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Standard versus Tubeless Percutaneous Nephrolithotomy: A Systematic Review

Key Words

Stones • Nephrolithotomy • Tubed • Tubeless • Percutaneous nephrolithotomy

Abstract

Objective: This article systematically analyses comparative studies to evaluate the efficacy and safety of tubeless percutaneous nephrolithotomy (PCNL) versus standard PCNL. **Methods:** The Medline, EMBASE, PsycINFO, Cochrane and DARE databases were searched from 1997 to February 2011. Comparative studies evaluating outcomes from standard versus tubeless PCNL were included. Primary outcome measures were post-operative pain scoring, analgesic requirements, duration of hospitalisation/convalescence, operation time, major/minor complications and stone-free rates. **Results:** Twenty-four studies were included (11 randomised control trials and 13 retrospective or prospective studies). Levels of pain recorded, analgesic requirements, duration of inpatient stay and convalescence time were all significantly reduced in the tubeless PCNL group. Cost was reduced in two studies. Morbidity was not significantly different between the groups. There was no significant difference between groups regarding stone-free status. **Discussion:** This systematic review has demonstrated that tubeless PCNL is a

viable alternative to tubed PCNL in uncomplicated cases. Benefits are as described above. There is no evidence suggesting that patient safety is compromised by the absence of post-operative nephrostomy. The tubeless method has been reported in challenging cases such as stag-horn stones, horseshoe or ectopic kidneys. Promising outcomes have been demonstrated in elderly patients and when clinical needs demand a supracostal approach. Multi-centre randomised controlled trials are needed to fully establish the effectiveness of the tubeless method.

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Introduction

Percutaneous nephrolithotomy (PCNL) was developed in the 1970s as an adjunct to the open surgical management of large renal calculi [1]. Its high success rate, low morbidity and complication rates have meant that this minimally invasive modality has largely replaced the open surgical approach. PCNL is now the operation of choice for the management of large, complex renal calculi [2–7]. Historically temporary nephrostomy tubes of varying calibre and type have been left in place at the end of PCNL procedures for several reasons: drainage, tam-

ponade of bleeding and to permit second-look procedures [1–3, 8–11]. There is an ever-growing literature base documenting numerous technological and procedural refinements to this approach, such as the use of smaller calibre nephrostomies [4–6, 10]. Bellman et al. [9] challenged the need for a nephrostomy at all in their seminal work in 1997. Their study was based on 50 patients who were age-, sex- and procedure-matched. The authors highlighted compelling advantages of the tubeless approach: shorter hospitalisation and convalescence, reduced analgesic requirements and savings of up to USD 2,000 per case. Since then, there has been a literature base corroborating these outcomes [3–5, 8–14]. The technique involves internalising the renal drainage process (ureteric catheter or JJ stent placement) or alternatively no stent at all (totally tubeless PCNL) [4]. Despite the potential advantages of this approach, widespread uptake has been slow [15].

In this article, we systematically analyse published comparative studies to assess the role of the tubeless approach in PCNL. Our specific outcomes measures are clinical efficacy and complication rates, patient outcomes such as measure of pain, inpatient stay and convalescence period. We then distil the conferred advantages and disadvantages of the tubeless approach compared to the standard method.

Materials and Methods

This review was planned, performed and written according to guidelines from the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) [16].

Information Source and Search Criteria

Medline (1997 to present), EMBASE (1997 to present) and PsycINFO (1997–2011) databases were searched until January 2011. A combination of the following MeSH terms and keywords was used: ‘standard or tubeless’ or ‘tubed’ or ‘tubeless’ or ‘nephrostomy free’, ‘percutaneous nephrolithotomy’ or ‘PCNL’ or ‘calculi’ and ‘stones’, ‘nephrolithiasis’, ‘randomised control trial’, ‘comparative studies’; Cochrane and DARE (Database of Abstracts of Reviews of Effectiveness) databases were also checked for any systematic reviews. The only language restrictions were that at least the abstract had to be in English, thus permitting extraction of relevant data. References from selected articles and reviews were also evaluated to minimise the risk of missing relevant articles.

Study Selection and Data Collection

The authors (K.A. and T.A.) followed pre-defined inclusion criteria as per our research protocol to independently select potentially relevant articles through abstract screening. Full texts of relevant articles were retrieved and screened for inclusion. Where

differences of opinion emerged between the researchers regarding article eligibility, discussions were held in the department for formal review until a consensus was reached.

Eligibility Criteria

Only randomised and non-randomised comparative studies from 1997 to January 2011 assessing the use of standard versus tubeless PCNL were included in this analysis. As there were only a small number of randomised control trials in circulation, with generally small sample sizes, the decision was taken to include non-randomised articles to enhance representativeness. The primary outcomes measures of interest were: (1) post-operative pain scoring and analgesia requirements; (2) duration of hospitalisation and convalescence; (3) operation time; (4) major and minor complications; (5) stone-free rates.

Non-comparative studies were excluded from this review. In instances where there were published studies from the same authors and institutions where there was obvious overlap with regards to study period or primary data usage, we avoided duplication by including only the latest or most relevant study.

Datasets

Information was extracted and recorded from each article according to the following clusters; paper type, demographic data, pre-operative, intra-operative and post-operative variables.

Results

Study Selection

The initial search identified 78 potentially relevant study titles. Forty-two studies were excluded after the title and abstract review. Twenty-five studies were selected after full text review (fig. 1). Of these, one study was excluded due to duplication. One study was excluded as only a brief abstract with insufficient evidence was published. One more article was identified through the reference search. Finally, twenty-four comparative (tubed versus tubeless) studies were included in this systematic review.

Study Characteristics and Results

Thirteen randomised control trials are included with 11 case-control series making up the remainder of articles. Evidence varied from 1b to 2b according to the Oxford Centre for Evidence-Based Medicine [17].

Renal Drainage Post PCNL

In most trials included in this review, surgeons utilised a form of post-operative drainage of the urinary tract other than the ureter alone. Other researchers opted for a ‘totally tubeless’ approach and as such our analysis is sub-

Fig. 1. Search methodology for study inclusion.

categorised into three elements: (1) standard PCNL (tubed). (2) Tubeless with a ureteric stent: in 11 articles, standard PCNL groups were compared to groups where-by drainage was provided by ureteric stents [2–5, 7, 9, 10, 12, 18–20]. Within this category, 2 studies included three groups: two calibres of nephrostomy (large-bore and small-bore) compared with ureteric stents [3, 5]. A further 2 trials compared small-bore nephrostomies with ureteric stents [19, 20]. (3) Tubeless without a stent (totally tubeless): 6 articles compared standard PCNL to totally tubeless study groups, whereby surgeons utilised no ancillary drainage of the urinary tract whatsoever [8, 13, 21–24].

Stone Burden

Multiple measurement methods of assessing stone burden including volume, area and diameter were utilised across trials, hindering direct comparison. However, in only one study by Shah et al. [15] was there a statistically significant difference in stone burden between control and study groups (mean stone burden for stan-

dard PCNL 832 mm² vs. tubeless 322 mm², $p < 0.001$). Although the largest comparative study in this systematic review, stone-free rates between study and control groups were not significantly different. There was no significant disproportion in the number of cases of stag-horn calculi between the tubed and tubeless groups [2, 6, 12, 14, 15, 24].

Comparative Outcome Measures

Duration of Procedure

Of 24 studies in this review, 20 made comparisons between the overall duration of procedure [2–9, 12–14, 18–20, 22–27]. In 13 studies [2, 4, 7–9, 14, 18, 19, 22, 24–27] the procedure was shorter when tubeless. This was statistically significant for only 1 study [4]. In only 2 studies was the procedure longer for the tubeless approach versus the tubed approach; neither was statistically significant [13, 19]. Only 1 trial compared duration of operation for the two tubeless groups determining that there was no significant difference between the two [8].

Post-Operative Analgesic Requirements

In 22 studies [2–14, 18, 19, 21–24, 27–29], the range of analgesia needs post-operatively was less for tubeless patients, and this was significant in 13 studies [2–4, 6–11, 13, 18, 22, 27].

Pain Scoring

Two studies [5, 6] utilised a verbal rating scale to assess post procedure pain levels. For one study [6] pain was significantly reduced on post-operative day one but not so at follow-up. In the other trial [5], there was no significant difference post-operatively or at follow-up one week later (table 1).

Numerous trials assessed pain with visual analogue scale (VAS) scoring [4–6, 10, 11, 19]. Six studies compared VAS scores on day one [4–6, 15, 21, 26] and scores were significantly reduced in the tubeless with stent group for three studies [4, 15, 21]. Three studies compared VAS scores on day two and all found scores were significantly reduced in favour of the tubeless with stent group [4, 10, 11]. Two studies compared VAS scores at one week and found there to be no significant difference between the two groups [5, 21] (table 2).

Hospital Stay and Return to Work

Tubeless PCNL is associated with a shorter hospital stay [2–14, 18, 19, 21–24, 27], and multiple studies found

Table 1. Verbal rating score on day 1 post PCNL

Authors	PCNL	Verbal rating score on day 1 (mean $\pm$ SD)	p value	Verbal rating score at follow-up (mean $\pm$ SD)	p value
Feng et al. [5]	tubed	2.5 $\pm$ 0.16	0.28	1.9 $\pm$ 0.24 (day 7)	0.26
	tubeless with stent	2.5 $\pm$ 0.2		1.5 $\pm$ 0.28 (day 7)	
Giusti et al. [6]	tubed	3.1	<0.01	1.36 (day 10)	0.386
	tubeless with stent	1.9		1.45 (day 10)	

Table 2. Visual analogue score on day 1 post operation

Authors	PCNL	n	VAS on day 1 (mean $\pm$ SD)	p value	VAS on day 2 (mean $\pm$ SD)	p value	VAS at first follow-up (mean $\pm$ SD)	p value
Feng et al. [5]	tubed	10	3.7 $\pm$ 0.4	0.63	x	x	2.1 $\pm$ 0.4 (day 7)	0.8
	mini PCN	9	3.3 $\pm$ 0.5	x	x	x	2.5 $\pm$ 1.0 (day 7)	
	tubeless with stent	8	3.8 $\pm$ 0.5	x	x	x	1.6 $\pm$ 0.5 (day 7)	
Giusti et al. [6]	tubed	110	6.1	<0.001	x	x	1.93 (day 10)	0.428
	tubeless with stent	99	3.5		x	x	2.04 (day10)	
Berkman et al. [11]	tubed	29	2.5	<0.01	x		x	x
	tubeless with stent	24	1.6		x		x	
Agrawal et al. [10]	tubed	101	x	x	59 $\pm$ 5.1	<0.01	x	x
	tubeless with stent	101	x	x	31 $\pm$ 4.8		x	
Singh et al. [4]	tubed	30	9.67 $\pm$ 0.479	<0.001	6.63 $\pm$ 1.129	<0.001	x	x
	tubeless with stent	30	7.63 $\pm$ 0.490		6.03 $\pm$ 0.669		x	
Shah et al. [15]	tubed	386	7.1 $\pm$ 1.6	<0.001	5.2 $\pm$ 1.4	<0.001	x	x
	tubeless with stent	454	4.4 $\pm$ 2.1		2.8 $\pm$ 1.8		x	
Marcovich et al. [26]	tubed	20	3.8	0.18	2.6	0.93	x	x
	pigtail nephrostomy	20	2.8		2.2		x	
	tubeless with stent	20	4.5		3.3		x	

this to be statistically significant [3, 4, 9–13, 18, 30]. Patients returned to normal activities earlier when undergoing tubeless procedures [2, 3, 6, 9, 12, 23, 30]. These values were statistically significant in 6 trials [4, 9, 10, 13, 20, 25]. There was no statistically significant difference between the two tubeless groups (with or without stents) in our review with regards to duration of stay or of convalescence.

Cost

Only two trials made an assessment of total costs. In both cases, costs were reduced for tubeless procedures [5, 9] (table 3).

Stone-Free Rates

Initial stone-free rates were not statistically different between tubeless and tubed cases. Shah et al. [15] reported comparable stone-free rates at 3-month follow-up, 93.3 (tubed) and 93.8% (tubeless), respectively. Giusti et al. [6] reported similar figures: 95.4 and 98.9%, respectively. Table 4 demonstrates how the stone-free landmark was achieved across reviewed articles.

Ancillary Procedures

The requirement for ancillary procedures was not statistically significantly different between tubed and tubeless groups (table 4). In the case of Shah et al. [15], the majority of ancillary procedures were extracorporeal

Table 3. Cost of tubed vs. tubeless PCNL

Authors	PCNL	n	Cost, USD
Feng et al. [5]	standard PCNL	10	7,555 ± 619
	mini PCNL	9	6,565 ± 300
	tubeless with stent	8	5,562 ± 356
Bellman et al. [9]	tubed	50	3,750
	tubeless with stent	50	1,638

shock wave lithotripsy (ESWL) (tubed/tubeless n = 18/19) for both cohorts. In the tubed cohort, 1 patient had further ureteroscopy and 1 had flexible ureteroscopy. For the tubeless group, 19 patients had ESWL with 2 each of ureteroscopy, flexible ureteroscopy and repeat PCNL.

In the work of Sofer et al. [2], 4 subjects were treated with SWL and 2 with intrarenal surgery in the standard group, and 2 with SWL and 3 with intrarenal surgery in the tubeless group.

In the case of Yates et al. [29], although clearance for tubeless groups was 95 versus 71% in standard PCNL, the authors postulated that this was coincidental rather than reflecting true differing case complexity. Without giving an actual figure, in the majority of patients requiring further treatment, ESWL was the modality of choice.

In the study by Sofikerim et al. [18], all ancillary procedures were ESWL, 8.3% for standard and 4.2% for tubeless groups.

Whilst Istanbuluoglu et al. [8] did not specify which modality of ancillary procedure was instituted, in Kara et al. [22], two standard PCNL patients had ESWL, with one having retrograde intrarenal surgery. Only one patient in the tubeless group had ESWL.

In the study by Singh et al. [4], 10% of tubeless patients (3/30) had re-look PCNL under local anaesthetic via the same tract 2 days later and were completely stone-free at discharge. In the tubed group 2/30 (6.6%) patients with residual stones each received two SWL sessions and were later declared stone-free.

Major Complications

There were no statistically significant differences in incidences of major and minor complications between standard and tubeless Groups (table 5). Regarding blood loss and the need for transfusion, there was no statistically significant difference in measured blood loss (fall in haemoglobin or haematocrit levels) or transfusion rates amongst any of the studies shown (table 6).

Five trials [6, 8, 11, 15, 20] reported the use of embolisation for arteriovenous fistulae or pseudo-aneurysms. Whilst the incidence is higher in tubed groups, the figure lacks statistical significance (1–3 vs. 0–8.3%). Splenic injury is documented only by Shah et al. [15] with 1 case per group. No meaningful differences can be drawn from the incidence of pulmonary emboli reported in two reports [2, 22].

Regarding cases where hydrothorax required intervention, minimal conclusions can be drawn on significant differences between the two study groups as only two articles assessed this variable. In the largest study to date, Shah et al. [15] found the incidence was nearly half in the tubeless group (3/454) versus the standard group (6/386).

Minor Complications

Of five comparative articles reporting post-operative pyrexia, incidences were generally lower in tubeless groups, illustrated best by Shah et al. [15] (11.4 versus 5.79%). These however were not statistically significant.

Three studies measured duration of urinary leakage. In two, urinary leakage was significantly reduced in the tubeless groups. Desai et al. [3] compared standard large-bore nephrostomy with small-bore and tubeless subjects. As table 5 shows, small-bore nephrostomy was associated with a shorter duration of urinary leakage; likewise, tubeless PCNL was associated with a significantly shorter duration. Agrawal et al. [10] found that the incidence of urinary leakage was significantly reduced in tubeless cases. Although lacking significance values, this was unanimously the case for four further articles [2, 14, 15, 28].

There was no significant difference between standard and tubeless study groups in the incidence of urinary tract infections. In fact, Gupta et al. [7], the largest trial documenting post-operative urinary tract infections, had comparable incidences of 27 and 25% in population sizes of 184 and 135, respectively.

Desai et al. [3] reported hydronephrosis in 9/10 tubed and 8/10 tubeless patients on renal ultrasound in the early post-operative period. Basiri et al. [28] reported three cases of tubed patients having dilation on intravenous pyelogram at 3-month follow-up ($p = 0.03$) with no similar episodes in tubeless (without stents) patients.

Collection on Ultrasound in the Immediate Post-Operative Period

Regarding urinary collections seen on ultrasound in the post-operative period, Istanbuluoglu et al. [8] reported only one tubed candidate (out of 92). Singh et al. [4]

Table 4. Method for determining initial stone-free status and use of ancillary procedures

Authors	Method for determination of initial stone-free status	Timing	Initial stone-free status	Residual stone burden	Ancillary procedures	Method for determination of follow-up stone-free status
Sofer et al. [2]	1. Contrast nephrography 2. Flexible nephroscopy 3. Backward endoscopic surveillance of the working tract 4. Unenhanced CT	1–3. Intra-operatively 4. CT KUB on day 1 post operation	1. Tubed: 90% 2. Tubeless with stent: 92%	1. Tubed: 49 mm ² 2. Tubeless: 52 mm ² (n = 5)	1. Tubed: 4 × SWL, 2 × RIRS, 17 × second-look PCNL (28%) 2. Tubeless: 2 × SWL, 3 × RIRS	x
Singh et al. [4]	XR	Day 1 post operation	1. Tubed: 90% 2. Tubeless with stent: 93.3%	1. Tubed: n = 3 (10%) 2. Tubeless: n = 2 (6.6%)	1. Tubed: n = 3; second-look PCNL pre discharge; all stone-free at time of discharge 2. Tubeless: both 2 × SWL; stone-free after 3 weeks	x
Falahatkar et al. [14]	XR KUB/ultrasound	Day 1 and 4 weeks post operation	1. Tubed: 77.8% 2. Tubeless w/o stent: 92.6%	x	x	x
Feng et al. [5]	Rigid nephroscopy	Intra-operatively	1. Standard PCNL: 37.5% 2. Mini PCNL: 62.5% 3. Tubeless with stent: 71.4%	Not quantified	SWL (n: not quantified)	XR KUB
Crook et al. [21]	Nephroscopy/fluoroscopy	Intra-operatively	1. Tubed: 84% 2. Tubeless without stent: 96%	x	x	x
Kara et al. [22]	1. Nephroscopy 2. XR and ultrasound	1. Intra-operatively 2. XR KUB/ultrasound day 1 and 7	1. Tubed: 90% 2. Tubeless without stent: 96%		1. Tubed: 2/30 (6.6%) SWL, 1/30 RIRS 2. Tubeless without stent: SWL 3.3%, 1/30	XR KUB/ultrasound day 7 and 3 months
Karami et al. [23]	1. Fluoroscopy 2. AXR and ultrasound	1. Intra-operatively 2. 24 h	1. Tubed and tubeless without stent: 90%	x	x	x
Sofikerim et al. [18]	AXR	Prior to discharge	1. Tubed: 83% 2. Tubeless with stent: 79%	x	1. Tubed: 2/24 (8.3%) SWL 2. Tubeless with stent: 1/24 (4.2%) SWL	x
Yates et al. [29]	1. Endoscopy and fluoroscopy 2. XR KUB	1. Intra-operatively 2. Pre discharge	1. Tubed: 71% 2. Tubeless with stent: 95%	x	1. Tubed: 16 (29%) SWL 2. Tubeless: 2 (5%) SWL	XR KUB
Shah et al. [15]	1. Fluoroscopy/endoscopy 2. XR KUB/ultrasound	1. Intra-operatively 2. 24 h	1. Tubed: 88.6% 2. Tubeless with stent: 89.4%	1. Tubed: n = 24 (6.2%) 2. Tubeless: n = 26 (5.8%)	1. Tubed: 37% second-look PCNL/nephroscopy at 24/48 h, 18 ESWL, 1 ureteroscopy, 1 flexible ureteroscopy 2. Tubeless with stent: 19 ESWL, 2 ureteroscopy, 2 flexible ureteroscopy, 2 PCNL	XR KUB/ultrasound 7 days
Istanbulluoglu et al. [8]	Fluoroscopy/pyelography	1. Intra-operatively	x	x	1. Tubed: 10% 2. Tubeless with stent: 9.7 % 3. Tubeless without stent: 6.9%	x

AXR = Ancillary X-ray; CT = computed tomography; KUB = kidneys, ureters and bladder; RIRS = retrograde intrarenal surgery; XR = X-ray.

Table 5. Incidence of complications

Complications	Tubed	Tubeless with stent	Tubeless without stent
Transfusion rates, % [2, 4–6, 8, 9, 11–13, 19, 21–24]	1–16.6	1.51–11	0–9.3
Average Hb drop, g/dl [2, 4, 8, 10, 12, 19, 21, 24, 27, 29]	0.39–2.25	0.36–1.7	1.18–1.57
Embolisation, % [6, 8, 11, 15, 20]	1.08–3.4	0.6–8.3	x
Splenic injury, % [15]	0.25	0.22	x
Hydrothorax necessitating intervention, % [2, 15]	1.3–6.7	0.66	x
Incidence of PE, % [2, 22, 23]	1.6–3.3	1.5–3.3	3.30
Tract loss [4]	1/30	x	x
Sepsis, % [4, 15, 21]	1.8–5	1.1–3.9	x
Bowel injury [15]	1/386	x	x
Obstructed renal system post nephrostomy removal [20]	1/12	x	x
Caliceal perforation [4]	1/30	x	x
Retroperitoneal haematoma [6, 15, 29]	1/55, 1/386	1/99, 1/46, 1/484	x
Perinephric collection [8]	1/92	x	x
Urinary retention [29]	1/55	x	x
Ileus [29]	1/55	x	x
Delayed haematuria [15, 29]	9/386	2/46, 8/456	x
Respiratory failure requiring ICU [29]	x	1/46	x
Chronic loin pain [29]	3/55	x	x
Stent migration [20, 29]	x	1/46, 3/12	x
Clot clonic [29]	x	1/46	x
Pleural effusion [22]	1/30	x	x
Pleural empyema [2]	1/60	1/66	x
Pyrexia, % [8, 10, 14, 15, 22, 24]	2.17–11.4	0–6.7	1.38–6.77
Duration of leak, h [3, 4, 7]	16.4–21.4 (± 5.7)	0–6.2	x
Incidence of urinary leak, % [2, 10, 14, 15, 28]	2.33–11.1	x	x
Urinary tract infection, % [2, 4, 7, 14, 21, 23]	0–27.1	0–25	6.67–8
Prolonged drainage, % [8]	3.26	x	4.65

Table 6. Mean decrease in haematocrit (HCT)

Authors	PCNL	Sample size	Decrease in HCT (%), mean $\pm$ SD	p value
Desai et al. [3]	large-bore nephrostomy	10	3.9 $\pm$ 0.7	0.23
	small-bore nephrostomy	10	3.0 $\pm$ 1.0	0.16
	tubeless with antegrade 6-Fr double-J stent	10	4.2 $\pm$ 0.7	0.2
Feng et al. [5]	standard PCNL with 34-Fr sheath (22-Fr nephrostomy)	10	6.9 $\pm$ 1.1	0.47
	mini PCNL with 26-Fr sheath (22-Fr nephrostomy)	9	5.7 $\pm$ 1.0	
	tubeless with double-J stent	8	6.7 $\pm$ 0.8	
Giusti et al. [6]	tubed	110	5.9	0.23
	tubeless with stent	99	5.5	
Kara et al. [22]	tubed	30	3.2 (3–4)	>0.05
	totally tubeless	30	3.9 (3–5)	

Table 7. Clinical outcomes and pre-operative stone burden

Mean, variable	Tubed	Tubeless with stent	Tubeless without stent	References
Stone burden				2–8, 10, 15, 18, 20–22, 24–29
mm ³	5.52–8.36	4.38	6	
mm	13.8–36	12.1–32	17.5–25.8	
mm ²	264–1,044	250–924	461	
Operating time, min	44.5–158	43–142	41–75	2–9, 12–14, 18–20, 22–27
Hospital stay, days	1.6–5.2	0.6–3	1.6–3.38	2, 3, 6, 9, 12, 23, 30
Return to normal activities, days	7–31.4	4.18–18.3	7–12.7	2–14, 18, 19, 21–24, 27
Stone-free rates, %				
Initially stone-free	37.5–90	71.4–93.3	83–96	2, 4–6, 14, 15, 18, 21–23, 27
Stone-free at follow-up	93.3–95.4	93.8–98.9	x	5, 15
Ancillary procedures	5.2–29	3–9.76	3.3–7.0	2, 4, 8, 15, 22, 27, 31

reported a mean urinary collection that was ‘insignificant’ for the tubed group and less than 15 cm³ for the tubeless with stent group. At follow up, only Basiri et al. [28] reported one tubeless without stent patient having a collection on ultrasound at 3 months.

Discussion

This article distils much of the comparative work done on nephrostomy-free PCNL. As reported in multiple trials, morbidity is not significantly increased and key outcome measures such as duration of inpatient stay, pain scores, analgesic requirements and time to returning to normal activities are significantly reduced in tubeless PCNL (tables 5–7).

As Zilberman et al. [31] discovered, there is much heterogeneity in the existing literature with regards to definitions of ‘tubeless’ and at the outset, this challenged precise inter-article comparison. This review adapted to this by subdividing groups into tubed, tubeless with a ureteric stent or without a stent. The same authors also highlighted the intermittent consistency between studies in type of nephrostomy used. Four articles compared study groups with small calibre nephrostomies whereas ten compared large calibre nephrostomies. In two cases the grade of nephrostomy was not specified [19, 32]. This variation in terminology and approach to ‘tubeless’ between comparative studies may affect conclusions drawn on the subject, and future randomised trials are encouraged to adhere to consensus to reduce inter-study bias.

Excluding the work of Shah et al. [15], there was no significant difference in initial stone burden between

tubed and tubeless groups in all trials. Efficacy outcomes, namely stone-free status and the need for ancillary procedures, were not significantly different either between groups. However, as demonstrated in table 4, variations exist in the definitions of stone-free status with inconsistencies in timings, types and imaging modalities used. Further randomised control trials should adhere to universal standards so ensure reliability when comparing stone-free rates in future meta-analyses and reviews.

A thorough review of published complications relating to PCNL has shown no convincing evidence that the tubeless approach is associated with any increase in major or minor complications. Blood transfusion rates were uniform across all three groups (tubed: 1–16.6%; tubeless with stent: 1.5–11%; tubeless without stent: 0–9.3%) as were changes in haemoglobin and haematocrit levels. Embolisation rates to treat arteriovenous fistulae and pseudoaneurysms were somewhat higher in the tubed group. The large range in embolisation rates for the tubeless with stent group is biased by a small sample size in the study by Choi et al. [20]. Although not statistically significant, the large power derived from their large sample size of 386 standard and 454 tubeless patients means that attention should be granted to the work of Shah et al. [15] with regards to this variable. Incidence of embolisation was 1.3 and 0.66% for tubed and tubeless groups, respectively. Other complications including pulmonary emboli, tract loss, retroperitoneal haematoma and bowel injury occur in such low frequency that direct comparison would be misleading.

Minor complications demonstrate no affinity for any of the PCNL approaches. The incidence and duration of urinary leakage was found to be lower in tubeless groups.

The strengths of this study include its focus solely on comparative studies to assess demographically matched study groups and the inclusion of randomised trials to enhance reliability of conclusions. The inclusion of non-randomised studies enables a larger patient population to be drawn upon, enhancing the generalisability of these data. Furthermore, it is the first study to specifically address ambiguity in the term 'tubeless' by subcategorising into with and without stent groups. A thorough review of the complications has been performed and many of the major and minor complications occur less frequently in the 'tubeless without stent' category.

Zilberman et al. [31] cite Munver et al. [33] who advise caution when utilising the supracostal approach for managing complex renal calculi as the risks of hydrothorax or pneumothorax may be higher. However, the same article cites Sofikerim et al. [18] and Shah et al. [34] in stating that tubeless PCNL may 'significantly' decrease patient morbidity whilst not compromising safety with an increased incidence of intra-thoracic complications when opting for a supracostal approach for clinical need. Shah et al. [34] ran a trial comparing both approaches in only supracostal access PCNL. They concluded that supracostal tubeless PCNL was 'feasible and safe', with the advantages of reduced post-operative analgesia and shorter hospital stay without enhancing the risk of post-operative pleura-pulmonary complications. Re-analysing the comparative studies in this review, the use of supracostal access was assessed and found to be present in five articles

[2, 6–8, 22]. There are no specific reports in this series of supracostal access in tubeless PCNL increasing the incidence of intrathoracic complications.

Another important population to be considered is the elderly. Kara et al. [22] performed a randomised study in patients over 60 years and found that not only the tubeless procedure was safe and clinically effective, but also inpatient stay and analgesic requirements were significantly less than with standard PCNL.

Aghamir et al. [25] performed a prospective trial to assess applicability of totally tubeless PCNL in patients with renal anomalies including horseshoe, malrotated and ectopic kidneys. In cases of atypical renal anatomy, the tubeless approach was associated with a significantly diminished duration of stay, recovery period and analgesia requirements ($p < 0.001$). Meanwhile, there was no significant difference in complication rates, stone-free outcomes and duration of the procedure itself.

Implications of this study are to emphasise that in certain patients, nephrostomy-free PCNL can be performed safely to achieve acceptable stone-free outcomes. Advantages of the tubeless method include diminished hospital stay, return to work time, operative time and analgesic requirements.

Limitations of the study include the small number of randomised control trials and the small study size of many of the studies included. Multi-centre randomised controlled trials evaluating the need for ureteric stenting in these cases are required.

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