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<https://escholarship.org/uc/item/2723k53s>

Journal

Journal of Endourology, 30(4)

ISSN

0892-7790

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Publication Date

2016-04-01

DOI

10.1089/end.2015.0594

Peer reviewed

Methylene Blue Injection as an Alternative to Antegrade Nephrostography to Assess Urinary Obstruction After Percutaneous Nephrolithotomy

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Abstract

Aims and objectives: Percutaneous nephrolithotomy (PCNL) remains an effective treatment for large stones. When nephrostomy tube (NT) is left post operation, antegrade urine flow is often confirmed with antegrade nephrostography (ANG) before tube removal. We compare methylene blue (MB) test combined with NT capping trial against ANG to assess antegrade urine flow after PCNL.

Materials and Methods: One hundred one consecutive patients undergoing PCNL were prospectively enrolled between 7/2014 and 4/2015. An NT cap was placed the morning of postoperative day 1 (POD1). Failure was defined as need to uncap the NT for any reason. Two hours after capping, 7cc MB was injected into the NT. Positive MB test was defined as presence of blue per bladder Foley. ANG was then performed to assess antegrade urine flow. NTs were removed before discharge home when antegrade flow was documented. Primary outcomes included presence of antegrade flow on ANG and NT removal before discharge home. Receiver operating characteristic (ROC) and areas (Area under the ROC [AUC]), as well as Cohen's kappa coefficient (κ), were calculated comparing agreement of capping trial, MB, and ANG with NT removal.

Results: One hundred one subjects were included in this analysis. 52.9% were left-sided surgeries and 60.4% utilized lower pole punctures. On ROC areas evaluating tests for agreement with NT removal before discharge, MB AUC 0.71 (95% CI 0.60–0.83), capping trial AUC 0.66 (95% CI 0.57–0.75), combined capping trial and MB AUC 0.72 (95% CI 0.61–0.84), and ANG AUC 0.78 (95% CI 0.68–0.88). In predicting NT removal, ANG performed better than capping trial alone ($p=0.042$), but no differences were seen between MB and ANG ($p=0.229$), combining the capping trial with MB test and ANG ($p=0.266$) or combined testing and MB alone ($p=0.972$).

Conclusions: Combining capping trial with MB injection is similarly accurate for predicting NT removal after PCNL compared to ANG. Capping trial and MB may be used in combination to obviate the need for ANG.

Introduction

PERCUTANEOUS NEPHROLITHOTOMY (PCNL) is an effective surgical option for fragmenting and extracting large and complex kidney stones not amenable to removal by ureteroscopic or shockwave lithotripsy approaches. The American Urologic Association (AUA) guidelines recommend PCNL as the first-line treatment for patients with staghorn stones.¹ While safe, PCNL requires obtaining access into the collecting system through direct needle puncture and tract dilation, and may be complicated by bleeding, infection, fever, injury to nearby structures, or postoperative obstruction of the urinary tract.² Many postoperative renal drainage management strategies are employed for this surgery, and nephrostomy tube (NT) placement in the absence of

a ureteral stent is a common practice.³ Perhaps the most common imaging study for evaluating antegrade urine flow down the ureter remains antegrade nephrostography (ANG), selected for its functional ability to visualize antegrade flow of contrast to the bladder and relatively decreased radiation exposure to patients compared to CT.⁴

While some studies suggest that ANG may not be necessary for the average patient to guide postoperative patient management,^{4,5} others continue to recommend ANG to rule out residual stone fragments, urinary extravasation, and distal obstruction.⁶ No study to date has formally evaluated the effectiveness of alternative methods at establishing antegrade flow after PCNL.

Alternatives to the postoperative ANG include capping trial and methylene blue (MB) dye injection test. During a

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capping trial, the NT is obstructed by a cap or clamp. Effectively passing such a trial is clinically defined when a patient remains asymptomatic during the period of capping (i.e., no increased pain, fevers, chills, nausea, or vomiting). A persistently asymptomatic capped patient is assumed to have an unobstructed antegrade flow of urine. If the patient develops symptoms of pain, fever, and/or nausea that are relieved after the cap is removed, antegrade flow is assumed to be obstructed. The MB dye test involves instilling a quantity of MB into the proximal open end of the NT and waiting for blue-green coloration of the urine in the bladder catheter bag. Color change in downstream urine is interpreted to represent a patent unobstructed urinary tract. While both tests have been used by urologists,⁷ there remains no study in the literature formally comparing these two tests to ANG.

The objective of this study was to compare the MB dye test and capping trial against ANG to assess antegrade urine flow in a prospective manner among patients undergoing PCNL.

Materials and Methods

Study population

After obtaining appropriate approval by the University of California, San Francisco (UCSF) institutional review board, all patients undergoing consecutive PCNL at two institutions (UCSF and San Francisco General Hospitals in San Francisco, CA) for the study period were included for this study. Participants were included if they underwent PCNL during the enrollment period and excluded if no NT was placed during surgery or if a ureteral stent was left in place postoperatively.

Data collection

Prospective enrollment of consecutive patients undergoing PCNL was performed between July 2014 and April 2015 by two surgeons (M.L.S. and T.C.). All patients included were aged ≥ 18 undergoing PCNL, while pregnant patients and patients in whom an NT was not used postoperatively were excluded. Hematocrit and creatinine were recorded preoperatively, immediately after each surgery and on POD1. Body mass index (BMI), patient age, type and size of NT, stone size, estimated blood loss (EBL), preoperative urine culture, and length of hospital stay were also recorded for each patient.

Surgical description

For these surgeries, after induction of general anesthesia, the patient was placed in the dorsal "frog-leg" position. A well-lubricated 17F flexible cystoscope was then used to identify the ureteral orifice on the operative side. A 0.035 inch coaxial guidewire was advanced up the ureter, over which a 5F ureteral exchange catheter was placed into the proximal ureter. After foley catheter placement into the bladder, the ureteral stent was secured to the foley catheter. The patient was then repositioned to the prone position. Using either fluoroscopic or ultrasound guidance, a renal access needle was inserted into the desired calix. A J-tipped coaxial guidewire was then advanced into the collecting system and the renal access tract was dilated with a 10F dilator. A safety wire introducer was then advanced and, when possible, a second safety wire placed in the collecting system. A balloon dilator was used to dilate the tract to 30F

for all cases and the access sheath advanced into the collecting system to facilitate nephrolithotomy. An offset rigid nephroscope and CyberWand were used to fragment stones. After stone removal, an NT was placed through tract and antegrade nephrostogram performed before removing the access sheath to confirm tube position within the collecting system. A plain radiograph was performed in the recovery area to confirm NT position in the kidney and evaluate for residual stones. At our institution, patients were routinely admitted to the hospital following PCNL and subsequently observed to confirm no evidence of persistent bleeding or infection and to establish antegrade flow from the instrumented kidney to the bladder before NT removal.

NT evaluation

For this prospective study, all patients' NTs were managed in the same manner. On postoperative day 1 (POD1), a cap was placed on the NT to initiate a capping trial. Capping trial failure was defined as the need to uncap the NT for clinically significant fever ($>38.3^{\circ}\text{C}$), pain, nausea, or vomiting. Two hours after capping, 7cc of dilute MB was instilled into the NT and the tube was recapped. A positive MB test was defined as blue coloration of urine in the collection bag draining from the bladder Foley catheter. Two hours after the MB test, antegrade nephrostography (ANG) was performed by interventional radiologists (IR) to evaluate for radiographic evidence of antegrade urine flow. A positive test was defined as contrast flow fluoroscopically present from the kidney to the bladder. A clinical decision on tube management was made after completion of all three tests for every study participant and patients' postoperative care and discharge disposition were determined as clinically indicated by the managing physician. The NT was removed in patients free of infection and with diagnostic evidence of antegrade urine flow. In patients deemed unsafe for NT removal, due to pain, infection, or obstruction, a repeat ANG was performed in the outpatient clinic 1 to 2 weeks following discharge and a determination for safe NT removal was made based on clinical evidence.

For all patients, residual stone burden is assessed using a combined renal-bladder ultrasound and KUB radiograph performed after surgery. Patients with no evidence of stone on these studies are considered stone free. This is done at the follow-up appointment, which occurs around 4 weeks after surgery.

Statistical methods

Fisher's exact test was used to test the hypothesis of different distributions of a categorical variable in either groups discharged home with NT in place or those whose NTs were removed before discharge home, and in groups with negative/positive ANG. The same hypothesis was tested for a numerical variable using the two-sample Wilcoxon rank-sum test. Differences were considered significant at $p \leq 0.05$.

As previously described, we also combined diagnostic tests (triage test) to assess accuracy at predicting the desired clinical outcomes.⁸ The triage test is a *post hoc* test that requires two outcomes to be positive for a positive result. In this case, the two positive outcomes were (1) tolerating a capping trial without fever ($>38.3^{\circ}\text{C}$), pain, nausea, or vomiting and (2) visualization of blue coloration of urine in the collection bag draining from the bladder Foley catheter

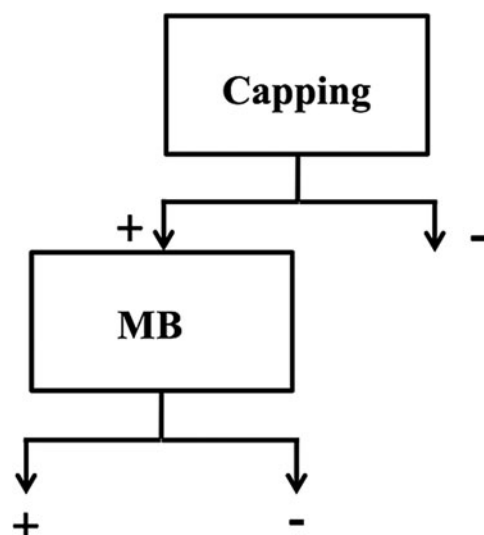


FIG. 1. Triage test: Combination of capping trial and methylene blue (MB) test. The triage test is positive if both the capping trial and MB tests are positive.

following injection of MB per NT. For the purposes of this combined test, the triage test was considered positive if both the capping trial and MB tests were positive (Fig. 1).⁸

Sensitivity, specificity, positive predictive values (PPV) and negative predictive values (NPV), likelihood ratios, and

ROC areas were calculated for evaluating and comparing the ability of capping trial, MB injection test, and ANG to predict NT removal and ANG results. Areas under ROC curves were compared using the algorithm suggested by DeLong et al.⁹ The agreement between diagnostic tests were evaluated using Cohen's kappa statistic.¹⁰ Magnitude guidelines for Cohen's Kappa have appeared in the literature.¹⁰ The following values have been characterized: <0 as indicating no agreement, 0 to 0.20 as slight, 0.21 to 0.40 as fair, 0.41 to 0.60 as moderate, 0.61 to 0.80 as substantial, and 0.81 to 1 as almost perfect agreement.¹⁰

Finally, we developed a multivariate model using the combined (triage test) of capping trial + MB injection test with the significant univariate predictor of decrease in Hct on POD1 and calculated areas under ROC for our desired clinical outcomes. Statistical analyses were performed using Stata13 (StataCorp, College Station, TX).

Results

One hundred one subjects underwent PCNL during the study period. 52.9% were left sided and 60.4% were performed through lower pole punctures. Demographic data and associations with positive ANG and NT removal are summarized in Table 1. No significant associations were seen with these variables when evaluating the clinical outcomes of NT removal and ANG results except for the mean hematocrit drop on the immediate postoperative blood test. Patients with

TABLE 1. DEMOGRAPHICS PREDICTING ANG AND NT REMOVAL BEFORE DISCHARGE HOME

	Total (n = 101)	Positive ANG	Negative ANG	p	NT removed	Discharged with NT	p
Laterality							
Right side, n (%)	48 (47.1%)	26 (74.3%)	9 (25.7%)	0.34 ^a	30 (63.8%)	17 (36.2%)	0.55 ^a
Left side, n (%)	54 (52.9%)	28 (63.6%)	16 (36.4%)		31 (57.4%)	23 (45.6%)	
Age (mean years ± SD)	50.2 ± 15.1	50.1 ± 15.1	50.4 ± 14.7	0.95 ^b	51.5 ± 14.8	50.7 ± 15.1	0.79 ^b
Hospital							
UCSF, n (%)	83 (81.4%)	44 (71.0%)	18 (29.0%)	0.38 ^a	50 (61.0%)	32 (39.0%)	0.8 ^a
SFGH, n (%)	19 (18.6%)	10 (58.8%)	7 (41.2%)		11 (57.9%)	8 (42.1%)	
NT type							
Cope, n (%)	28 (27.5%)	14 (58.3%)	10 (41.7%)	0.07 ^a	14 (50.0%)	14 (50.0%)	0.3 ^a
Foley, n (%)	71 (69.6%)	37 (74.0%)	13 (26.0%)		46 (65.7%)	24 (34.3%)	
Malecot, n (%)	3 (2.94%)	0 (0%)	2 (100%)		2 (66.7%)	1 (33.3%)	
NT Size (French ± SD)	14.4 ± 2.8	14.7 ± 2.4	13.9 ± 3.4	0.23 ^b	14.8 ± 2.5	14.3 ± 2.9	0.33 ^b
Puncture location							
Upper pole, n (%)	27 (26.7%)	14 (66.7%)	7 (33.3%)	1 ^a	15 (57.7%)	11 (42.3%)	0.96 ^a
Lower pole, n (%)	61 (60.4%)	33 (68.8%)	15 (31.3%)		38 (62.3%)	23 (37.7%)	
Middle pole, n (%)	13 (12.9%)	6 (66.7%)	3 (33.3%)		8 (61.5%)	5 (38.5%)	
Number of punctures (n ± SD)	1.3 ± 0.8	1.3 ± 0.8	1.3 ± 0.6	0.88 ^b	1.3 ± 0.8	1.3 ± 0.7	0.81 ^b
EBL (mean mL ± SD)	111.0 ± 82.9	110.8 ± 78.2	111.5 ± 94.2	0.98 ^b	100.4 ± 76.2	127.2 ± 92.0	0.12 ^b
POD0 Hct drop (mean% ± SD)	2.8 ± 3.7	2.0 ± 3.4	4.3 ± 3.9	0.02 ^b	2.1 ± 3.2	4.2 ± 4.4	0.01 ^b
Cr Rise POD0 (mean mg/dL ± SD)	0.03 ± 0.14	0.01 ± 0.15	0.07 ± 0.13	0.1 ^b	0.02 ± 0.16	0.07 ± 0.21	0.18 ^b
BMI (mean kg/m ² ± SD)	30.4 ± 8.9	29.3 ± 8.6	32.7 ± 14.5	0.22 ^b	30.3 ± 11.1	29.5 ± 8.9	0.69 ^b
Preoperative urine culture							
Positive, n (%)	45 (45.9%)	23 (69.7%)	10 (30.3%)	1 ^a	29 (65.9%)	15 (34.1%)	0.53 ^a
Negative, n (%)	53 (54.1%)	30 (69.8%)	13 (30.2%)		31 (58.5%)	22 (41.5%)	
Stone size (mean size cm ± SD)	2.97 ± 1.47	2.96 ± 1.46	2.98 ± 1.53	0.97 ^b	2.96 ± 1.50	3.47 ± 1.81	0.17 ^b
Length of stay (mean # days ± SD)	2.3 ± 1.4	2.4 ± 1.5	2.1 ± 1.3	0.4 ^b	2.3 ± 1.5	2.0 ± 1.2	0.49 ^b

^aWilcoxon rank-sum test for continuous variables.

^bFisher's exact test for categorical variables.

ANG=antegrade nephrostography; BMI=body mass index; EBL=estimated blood loss; NT=nephrostomy tube; POD0=postoperative day 0; SFGH=San Francisco General Hospital; UCSF=University of California, San Francisco.

TABLE 2. PREDICTIVE POWER AND AGREEMENT OF METHYLENE BLUE INJECTION TEST AND CAPPING TRIAL IN PREDICTING ANTEGRADE FLOW ON ANG

	<i>Methylene blue</i>	<i>Capping trial</i>	<i>Combined</i>
Sensitivity	81.4% (66.6%–91.6%)	95.9% (86%–99.5%)	81.0% (65.9%–91.4%)
Specificity	68.2% (45.1%–86.1%)	33.3% (15.6%–55.3%)	77.3% (54.6%–92.2%)
PPV	83.3% (68.6%–93%)	74.6% (62.1%–84.7%)	87.2% (72.6%–95.7%)
NPV	65.2% (42.7%–83.6%)	80% (44.4%–97.5%)	68% (46.5%–85.1%)
Likelihood ratio (+)	2.56 (1.36–4.79)	1.44 (1.08–1.92)	3.56 (1.63–7.8)
Likelihood ratio (–)	0.27 (0.14–0.54)	0.12 (0.028–0.75)	0.25 (0.13–0.48)
ROC area	0.748 (0.632–0.864)	0.646 (0.546–0.747)	0.791 (0.683–0.899)
kappa	0.49	0.344	0.564

NPV, negative predictive values; PPV=positive predictive values; ROC, receiver operating characteristic.

a greater hematocrit drop postoperatively were more likely to have a negative result on the ANG ($4.3\% \pm 3.9\%$ vs $2.0\% \pm 3.4\%$, $p=0.017$) and more likely to be discharged home with the NT in place ($4.2\% \pm 4.4\%$ vs $2.1 \pm 3.2\%$, $p=0.012$).

On an average, capping trial, MB test, and ANG occurred on postoperative day 1.3 ± 0.7 days. Sensitivity, specificity, PPV and NPV, likelihood ratios, receiver operating characteristic (ROC), and areas, as well as Cohen's kappa coefficient (κ) are detailed in Table 2 characterizing predictivity and agreement of clinical tests with antegrade flow on ANG, and in Table 3 characterizing predictivity and agreement of clinical tests with NT removal before discharge home.

On comparison of AUC predicting NT removal, the MB test was found to perform slightly better than a capping trial at borderline significance with AUC of 0.72 (95% CI 0.61–0.84) vs 0.59 (95% CI 0.50–0.68), $p=0.057$. ANG was found to have a significantly better association with NT removal compared to capping trial with AUC of 0.77 (95% CI 0.66–0.87) vs 0.64 (95% CI 0.54–0.74), ($p=0.042$). No statistically significant differences were noted when comparing MB test and ANG ($p=0.229$), a combined test of both MB injection and capping trial against ANG, ($p=0.266$) or the combined test of both MB injection test and capping trial against an MB test alone, ($p=0.972$).

Our multivariate model, using the combined triage test of capping trial + MB test with the significant univariate predictor of decrease in Hct on POD1, had the most predictive area under the ROC curve for predicting ANG at 0.81 (95% CI 0.70–0.90) and NT removal before discharge home at 0.77 (95% CI 0.64–0.85) (Fig. 2).

Discussion

In 1976, a novel technique for removing renal calculi through a percutaneous approach was first introduced by Fernström and Johansson¹¹ and since that time, improvements in technique, enhancements in technology, and increased surgeon experience have lead to increased stone-free rates and decreased morbidity for patients for PCNL. These improvements are reflected in the most recent guidelines for staghorn calculi recommending PCNL as first-line therapy.¹ Following percutaneous surgery, NTs provide a route of urinary drainage, preventing obstruction from blood clots, inflammation/edema of the ureteropelvic or ureterovesical junction, residual stone fragments, or iatrogenic injury to the ureter.³

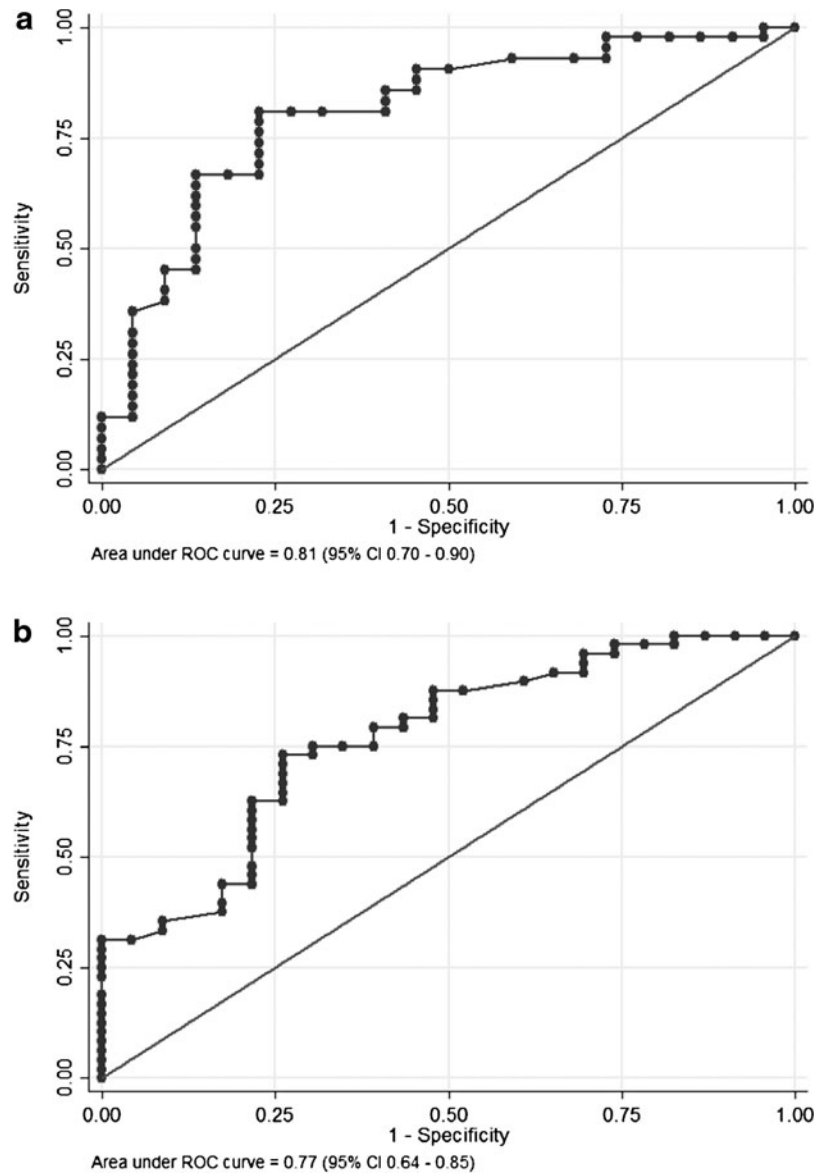
Currently, there is no consensus on the optimal imaging modality that should be used to assess post-PCNL stone-free status and establish antegrade flow before NT removal. Many imaging modalities are used to establish stone-free status, including plain film x-ray, ultrasound, nephrostogram, second-look nephroscopy, and CT scan.^{4,6,12–16} Each imaging study is associated with varying degrees of sensitivity at detecting residual stone fragments as well as clinical invasiveness and side effects for patients. These side effects include increased radiation exposure and subsequent risk for secondary malignancy.^{17,18} Noncontrast CT scan has the highest sensitivity of identifying residual stone fragments following PCNL (approaching 100%) compared to plain film radiography (82%), ultrasound (68%), and linear tomography (89%).¹⁶

For establishing the presence of antegrade urine flow down the ureter, even less consensus exists. Antegrade

TABLE 3. PREDICTIVE POWER AND AGREEMENT OF METHYLENE BLUE INJECTION TEST, CAPPING TRIAL, AND ANTEGRADE NEPHROSTOGRAM IN PREDICTING NT REMOVAL BEFORE DISCHARGE HOME

	<i>Methylene blue</i>	<i>Capping trial</i>	<i>Combined</i>	<i>ANG</i>
Sensitivity	77.6% (63.4%–88.2%)	96.2% (87%–99.5%)	75.0% (60.4%–86.4%)	86.8% (74.7%–94.5%)
Specificity	65.2% (42.7%–83.6%)	35.5% (19.2%–54.6%)	69.6% (47.1%–86.8%)	69.2% (48.2%–85.7%)
PPV	82.6% (68.6%–92.2%)	71.8% (59.9%–81.9%)	83.7% (69.3%–93.2%)	85.2% (72.9%–93.4%)
NPV	57.7% (36.9%–76.6%)	84.6% (54.6%–98.1%)	57.1% (37.2%–75.5%)	72.0% (50.6%–87.9%)
Likelihood ratio (+)	2.23 (1.25–3.98)	1.49 (1.14–1.95)	2.46 (1.3–4.67)	2.82 (1.57–5.07)
Likelihood ratio (–)	0.34 (0.19–0.63)	0.11 (0.03–0.45)	0.36 (0.21–0.63)	0.19 (0.09–0.40)
ROC area	0.714 (0.598–0.830)	0.659 (0.569–0.748)	0.723 (0.608–0.837)	0.780 (0.679–0.882)
kappa	0.413	0.361	0.422	0.566

FIG. 2. ROC curves of multivariate predictive models for (a) ANG and (b) NT removal before discharge home. Predictive variables include hematocrit drop from immediately post operation to POD1 and the results of the combined test (capping trial and MB Test). ANG, antegrade nephrostography; NT, nephrostomy tube; POD1, postoperative day 1; ROC, receiver operating characteristic.



nephrostogram may be the most widely used imaging modality.⁴ During an ANG, the contrast is injected through the patient's NT and the urinary tract is evaluated fluoroscopically for antegrade flow of contrast from the kidney to bladder. While there remains a lack of consensus among endourologists about the necessity of postoperative ANG, at our institutions, we routinely utilize ANG to identify clinically significant residual stone fragments and/or urinary obstruction following PCNL before NT removal. This technique has the benefit of real-time assessment of antegrade flow combined with radiographic identification of residual stone fragments. In addition, it is associated with a 710-fold decrease in the amount of radiation delivered compared to unenhanced helical CT scan.^{19,20} Despite these benefits, ANG is also associated with inherent risks, including potentially unnecessary patient radiation exposure, additional cost, and risk of prolonged hospital stay based on availability of the fluoroscopic imaging suite and personnel.

Previous research has investigated the clinical utility of ANG following PNL. Work by Andonian et al. found that

16% of patients following PNL had persistent urinary leak following removal of NT suggesting distal ureteral obstruction. Obstruction seen on the ANG performed on all patients predicted resultant urinary leak and could have alerted the clinical team to the need for prolonged NT drainage.⁶ In a prospective trial by Khawaja et al., 119 patients underwent PNL with placement of an intraoperative NT. No patients underwent ANG postoperatively; rather patients underwent a capping trial and were followed clinically to establish antegrade flow before removal of NT. The authors found that all patients recovered uneventfully and concluded that ANG was clinically unnecessary, inconvenient, and only increased cost with no benefit over plain film x-ray.⁴ Unfortunately, no data were included regarding the number of patients who failed capping trial and no gold standard was utilized to compare efficacy.

Avoiding ANG for NT management has the potential to bring immediate benefit to the patient and treatment team. Radiation from one postoperative nephrostogram contributes roughly 1.6 mSv, equivalent to roughly twice the dosage of

an abdominal plain film.²¹ Reducing this radiation exposure to patients may be of long-term benefit for patients, particularly in the case of nephrolithiasis patients, who are at high risk for increased lifetime cumulative radiation exposure from imaging studies.^{17,18}

Furthermore, while cost of an ANG varies across hospitals, standard Medicare reimbursement is \$116.20 for the surgery (CPT 50394) and \$51.82 for the fluoroscopic interpretation (CPT 76000).²² This compares to a cost of \$0.62 for a catheter plug (Product Code: 30080)²³ and \$0.96/mL of MB (Product code: 17478-0504-10).²⁴ Ultimately, this translates to a saving of \$166.44 per PCNL with using these alternative methods of interrogating the NT. In our case, this would have resulted in a saving of \$16,810, had we avoided using ANG for the patients included in this study. Rising healthcare costs remain a national concern and seeking novel ways to eliminate waste in healthcare spending is an important clinical consideration. Cost-control strategies are now being mandated in medical education²⁵ as a means of creating future physicians with an ethos of practicing economically responsible medicine.^{26,27} The MB test and capping trial represent two bedside, low cost, and low risk alternatives to ANG.

The administration of MB into the collecting system was well tolerated in our study and there were no adverse events. Furthermore, there were no cases of spillage on the skin. One theoretical contraindication to using MB would be a previous allergic reaction to the agent. This has been published previously in the context of MB-treated plasma given to patients²⁸ and intradermal injection.²⁹ However, MB has also been used to treat refractory anaphylaxis.³⁰ No allergic reaction or adverse event related to MB administration was encountered in any of our study subjects. The minimal risk of capping trial is limited to discomfort to the patient and incurs no additional cost compared with a catheter plug.

Our results demonstrate that the MB injection test is as effective at establishing antegrade flow and predicting NT removal as the ANG. It is made even more effective when combined with a capping trial. These simple clinical tests can be performed by a nurse practitioner or resident at the patient's bedside and require little to no experience to interpret. In addition to providing cost savings for each PCNL, the test also can be performed quickly and safely in the patient's hospital room. A positive test can be interpreted in minutes. This can result in more efficient hospital discharges and obviates the need to coordinate additional postoperative imaging studies after PCNL.

One interesting finding was the improved benefit of including drop in Hct at predicting NT removal following PCNL. Multiple clinical factors are taken into consideration when deciding whether to remove an NT following surgery, including infection, pain level, unusual anatomy, or urinary obstruction. While change in Hct following surgery is a quantifiable variable (and more accurate than the estimate of blood loss), it is influenced by multiple factors, including amount of intraoperative blood loss and perioperative hydration status. It is possible that increased bleeding, reflected by increased Hct drop, can result in an increased clot burden in the collecting system and increased inflammation at the ureteropelvic junction. These factors could increase the risk of postoperative obstruction and therefore decrease the chance of NT removal.

This study also has important weaknesses worth discussing. This was not a randomized trial and most clinical deci-

sions regarding time of discharge and status of NT were made based on the results of the antegrade nephrostogram. In addition, our protocol involved a systematic ordering of the tests; capping trial followed by the MB injection test followed by the antegrade nephrostography study. We chose the order of diagnostic tests based on the clinical flow in our hospital as well as the establishment of safety for administering MB. Clamping trial began during morning rounds to ensure the patient was clinically stable and free from infection. Waiting two hours before MB confirmed that the patient could tolerate an injection into the collecting system free from pain or discomfort. Since this fluoroscopic study had to be coordinated with the availability of the interventional radiology suite, for some patients, there was more than a 2-hour delay between the time of MB injection and antegrade nephrostogram, providing time for postoperative obstruction related to inflammation to resolve. It is possible that the small improvement seen using the gold standard ANG was simply due to the extra two hours to allow for decreased inflammation on the collecting system for antegrade flow to return. To not delay discharge from the hospital for the patient, however, we were unable to delay ANG any longer than what was performed or repeat an MB trial after ANG. We designed this trial in such a way for each patient to serve as their own internal control and minimize their risk in participating in this study, but such a design is associated with such types of limitations.

It is important to note that the clamping trial and MB test do not provide any imaging of the upper urinary tract. As such, it cannot be used to evaluate residual stone fragments, but simply as a less-invasive method for establishing antegrade flow in the perioperative setting before NT removal.

Despite these limitations, we propose that performing a capping trial and an MB test on all patients following PCNL is a cost-effective and time-efficient means of evaluating antegrade flow following surgery.

Conclusion

Combining a capping trial with MB test results yields equivalent accuracy in determining antegrade urine flow when compared with ANG. These tests are also similarly accurate for predicting NT removal after PCNL compared to ANG. A capping trial and MB test may potentially be used in combination to obviate the need for ANG, which can be costly and time-consuming.

Author Disclosure Statement

No competing financial interests exist.

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Abbreviations Used

ANG	¼	antegrade nephrostography
AUA	¼	American Urologic Association
AUC	¼	Area under the receiver operating characteristic curve
BMI	¼	body mass index
EBL	¼	estimated blood loss
Hct	¼	Hematocrit
IR	¼	interventional radiologists
MB	¼	methylene blue
NPV	¼	negative predictive values
NT	¼	nephrostomy tube
PCNL	¼	percutaneous nephrolithotomy
PODI	¼	postoperative day 1
PPV	¼	positive predictive values
ROC	¼	receiver operating characteristic
UCSF	¼	University of California, San Francisco
κ	¼	Cohen’s kappa coefficient