. All patients requiring transfusion had BMI less than 30 (nine patients). There were no other differences between the groups. Stents were removed at 1 week. While obesity made the case more complex, this group did have exclusion criteria including greater than two accesses, perforation of the collecting system, operative time greater than 2 h, residual stones, significant bleeding, or plan for second-look nephroscopy.

The first case report of bilateral tubeless PCNL was by Weld and Wake [41]. Shah et al. then reported a small retrospective analysis of 20 patients comparing bilateral PCNL to bilateral tubeless PCNL [42]. Results showed less analgesia and a 20 h earlier discharge but this was not statistically significant because of the small sample size. Also, their study was limited because the tubeless group was a more recent cohort so it is unclear whether discharge was sooner because protocols were improved and as a result of less time in the hospital, less analgesia was measured. Additionally, stone burden was much larger in the standard group and there were twice as many patients with staghorn calculi. This was illustrated in operating time as well as the standard group was much longer. Though this was a poor comparative study, it still demonstrated that bilateral tubeless PCNL can be done safely. Other groups have also reported these outcomes [41–43].

Tubeless has also been successfully reported in patients undergoing PCNL in the supine position as reported in 184 patients, spinal anesthesia in 10 patients (65 from 13), and patients with a history of open renal surgery in 25 patients, [44–46]. Lastly, patients with pelvic kidneys have successfully undergone the tubeless procedure laparoscopically assisted [47].

Tubeless in Children

Modifications have not been limited to adults. More groups are extending various techniques to children as well. Salem et al. [48] reported success in 20 children (average age 7.5 years) undergoing the tubeless procedure when comparing their outcomes to ten similar patients

undergoing the standard technique with a tube. They found the tubeless group had less pain, shorter hospital stay, and the technique was less "troublesome." They did have to convert to open surgery in one case because of extravasation and inability to access the kidney.

Totally tubeless PCNL has also been investigated in the pediatric population and while some groups showed it was safe and effective with decreased hospital stay and analgesic use, others have not shown a statistically significant benefit [49, 50].

Totally Tubeless PCNL

As technology advances and criteria for tubeless PCNL expands, several groups have reintroduced the totally tubeless procedure without internal or external drainage despite previously reported poor results by Winfield et al. [14]. Crook et al. [51] reported the totally tubeless procedure to be safe and well-tolerated in select patients in his experience with 100 patients over a 10-year period (1996–2006). Istanbullouglu et al. [52] performed a randomized trial in 2009 in 90 patients comparing totally tubeless to standard PCNL and also found it to be safe and effective in properly selected patients. Aghamir et al. [53] also conducted a randomized study in 60 patients evaluating the totally tubeless PCNL in patients with renal anomalies. They found the totally tubeless group to have decreased hospitalization time, analgesia, and return to normal activities. Totally tubeless was also shown to be safe and feasible in supracostal access [54].

Lastly, totally tubeless has also been reported in patients undergoing bilateral PCNL [55]. This group from Turkey in 2009 described their experience with six patients. Hospitalization was 1.8 days with only half of the patients being discharged after 1 day. One patient became anuric postoperatively for 16 h with a significant rise in creatinine requiring urgent bilateral stent placement. The only difference between this patient and the others was a larger hemoglobin decrease of 2.6 with the authors suggesting clot obstruction for this complication.

Types of Internal Drainage

With surgeons more often performing tubeless PCNL with internal drainage, groups have experimented with different types of stents. Double J, externalized stents exiting the urethral meatus, tail stents, and stents with flank tethers have all been used with good results.

Bellman introduced antegrade stent placement in the reverse direction with the tether exiting the flank [56]. He suggested removal in the office at 3–12 days postoperatively. It also may be possible to still reaccess the tract with this type of internal drainage if a second-look procedure is needed [15]. Tethers can also be left on double J stents distally as well.

Tail stents are generally 7/3 French. These were introduced to try to reduce stent symptoms as up to 78 % of stent patients may have urinary symptoms and discomfort affecting daily activities, inability to work, and loss of income as a result [57]. Dunn et al. [58] found reduced symptoms with the 7/3 French stent in a randomized single-blind study. Tethers can be left on tail stents for ease of removal as well but this requires retrograde placement at the beginning or end of the procedure. Yew and Bellman [59] reported this technical enhancement of their modified tubeless procedure and reported low pain scores and minimal stent symptoms. This technique also eliminates the need for office cystoscopy for stent removal. The one concern of leaving an internal catheter with an externalized tether is accidental premature removal.

One study looked at the difference between 6 French double-J stents and externalized 6 French stents in a prospective randomized analysis [60]. The external stent was removed with the Foley catheter on the first postoperative day. While both were found to be feasible, the externalized group reported no stent-related symptoms while 52 % of patients in the double-J group experienced symptoms. The Polaris stent placed in the reverse direction is one other unique type of stent worth mentioning that has been reported for internal drainage post-PCNL [61].

Hemostatic Agents in the Nephrostomy Tract

As tubeless PCNL has become more popular and many studies have shown complication rates to be similar to the standard technique, the main concern remains adequate hemostasis without having the tube to tamponade bleeding. Hemostatic agents have been around since the 1970s in nonurologic disciplines. The FDA defines these agents as materials that assist in hemostasis by accelerating the clotting process of blood [62]. There are liquid and flowable agents that are used to augment the clotting cascade. The liquid agents typically contain fibrinogen and thrombin to help produce a fibrin clot independent of patient factors [62]. The flowable agents typically contain gelatin, which provides a matrix for platelet adhesions and aggregation and when mixed with thrombin aids in clot formation. Unlike the liquid agents, gelatin has no fibrinogen and depends on patient factors to start the reaction that assists in clot formation. Gelatin material also expands upon contact with blood and therefore has an additional pressure effect for hemostasis [62]. Because of these properties and the concern for hemostasis in the tubeless procedure, surgeons began to experiment with these agents in the nephrostomy tract off-label. Choe et al. [62] thoroughly describe all of the different hemostatic agents available and their mechanism of action. Below is a summary of the agents and the studies conducted using them to seal the nephrostomy tract.

Fibrin Glue

Fibrin glue was first used in the urologic discipline for ureteral and renal trauma in the late 1980s and was shown to be safe [63]. Once introduced, the indications for its use expanded and surgeons began to use it in reconstructive surgeries to heal fistulae, simple prostatectomies, and to patch complications and other urologic injuries [64].

The first report of using fibrin glue for hemostasis of a percutaneous nephrostomy tract was also in the late 1980s [65]. It wasn't until 2003, however, that the first larger report was published. In a retrospective review of 43 patients undergoing tubeless PCNL, 20 patients had tisseel placed to seal the tract and were compared to tubeless alone [66]. Hospital stay was shorter in the fibrin group. Analgesia requirement was less but this was not statistically significant. There was no difference in hematocrit drop. Postoperative fevers occurred in 15 % of the fibrin group and one patient developed a wound seroma, all requiring readmissions. Postoperative CT did not reveal any differences between the groups. There were several limitations with this study including the fibrin group being a more recent cohort and thereby possibly having improved protocols. Also because the fibrin patients had a shorter hospital stay, this may account for less analgesia recorded as this was not adjusted for admission time. There were also no validated pain questionnaires used in this study for assessment. Also, fever occurrence in 15 % of patients in the study group suggests that fibrin may cause this reaction; however, the authors state those patients had preexisting UTI.

Noller et al. [67] also successfully reported fibrin sealant in ten kidneys after percutaneous renal stone surgery without complications. These patients were discharged in 1.1 days with an 80 % stone-free rate. None had urinary extravasation on CT scan with IV contrast performed postoperatively.

Shah et al. [68] performed a prospective randomized controlled trial in 2006 in 63 patients comparing tisseel fibrin sealant to tubeless PCNL without the use of a hemostatic agent. They found no difference in hematocrit change or transfusion rate. Patients with tisseel used had less postoperative pain and required less analgesia. They were also discharged 5 h earlier but this was not statistically significant. Only renal ultrasound and KUB were done postoperatively and stone-free status was considered if residual fragments were less than 4 mm. One patient in experimental group had a 6 g/dl hemoglobin drop with

retroperitoneal hematoma and septicemia requiring ICU care. This demonstrates despite efforts to prevent bleeding it can still occur. Of note, one potential concern that Uribe discusses in an editorial is the possible lithogenic effects of these agents. No data or reports have illustrated this to date.

Gelatin Matrix

Gelatin is another type of hemostatic agent that has been recently used after percutaneous renal surgery for assistance in clotting. Additionally this type of agent expands upon contact with blood creating an additional compressive effect. Clayman's group describes their technique with floseal and reports its successful use in patients [69, 70]. Comparing it to a 10 French cope loop catheter, there was no difference in postoperative pain or blood loss but there was a trend toward shorter hospitalization but sample size was small. This group chooses to use gelatin because in vitro studies showed fibrin glue congealed when it came into contact with urine causing a thicker mucoid material that did not dissolve after 5 days [71]. Their concern with using fibrin is that it has the potential to cause urinary obstruction. When studying gelatin the same group found that when in contact with human urine the matrix formed a fine suspension of particles. This group of investigators also conducted another study in pigs where they injected floseal or tisseel into the collecting system and at 5 days they found obstruction in 50 % of the pigs [72]. For this reason, they use gelatin and to avoid possible obstruction their technique is to use a 7 French 11.5 mm occlusion balloon in a retrograde fashion extended to the parenchyma (6/7). Patients from their studies did well without obstruction. Bellman also noted in an editorial comment that they realized with further experience that floseal was more superior than fibrin glue and they now use floseal [69].

Aghamir et al. [53] also investigated gelatin in a prospective randomized trial in 20 patients to seal the tract. They found no difference in bleeding or extravasation from the tract. Singh et al. [73] prospectively investigated 50 patients in a randomized fashion using spongostan, an absorbable gelatin tissue hemosealant. They found no difference in hematocrit drop but the study group had a shorter hospital stay ($p=0.057$), decreased urinary extravasation (1 h vs. 6 h), less analgesia requirement, less pain, and quicker time to return to work. Only ultrasound and KUB/IVP were performed postoperatively. Discharge was 6–8 h earlier. No gross soakage was observed on dressings in either group though mean collections were larger in the gelatin group. One limitation of this study was unbalanced stone size between the groups as burden was significantly larger in the standard group. Despite this mean operative time was 30 min longer in the gelatin group. Stents were kept in place for 4–6 weeks. One potential concern is displacement of the sponge into the collecting system leading to obstruction, but the authors claim complete dissolution of spongostan based on an in vivo study. Based on these results showing limited benefit and a high expense, they conclude gelatin should be used only in cases of persistent visible diffuse hemorrhage despite tamponade.

Summary of Hemostatic Agents

With the goal of these agents being to enhance hemostasis, most of the studies conducted found no change in hematocrit. Given the extra expense and potential complications discussed, these studies do not support the routine clinical use of hemostatic agents in tubeless PCNL. Some authors suggest these agents may be beneficial in robust bleeding but realistically tube placement should be highly considered in these circumstances. Additionally these studies do not show a difference in the degree of urinary extravasation based on imaging and dressing assessment but most studies did not objectively measure this parameter. There may be a benefit, but the literature to date does not illustrate a profound difference to justify this extra expense. Further study is needed in a large multi-institutional prospective randomized trial.

Diathermy Coagulation

While many groups have experimented with agents to promote hemostasis some groups have chosen to use diathermy coagulation for control of bleeding. The benefits of this technique are no potential for viral transmission, unlike the human-based hemostatic agents, less cost than fibrin glue and gelatin matrix, and no possibility of allergic reactions. Concerns are potential destruction of tissue and vascularization leading to inhibition of proper healing of the tract.

Jou et al. [74] reported their experience in 249 patients using spot electrocauterization of bleeding points with an elongated 8 French electrode probe through the working channel along the nephrostomy tract. While there was no difference in operative time, hospital stay or infection rate, they did find a statistically significant transfusion rate 1.2 % versus 6.5 % (control group = 92 pts). They did not report pain assessment or analgesic measurements. A French group also reported success using a rollerball in the tract and good, safe results with use of a 26 French resectoscope [75]. Other investigators report this technique to be simple and effective [76].

Conclusion

As our field continues to advance more modifications of drainage post-PCNL will continue. The above studies show the tubeless procedure may improve patient comfort postoperatively with the avoidance of an external tube. As such, it may reduce hospital stay and analgesic requirement allowing for earlier return to normal activity. Additionally, site leakage may be less also improving patient comfort. Disadvantage of this modification is the need for a second procedure for stent removal at a later date which entails a cost and extra burden for the patient unless the internal drainage is externalized for ease of removal, but this carries the risk of early dislodgement. Additionally, many patients suffer from stent-related symptoms, a parameter not reported by most groups studying the modified procedure. This could theoretically lead to prolonged time to convalescence rather than the reported quicker return to normal activity. Furthermore, the tubeless procedure eliminates the ability to reaccess the tract if residual stone remains. Though ureteroscopy remains an option in these cases, percutaneous nephroscopy through and existing tract may be simpler, but this has not been studied. The totally tubeless procedure eliminates the convenient possibility of both of these options.

Table 5.1 Inclusion criteria for tubeless percutaneous nephrolithotomy

Minimal bleeding at completion of the case
Single-tract procedure
Complete clearance of stone
Small stone burden
Singular stone location
Normal renal function
No perforations
No complications
Healthy, low-risk patients
Unilateral procedure
Operative time less than 3 h

While the tubeless PCNL remains a modification that carries great potential benefit, careful patient selection is still encouraged. While many groups have reported success in complex groups, the potential for risk may outweigh the currently calculated benefit on certain cohorts. We recommend maintaining a strict inclusion criteria when selecting these patients (Table 5.1). Additionally, some patients who have had stents previously and did not tolerate them may do better with a nephrostomy tube rather than internal drainage so patient preference should be discussed as well. Additionally, internal drainage with tube placement and early tube removal, particularly in complex patients, is one option that should be considered as it has shown equivalent results and carried additional benefits, though the existing literature with this technique is limited. Absolute or relative contraindications for the tubeless procedure are shown in Table 5.2.

Lastly, while some groups have reported a significant cost advantage with the tubeless procedure, most groups have not analyzed this

Table 5.2 Absolute/relative contraindications for tubeless percutaneous nephrolithotomy

Staghorn calculi
Solitary kidney
Renal dysfunction
Bilateral procedure
Supracostal access
Multiple accesses
Altered anatomy
Poor hemostasis
Pyonephrosis
Residual stone burden
Suspected infection stones
Perforation of pelvicaliceal system or other collecting system injury
Prolonged OR time
Higher-risk patients

parameter in a sophisticated manner and further study is needed [18]. Bellman et al. [16] reported a 129 % increased procedure cost in the standard tube group but these results need to be verified and extended to the postoperative period.

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