



The sentinel stent? A systematic review of the role of prophylactic ureteric stenting prior to colorectal resections

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Abstract

Purpose ‘Prophylactic’ ureteric stents potentially reduce rates, and facilitate intraoperative recognition, of iatrogenic ureteric injury (IUI) during colorectal resections. A lack of consensus surrounds the risk–benefit equation of this practice, and we aimed to assess the evidence base.

Methods A systematic review was performed according to PRISMA guidelines. MEDLINE, Scopus, EMBASE and Cochrane databases were searched using terms ‘ureteric/ureteral/JJ/Double J stent’ or ‘ureteric/ureteral catheter’ and ‘colorectal/prophylactic/resection/diverticular disease/diverticulitis/iatrogenic injury’. Primary outcomes were rates of ureteric injuries and their intraoperative identification. Secondary outcomes included stent complication rates.

Results We identified 987 publications; 22 papers met the inclusion criteria. No randomised controlled trials were found. The total number of patients pooled for evaluation was 869,603 (102,370 with ureteric stents/catheters, 767,233 controls). The most frequent indications for prophylactic stents were diverticular disease (45.38%), neoplasia (33.45%) and inflammatory bowel disease (9.37%). Pooled results saw IUI in 1521/102,370 (1.49%) with, and in 1333/767,233 (0.17%) without, prophylactic ureteric stents. Intraoperative recognition of IUIs occurred in 10/16 injuries (62.5%) with prophylactic stents, versus 9/17 (52.94%) without stents ($p = 0.579$). The most serious complications of prophylactic stent use were ureteric injury (2/1716, 0.12%) and transient ureteric obstruction following stent removal (13/666, 1.95%).

Conclusions Placement of prophylactic ureteric stents has a low complication rate. There is insufficient evidence to conclude that stents decrease ureteric injury or increase intraoperative detection of IUIs. Apparently higher rates of IUI in stented patients likely reflect use in higher risk resections. A prospective registry with harmonised data collection points and stratification of intraoperative risk is needed.

Keywords Colorectal · Ureter · Stent · Iatrogenic injury · Resection

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Introduction

Background

Ureteric injuries are a rare but feared complication of abdominal and pelvic surgery. They are a cause of significant morbidity, including intra-abdominal sepsis, renal failure and loss of the ipsilateral renal unit [1] and have been reported to incur hospital costs in excess of \$31,000 per injury [2]. The overall incidence of iatrogenic ureteric injury related to colorectal surgery in modern series is low, with reported rates generally < 2% [2–8]. Nonetheless, general and colorectal surgical procedures are recognised amongst the most common contributors to iatrogenic ureteric injuries overall [1, 9,

10], and the incidence may be rising in the era of minimally invasive surgery [1, 5, 11]. Close proximity of the ureters to the operating field, especially during dissection of the inferior mesenteric artery pedicle, makes them vulnerable to injury (transection, ligation, crush, thermal injury or devascularisation) [12, 13] during colorectal resections, with increased risk in the context of distorted anatomy secondary to inflammation, malignancy, prior abdominal surgery or irradiation [13, 14]. Immediate (intraoperative) diagnosis and repair of iatrogenic ureteric injuries are desirable to minimise long-term morbidity [15–17].

There is a need for strategies to reduce the risk of ureteric injury, and to facilitate immediate recognition, during colorectal procedures. The preoperative placement of prophylactic ureteric stents or catheters has long been discussed as a technique that may assist colorectal surgeons in identifying and avoiding the ureters, and in recognising ureteric injury when it occurs [18, 19]. Debate surrounds this topic, however, with no consensus on the precise benefit of prophylactic ureteric stents, and some concerns regarding potential stent-related complications. Whilst the European Association of Urology (EAU) guidelines state that ‘visual identification of the ureters and meticulous dissection in their vicinity are mandatory to prevent ureteral trauma during abdominal and pelvic surgery’ (grade A recommendation), the use of ‘preoperative prophylactic stents’ are recommended only ‘in selected cases (based on risk factors and surgeon’s experience)’ (grade B) [20]. The American Society of Colon and Rectal Surgeons guidelines in surgery for diverticulitis state ‘ureteral stents are used at the discretion of the surgeon’ (grade 2C) [4].

Aims and outcomes

This systematic review aimed to assess the evidence base for the use of prophylactic ureteric stents or catheters in colorectal surgery. The primary outcomes were to assess whether ‘prophylactic’ ureteric stent use results in a reduction in iatrogenic ureteric injuries, and whether stent insertion increases intraoperative identification of ureteric injury.

As secondary outcome measures, we aimed to assess the complication rate specific to ureteric stenting in this context and the impact of prophylactic stent insertion on overall cost and time added to procedure. We also wished to explore surgeon and departmental variation regarding indications for stenting prior to colorectal surgery, the timing of insertion and removal of prophylactic stents insertion prior to surgery, the use of unilateral versus bilateral ureteric stents and the type/material of stent used.

Materials and methods

Search strategy

This review was prospectively registered with the PROSPERO database, an international register of systematic reviews (record CRD42018086182) [21] (Online resource 1). A systematic review was conducted with reference to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement, designed to improve the reporting of such studies [22]. Two reviewers independently performed a literature search of the Pubmed/MEDLINE, Scopus, EMBASE and Cochrane Central Register of Controlled Trials databases, using the search terms ‘Ureteric stent’, ‘Ureteral stent’, ‘JJ stent’, ‘Double J stent’, ‘Ureteric catheter’ or ‘Ureteral catheter’ combined with one of ‘Colorectal’, ‘Prophylactic’, ‘Resection’, ‘Diverticular disease/diverticulitis’ or ‘Iatrogenic injury’ in Title or Abstract sections. A sample search is included as Online resource 2. The search strategy was re-run just prior to article submission. Articles were screened by title and abstract, with potentially relevant articles retrieved for formal assessment of eligibility for inclusion. The reference list of retrieved articles was trawled to identify additional relevant papers. Any disagreements surrounding study selection were resolved by discussion between the two reviewers.

Inclusion criteria

English-language articles published in print or online between January 1980 and November 2018 were included. Papers assessing the use of prophylactic ureteric stents in the setting of both benign and malignant disease, and for both minimally invasive and open colorectal procedures, were included. Papers discussing the intentional en bloc resection of the ureter in the management of locally advanced malignancy were excluded. Exclusion criteria were also applied to individual case reports, animal studies and papers scoring below 7 on the quality assessment checklist (Fig. 1). No other limitations were applied to study type.

Data extraction

Papers meeting inclusion criteria were reviewed in full, with data extraction performed according to a pre-defined data extraction form (Online resource 3).

Quality assessment

No randomised controlled trial was identified comparing colorectal procedures with and without the use of prophylactic ureteric stents. To assess study quality, a modified version of the Downs and Black [23] quality assessment checklist,

Fig. 1 Modified Downs and Black Quality Assessment Checklist

Downs & Black Modified

1. Is the hypothesis/aim/objective of the study clearly described?
2. Are the main outcomes to be measured clearly described in the introduction or methods section?
3. Are the characteristics of the patients included in the study clearly described?
4. Are the interventions of interest clearly described? (method of stent/catheter placement and colorectal surgery lap vs open, elective vs emergency)
5. Are the main findings of the study clearly described?
6. Have all the important adverse events that may be a consequence of the intervention been reported (ie, perioperative complications)?
7. Have the characteristics of patients lost to follow-up been described? External validity
8. Were the subjects asked to participate in the study representative of the entire population from which they were recruited?
9. Were characteristics of subjects eligible for, but not included in, study specified, or was a control group used?
10. Were the staff, places, and faculties where the patients were treated representative of the treatment the majority of patients receive? (Ie, are RF ablation methods in this study similar to in other studies included?) Internal validity
11. Was an attempt made to blind those measuring the main outcomes of the intervention?
12. If any of the results of the study were based on “data dredging,” was this made clear? (0 or -1)
a. Are all planned analyses in the methods section?
b. Were the statistical tests used to assess the main outcomes appropriate?
c. Were the main outcome measures used accurate (valid and reliable)?

tailored previously to allow assessment of non-randomised studies [24], was used (Fig. 1). One question from this—number 9: ‘Were those subjects who were prepared to participate representative of the entire population from which they were recruited?’—was modified to ‘Have the characteristics of patients eligible for, but not included in the study been specified?’ as the nature of these retrospective reviews meant patients were unlikely individually invited to participate. The modified scoring system reflects the quality of studies on a scale of 0–13, with higher scores assigned to better-quality studies.

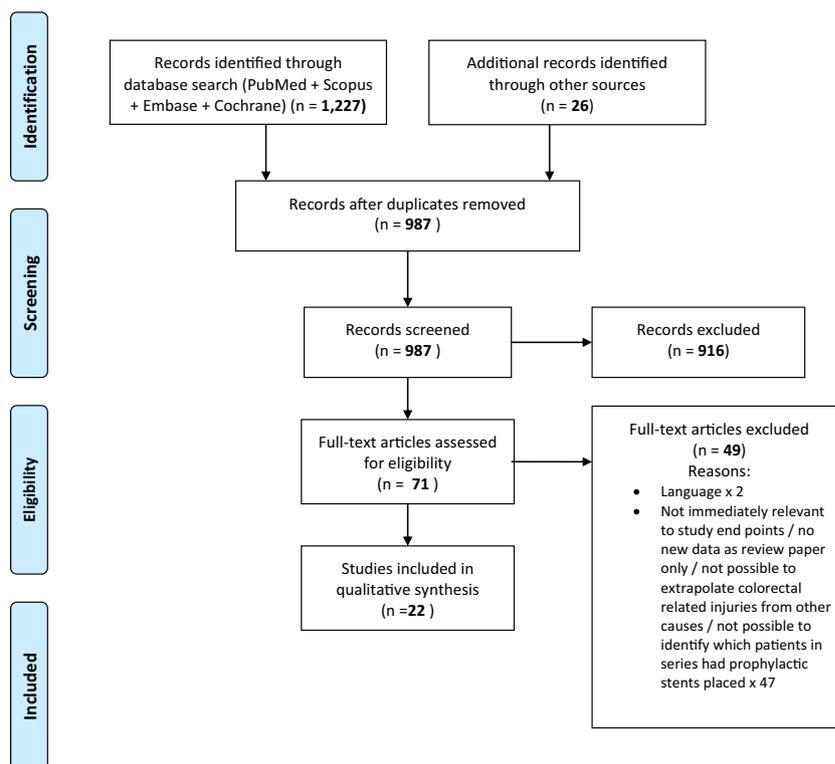
Statistical analysis

Due to the low quality and heterogeneity of studies in the present review, a meta-analysis was not performed [25], and a systematic review was used to present the current evidence.

Results

The literature search and a review of retrieved papers’ bibliographies yielded 987 publications, following removal of duplicates. Of these, 22 papers met criteria for inclusion (Fig. 2). Of the selected 22 papers, two studies were prospective observational in design [26, 27], two studies were prospective with the primary outcome assessing timing of stent insertion relative to colorectal procedure (sequential versus simultaneous) [28, 29] and the remaining 18 papers were retrospective in nature. Nineteen centres from 6 countries (USA, Canada, UK, Germany, India and Korea) were represented. Three studies looked at data from the US National Inpatient Sample: Chiu [8] (data 2000–2013, diverticular disease only), Coakley [3] (data 2012–2014, elective colectomy only) and Speicher [30] (data 2005–2011, laparoscopic abdominoperineal resection, low anterior resection

Fig. 2 PRISMA flow diagram



and segmental colectomy only). This may have led to a degree of overlap; however, it was not possible to identify and remove duplicated patients, and removing an entire study would have sacrificed a large volume of relevant data. All studies scored between 8 and 12 on modified Downs and Black quality assessment checklist scored out of 14 (Fig. 1). As all studies exceeded the intended quality assessment cut-off value of 7, no studies were excluded based on lack of quality.

For simplicity, and due to differing terminology used in the literature, all prophylactic ureteric/ureteral stents or catheters are termed ‘ureteric stents’ in the results and discussion, and cohorts described as ‘stented’ (placement of a prophylactic ureteric catheter/stent on an intention-to-treat basis) or ‘non-stented’ (neither placement, nor attempted placement, of prophylactic ureteric catheter or stent). The specific types of ureteric stent or catheter used in each study are outlined in Table 5.

Demographics

The demographics are outlined in Tables 1, 2, and 3. Patient mean age varied 43–69 years old. All studies looked at mixed male/female cohorts.

The total number of patients pooled for evaluation of rates of ureteric injury was 869,603 of whom 102,370 had ureteric stents/catheters and 767,233 acted as controls.

Indications for prophylactic stents

Two centres used prophylactic ureteric stents/catheters as routine in distal colorectal resections [18, 31], whilst the remainder used them at the discretion of the colorectal surgeon, or did not specify. Of 5968 patients of mixed disease populations with underlying condition specified who received prophylactic ureteric stents, diverticular disease was the indication for colorectal resection in 2708 (45.38%), neoplasm (including neoplastic polyps) in 1996 (33.45%) and inflammatory bowel disease in 559 (9.37%) [3, 18, 26–38]. A large series looking exclusively at surgery for diverticular disease [8] was excluded from this specific analysis of indications to avoid skewing the results; as by definition, patients with non-diverticular pathology were excluded from this sample. Colorectal procedures in individual series range from all colorectal resections to primarily low anterior resections and abdominoperineal resections (Tables 1, 2, and 3).

Where discussed, reasons for electing to insert prophylactic ureteric stents were described as ‘anticipated... adhesions’ [27, 38]; ‘complicated diverticular disease, previous pelvic surgery, obesity’ [35]; ‘anticipation of difficult procedure: bulky rectal tumours, complex enteric fistulae, excision/redo ileal pouch, pelvic sepsis’ [29]; and ‘surgeon preference’ [38].

Table 1 Primary outcome—rates of ureteric injury (open colorectal resections)

Study	n	Modified Downs and Black score	Demographics	Disease	Surgery	Indications for stent insertion	% with ureteric stents/catheter inserted	Unilateral/bilateral stents	Outcomes: rate of ureteric injuries	Outcome: recognition of ureteric injury
Bothwell [41] 1994 (Philadelphia) Retrospective	561	10	M:F 48:52 Mean age 69 (18–99)	Mixed benign/malignant —breakdown unclear in stented population	Distal colectomies	Surgeon's discretion	92 (16.4%) of distal colectomies overall. Highest for APR (25%) and low anterior resection (22.4%)	Bilateral insertion attempted in all	Unstented group: 2/469 = 0.43%	Unstented group: 1/2 injuries identified intraoperatively, 1/2 identified postoperatively Intention to stent group: 1/2 identified intraoperatively, 1/2 (secondary to stent attempt) identified postoperatively day 3 ureteric injuries recognised
Leff [19] 1982 (New Jersey) Retrospective	194	10	Unknown	Mixed benign malignant: carcinoma 67.7% (134/194), diverticulitis 17.2% (34/194), IBD 11.1% (22/194)	Colon and rectal resections Low anterior resection 32.8% (65/194), sigmoidectomy 57/194 (28.7%), APR 15.1% (30/197)	Routine practice for rectal and left colon procedures, surgeon discretion for right colon procedures	All study cohort n = 194	Bilateral attempted in 94.3%	4/194 (2.06%)	3/4 ureteric injuries recognised intraoperatively, 1/4 delayed presentation (suspected devascularisation injury) 3/5 recognised intraoperatively
Kutiyavavala [44] 1999 (Leicester) Control Retrospective	251	8	Not reported	Malignancy in 206/251, diverticular 25/251	Malignancy in 206/251, diverticular 25/251	Stents not used	N/A	N/A	5/251 (1.99%)	
Kyzer [33] 1994 (Quebec) Retrospective	118	11	Mean age 55.7 56 male, 62 female	Malignancy 50.8% Diverticular 32.6% Crohn's 10.8%	Open colorectal procedures	Surgeon's discretion	All study cohort n = 118	Bilateral in 60%	1/118 stented (0.85%)	1/1 recognised intraoperatively
Merola [28] 2017 (Yale, Connecticut) Retrospective	374	11	Mean 61.5 years 43.6% male	Malignancy 119/374 (38.5%), diverticular IBD 24/374 (6.4%)	Open colectomy	Anticipated dense adhesions, known urological pathology, surgeon preference	52/374 (13.9%)	Unclear	Stented: 1/52 (0.3%) Non-stented: 0/322	1/1 injuries (in stented patient) recognised postoperatively
Palaniappa [45] 2012 (Mount Sinai) *Open arm Retrospective	7	10	5:2 male:female Mean age 55 years	Mixed 5/7 IBD	Mixed colorectal	Surgeon's discretion	2/7 injuries had prophylactic stents	Unclear	7/4669 (0.15%) injury rate, proportion stented unclear	4/7 injuries recognised intraoperatively

Majority do not specify elective/emergency breakdown

*No statistically significant difference in intraoperative detection rates of ureteric injuries between stented and non-stented patients

Table 2 Primary outcome—rates of ureteric injury (laparoscopic/robot-assisted colorectal resections)

Study	<i>n</i>	Downs and Black score	Demographics	Disease	Surgery	Indications for stent insertion	<i>N</i> with ureteric stents/catheters inserted	Unilateral vs bilateral stents	Outcomes: rate of ureteric injuries	Outcomes: recognition of ureteric injury
Beraldo [32] 2013 (Hamburg) Standard Retrospective	89	11	56 M:44 F Mean age 66 (36–88)	Benign 54/89 (66%) Malignant 35/89 (39%)	Laparoscopic distal colorectal resections (2.2% converted to open)	Routine practice for distal resections	All (100%) planned for stent, failed in 2/89 (2.25%)	Bilateral: low anterior resection/APR <i>n</i> = 15 Unilateral (left) for remainder <i>n</i> = 74	1/89 (1.1%)	1/1 (100%) recognised intraoperatively
Boyan [34] 2017 (New Jersey) Lighted Retrospective	465	11	Mean age: 60.9 years 46 M:54 F	Benign 305/465 (66%) Malignant 160/465 (34%)	Laparoscopic or robotic colorectal resections Most commonly low anterior resection/left colectomy	Not specified	All—study looked at only those with prophylactic stents. Denominator unclear	Initially bilaterally. Later, surgeons sometimes chose left only.	0/465	0
Chahin [35] 2002 (Michigan) Lighted Retrospective	66	11	Mean age 62.27 years 32 M:34 F	Benign (diverticular) 34/66 (51.5%) Carcinoma/neoplastic polyps 32/66 (48.4%)	Laparoscopic colorectal resections. Pathology of sigmoid colon in 56/66 (84.8%)	Not specified	All—study looked at only those with prophylactic stents. Denominator unclear	Initially bilaterally. Later, surgeons sometimes chose left only.	1/66 (1.5%)	0/1 recognised intraoperatively
Luks 2018 [39] (Yale, Connecticut) Retrospective	702	10	Mean age 60 M:F, 53:47	Stented cohort (<i>n</i> = 261): neoplasia incl polyps = 142 (54.4%), divertic <i>n</i> = 80 (30.7%), IBD <i>n</i> = 33 (12.6%)	Laparoscopic colectomy (elective)	Anticipated adhesions (35.2%), known urologic disease (16.5%), or surgeon preference (48.3%)	261 (37.2%)	Bilateral in > 98%	With stent: 2/261 (0.77%) Without stent 0/441 (0%)	2/2 (100%) recognised intraoperatively
Nam [27] 2002 (Korea) Standard Study type unclear	162	10	Stented group: mean age 55, M:F 31:36 Non-stented mean age 65, M:F 46:49	Mixed: Crohn's 24% (<i>n</i> = 40), diverticulitis 20% (<i>n</i> = 32), malignancy 44% (<i>n</i> = 72)	Laparoscopic segmental colectomy	Unclear	67/162 intention to stent	Bilateral	0 ureteric injuries sustained	N/A
Palaniappa [45] 2012 (Mount Sinai) *Laparoscopic arm Type of stent not specified Retrospective	7	10	0.7 male:female Mean age 64 years	Mixed 3/7 malignancy, 2/7 diverticulitis	Mixed colorectal	Discretion of operating surgeon	2/7 injuries had prophylactic stents	Unclear	7/1060 (0.66%) injury rate. Unclear proportion stented	3/7 injuries recognised intraoperatively*
Sahoo [40] 2012 (Cuttack India) Lighted Retrospective	22	11	Unknown	Mixed benign/malignant	Rectopexy, APR, LAR, segmental colectomy (elective)	For difficult laparoscopic colorectal surgery	All 22/22	Bilateral 15/22, unilateral 7/22	0 injuries	N/A
Senagore [36] 1994 (Michigan) Lighted Retrospective	49	11	Stent group mean 60.4 years and 5.3 male:female, non-stented mean 57.9 years, 8:17 male:female Stented group (<i>n</i> = 1795)	Malignancy 8/49, diverticular 14/49, neoplastic polyps 16/49	Laparoscopic-assisted colonic resections	Surgeon discretion, generally complicated diverticular disease, previous pelvic surgery, obesity	24/49 lighted ureteral catheter	Bilateral	0 injuries Stents visible in 83%	N/A
Speicher [3] 2014 (National US) 2005–2011	42,311	11	Stented group (<i>n</i> = 1795)	Stented group: diverticular disease	Laparoscopic APR, LAR, and segmental colectomy	Not specified (National database)—surgeon/	Not specified	Not specified	Not assessed	N/A

Table 2 (continued)

Study	<i>n</i>	Downs and Black score	Demographics	Disease	Surgery	Indications for stent insertion	<i>N</i> with ureteric stents/catheters inserted	Unilateral vs bilateral stents	Outcomes: rate of ureteric injuries	Outcomes: recognition of ureteric injury
Type of stent not specified			mean 58 years, 50.2% female	56.1% malignancy, 26.2% IBD		centre practice/discretion				
Retrospective			Non-stented (<i>n</i> = 40,516)	Non-stented: malignancy 40%, diverticular 24%						
Tsujimaka [37]	313	12	Stented group (<i>n</i> = 149)	Stented group: 38.3% Crohn's, 31.5% diverticulitis, 10.7% malignancy	Laparoscopic colorectal, segmental colectomy or proctectomy in 77.9% of stented patients and 64.1% of non-stented patients	Not specified	149/313 stented	Bilateral attempted as routine	0/149 stented, 0/164 non-stented	N/A
Standard Retrospective			Mean 54.3 years, 52.3% male	Non-stented benign tumour (2.4%), Crohn's 20.7%, malignancy 16.5%						

Where not specified, emergency/elective breakdown was unclear

*No statistically significant difference in intraoperative detection rates of ureteric injuries between stented and non-stented patients

Primary outcome: ureteric injury

The incidence of ureteric injuries for open/minimally invasive/mixed cohorts is outlined in Tables 1, 2, and 3. Overall, pooled results identify iatrogenic ureteric injury in 1521/102,370 (1.49%) of patients undergoing colorectal procedures with prophylactic ureteric stents/catheters sited [3, 8, 18, 26–29, 31–42], and in 1333/767,233 (0.17%) of patients undergoing colorectal procedures without prophylactic ureteric catheters/stents [3, 8, 26, 27, 35–38, 40, 43]. Therefore, higher rates of iatrogenic ureteric injury were identified in the stented population, odds ratio 8.67 (95% CI 8.05–9.33, *p* < 0.0001). For purely open colorectal procedures, a ureteric injury rate of 1.75% (8/456) was calculated in patients with ureteric stents [18, 27, 32, 40] and of 0.67% (7/1042) in patients without ureteric stents [27, 40, 43]. For purely laparoscopic/robotic approaches, a ureteric injury rate of 0.35% (4/1143) was identified in patients with ureteric stents [26, 31, 33–36, 38, 39]. Two centres used prophylactic ureteric stents/catheters as routine in distal colorectal resections; one of these studied patients underwent laparoscopic distal colorectal resections only, meaning the entire population was stented irrespective of perceived complexity [31]. The ureteric injury rate was 1/89 (1.1%) in this study. No cases of iatrogenic ureteric injury was reported in the non-stented purely laparoscopic/robotic cohort identified (*n* = 725) [26, 35, 36, 38] (Table 2).

Ureteric injury—timing of recognition

Overall, of 16 ureteric injuries in patients with prophylactic ureteric stents, 10 were recognised intraoperatively (62.5%) [18, 27, 31, 32, 34, 38, 40, 44] (Table 4). Of 17 ureteric injuries in patients without ureteric stents, 9 (52.94%) were recognised intraoperatively [40, 43, 44]. This difference did not demonstrate statistical significance (chi-square statistic, 0.308; *p* = 0.579). Lack of data pertaining to timing of recognition of laparoscopically incurred injuries prevented analysis of timing of recognition related to surgical approach.

Success of prophylactic catheter insertion

Failure of insertion of prophylactic stent or catheter on at least one side was reported in 6 studies and documented in 46/616 patients (7.47%) [18, 26, 29, 31, 36, 40] (Table 5).

Complications of prophylactic ureteric stents/catheters

Complications of prophylactic ureteric stent/catheter insertion are outlined in Table 5.

Table 3 Primary outcome—rates of ureteric injury (mixed open/laparoscopic cohorts)

Study	n	Downs & Black Score	Demographics	Disease	Surgery	Indications for Stent Insertion	No. with Ureteric Stents/Catheters Inserted	Unilateral vs Bilateral Stents	Outcomes: Rate of Ureteric Injuries	Outcome: Recognition of Ureteric Injury
Chiu [8] 2017 (Yale, US National 2000–2013) Retrospective	811,071	11	46.2% male, 53.8% female Mean age 59.3 ± 0.06 years	Diverticular disease	Partial colectomy 93.1% Anterior resection 6.9% Laparoscopic in 35.3% (Elective in 82.5% of lap and 54.7% of open cases)	Unclear (surgeon discretion/centre practice)	97,025 with and 714,046 without (19.3% of laparoscopic vs 12.3% of open stented)	Not specified	With stent: 1495 = 1.5% Without stent: 1008 = 0.1%	Not specified
Coakley [3] 2018 (North Carolina, US National 2012–2014) Retrospective	51,125	11	Mean age 60.9 ± 14.9	Mixed benign/malignant	Colectomy of any code (proctectomy not included) (Elective)	Surgeon/centre preference (42.2% n = 1048) used in acute/chronic diverticular disease	2486 (4.9%)	Not specified	With stent: 14 (0.6%) Without stent: 316 (0.65%) MV analysis, lower rates of ureteric injury (OR 0.446, 95%)	Not specified
Chong [29] 2018 (Mount Sinai) Prospective observational	49	10	Mean age 46.28 (sequential placement of stent), 43 (simultaneous placement) Male 22:female 27	Mixed (predominantly 46/49 benign)	Colorectal surgery, primarily laparoscopic. Laparoscopic hemicolectomy most common 15/49	Not specified	All (49/49)	Not specified	0/49	N/A
Hassinger [38] 2018 (Virginia) Retrospective	2910	11	Stented group mean age 59 years (50, 1–68.6) 43.4% male Mean age 58.1 (17–88), male:female 44:55	Mixed	Any colon or rectal resection (Predominantly elective)	Surgeon discretion	129/2910 (4.6%)	Mixed: 57.4% (74/129) bilateral; 42.6% (55/129) unilateral	With stent: no injuries Without stent: 22/781 (0.07%) p = 0.76	Not assessed
Pathak [42] 2015 (Mayo Clinic Florida) Retrospective	99	11	Unknown	Unknown	Unknown	Unknown	All 999	Bilateral	0 injuries	N/A
Pokala [30] 2007 (Cleveland Clinic Florida) Prospective (Randomised sequential vs simultaneous insertion)	24	11	Mean age 45, M:F, 1:3 (n = 12) (simultaneous), Mean age 46, M:F, 1:1 (n = 12) (sequential) group	Mixed, IBD 16/24, rectal cancer 3/24, diverticulitis 2/24	Redo ileal pouch–anal anastomosis, ileal pouch excision, low-anterior resection with or without J-pouch, abdominoperineal excision/recto ileal resection and enteric fistula repair	Anticipation of difficult procedure: bulky rectal tumours, complex enteric fistulae, excision/redo ileal pouch, pelvic sepsis	All 24	Bilateral	0 injuries	N/A
Sheikh [43] 1990 (Pennsylvania) Retrospective	59	Case series—cannot apply	Unknown	Unknown	Colorectal procedures	Not specified	All 59	Not specified	Not specified	Not specified

Where not specified, the elective-emergency breakdown was unclear

*Where not possible to separate arms

Table 4 Type of repair and outcomes of ureteric injuries

Study	Injuries (n)	Stented and recognised intraoperatively	Stented and recognised postoperatively	Unstented and recognised intraoperatively	Unstented and recognised postoperatively
Bothwell [41] (open)	4/561	1/4—primary repair over stent	1/4 (stent insertion had failed)—nephrostomy + stent	1/4—stent inserted and repair performed	1/4 re-exploration and ureteroureterostomy
Beraldo [32] (laparoscopic)	1/89	1/89—repair technique not specified	—	—	—
Boyan [34] (laparoscopic)	None	—	—	—	—
Chahin [35]	1/66	—	1/66 recognised day 2, managed by retrograde stent reinsertion	—	—
Chiu [8]	2503/811,071	Not evaluated	—	—	—
Coakley [3]	333/51,125	Not evaluated	—	—	—
Chong [29]	None	—	—	—	—
Hassinger [38]	Not evaluated	—	—	—	—
Kutiyanawala [44]	5/251	No stented patients	No stented patients	3/5—ureteric re-implant × 2 and ureteroureterostomy over stent in × 1	2/5 Nephrostomy + JJ stent × 1 (prolonged recovery, fistula) Relaparotomy + removal of ligasure × 1
Kyzer [33]	1/118	1/1 repair technique not specified	—	—	—
Leff [19]	4/194	3/4 OPEN intraoperative repair	1/4—delayed presentation as ureteral-cutaneous fistula	Not evaluated	Not evaluated
Luks [39]	2/261	2/2 intraoperative repair, type unspecified	—	—	—
Merola [28]	1/374	None	1 injury, recognised postoperatively—re-operation (repair not specified)	None	None
Nam [27]	None	—	—	—	—
Pathak [42]	None	—	—	—	—
Palaniappa [45] 2012 (Open arm)	7/4669	1/7 Ureteroneocystostomy	1/7 Nephrostomy	3/7 Ureteroneocystostomy × 1, ureteroureterostomy × 2	2/7 Bilateral nephrostomies × 1 Ureteroureterostomy × 1
Palaniappa [45] 2012 (Laparoscopic arm)	7/1060	1/7 Ureteroureterostomy	1/7 Ureteroneocystostomy	2/7 Ureteroneocystostomy × 1 Ureteroureterostomy × 1	3/7 Ureteroneocystostomy × 1 Nephrostomy × 2
Pokala [30]	0	—	—	—	—
Sahoo [40]	0	—	—	—	—
Senagore [36]	0	—	—	—	—
Sheikh [43]	Not reported	—	—	—	—
Speicher [31]	Not reported	—	—	—	—
Tsujinaka [37]	0	—	—	—	—

Table 5 Complications of prophylactic ureteric stent insertion

Study	Haematuria	Urinary tract infection	Urosepsis/pyelonephritis	Failure of insertion	Ureteric injury secondary to instrumentation	Acute kidney injury	Transient ureteric obstruction	Hydro-nephrosis	Late ureteric stricture
Bothwell [41]	None reported	None reported	Unknown (not mentioned)	10/92 unilateral failure 2/92 bilateral failure	1/92	Not specified	None	Not specified	Not evaluated
Beraldo [32]	Transient 11/89 (12.3%)	2/89 (2.2%) treated oral antibiotics	None	2/89	None (0/89)	Not specified	Not specified	2/89 - 1 treated conservatively - 1 requiring stent	Not evaluated
Boyan [34]	Transient 465/465 (100%)	0/465	0/465	None reported	0/465	Not specified	Not specified	None reported	Not evaluated
Chahin [35]	Transient 65/66 (98.4%)	4/66 (6.1%)	Not specified	None reported	1/66	4/66	4/662—renal failure—temporary renal replacement therapy 2—conservative All resolved	Not discussed, presumed in transient ureteric obstruction patients	Not evaluated
Chiu [8]	Complications not assessed								
Coakley [3]	Not evaluated	3.5% (MV analysis stents not associated with increased rate)	No increase from without-stent group	Not evaluated	Not evaluated	Not evaluated	Not specified	Not evaluated	Not evaluated
Chong [29]	Reported as prolonged in 1/49	None reported	None reported	None	None 0/49	Not specified	Not specified	None reported	Not evaluated
Hassinger [38]	Not evaluated	Not evaluated	Not evaluated	Not evaluated	Not evaluated	32.6% AKI defined by Cr \times 1.5 preoperative, versus control 10.5% ($p < 0.0001$). Bilateral stents 41.9% vs 20% unilateral ($p < 0.0001$)	Not specified	Not evaluated	Not evaluated
Kyzyr [33]	Not reported	15/90 with data newly positive post op 16%	No cases	Not reported	None 0/90	Not specified, presumed the 3/118 with obstructive oligo/anuria	2/118 anuria, 1/118 oliguria following simultaneous removal bilateral catheters	Not specified, presumed the 3/118 with obstructive oligo/anuria	Not evaluated
Leff [19]	Not reported	15/126 (12%) of cultured patients positive postoperative urine cultures	No cases	2/194 (1%) bilateral failure, 16/194 (8.25%) uni- or bilateral failure of attempted insertion	None 0/194	Not reported	1/194 (0.52%)	Not reported	Not evaluated
Luks [39]	4/261 (1.5%)	20/261 (7.7%) vs 10/441 (2.3%) without stent, $p < 0.001$	Not specified	Not specified	Not specified	Not specified	Not specified	Not specified	Not evaluated
Merola [28]	Report higher rates of new onset urological complications in stented vs non-stented patients (IR 4.29, CI 1.83–10.06, $p < 0.001$); however, details are not specified			2/67 bilateral failure	None 0/67	Not specified	None	Not specified	Not evaluated
Nam [27]	No morbidity			1/67 unilateral failure					
Pathak [42]	Not reported	None	None	Not reported	1/99	4/99	2/99	3/99. Clot \times 1 and transient ureteric obstruction \times 2	Not evaluated
Palaniappa [45]	Not reported	Not reported	Not reported	Bilateral failure 1/24 (sequential group)	Not reported	Not reported	Not reported	Not reported	Not evaluated
Pokala [30]	Not reported	1/24	None	Unilateral failure 2/24 (1 simultaneous group, 1 sequential)	None 0/24	None	None	None reported	Not evaluated
Sahoo [40]	Not specified	1/22 (similar rate to non-stented)	None	None reported	None 0/22	None reported	None	None reported	Not evaluated

Table 5 (continued)

Study	Haematuria	Urinary tract infection	Urosepsis/pyelonephritis	Failure of insertion	Ureteric injury secondary to instrumentation	Acute kidney injury	Transient ureteric obstruction	Hydro-nephrosis	Late ureteric stricture
Senagore [36]	Not specified	Not specified	Not specified	None reported	None 0/49	None (0/49)	None (0/49)	Not reported	Not evaluated
Sheikh [43]	Not specified	Not specified	Not specified	Not specified	Not specified	3/59	3/59	3/59 (presumed)	Not evaluated
Spetcher [31]	Not specified	Not specified	37/1795 (2.1%)	Not specified	Not specified	14/1795 (0.8%) renal insufficiency	Not specified	Not specified	Not evaluated
Tsujimaka [37]	Not specified	3 (2%)—not higher than control	Not specified	7 (4.7%) unilateral failure, 1 (0.7%) bilateral failure	None 0/149	3/1795 (0.2%) renal failure*	Not specified	Not specified	Not evaluated

Haematuria

Transient haematuria is reported in up to 100% of patients with prophylactic stents [33] (Table 5). Rates were not commented on in many studies.

Urinary tract infection

Where reported (10 studies), urinary tract infection occurred in 148/3779 (3.92%) patients with prophylactic stents, with individual studies reporting rates of 0–16% [3, 18, 29–34, 38, 41] (Table 5). Four studies, two using multivariate regression analysis, compared this rate to non-stented controls and found no statistically significant difference [3, 30, 36, 39]. One study, on adjusted analysis, did find a statistically significant increase in urinary tract infections (20/261 (7.7%) with stents versus 10/441 (2.3%) without stents, $p < 0.001$) [38].

Pyelonephritis

Where explicitly stated in patients with prophylactic stents/catheters (pooled $n = 869$), pyelonephritis occurred in none (Table 5). Pyelonephritis/sepsis was not, however, specified in the remaining studies and it is not possible from the data to ascertain if included under ‘urinary tract infection’.

Ureteric injury due to attempted stent placement

Where clearly specified or clarified by the authors (study $n = 14$), iatrogenic ureteric injury as a result of ureteric instrumentation during attempted stent placement occurred in 2/1716 (0.12%) [18, 26, 28, 29, 31–36, 38–41] (Table 5).

Renal impairment

Rates of acute kidney injury or renal failure were explicitly stated in 6 studies, and reported in 67 of 2197 cases (3.05%) [30, 34, 35, 37, 41, 42] (Table 5).

Transient ureteric obstruction

Where discussed, a rate of transient ureteric obstruction following stent removal (termed ‘reflex anuria’ by some authors) of 1.95% (13/666) was reported with the use of prophylactic ureteric stents. Individual studies reported rates ranging from 0% [26, 35, 39, 40] to 6.06% [34] (Table 5). All 13 cases of transient ureteric obstruction were associated with use of bilateral prophylactic stents. In 12/13 cases, stents were removed simultaneously immediately postoperatively or on the first postoperative day. Of these patients, 8/13 returned to theatre for attempted reinsertion of ureteric stents and 2/13 had a period of renal replacement therapy. No incidence of long-term renal impairment was identified.

Urinary retention

A rate of urinary retention of 23/663 (3.5%) was noted from pooled results of three studies [28, 33, 36], not significantly higher than controls [36] or expected local rates [33] (Table 5).

Late ureteric stricture

No follow-up strategy allowed evaluation of late-onset complications such as ureteric strictures.

Cost and time

The cost and timing implications associated with stenting are outlined in Table 6. Variable additional costs are ascribed to the use of prophylactic stents. The most costly stents/catheters employed are illuminated ureteric catheters, reported at \$167–\$236.80 per catheter [33, 34]. Taking all factors into the equation, such as purchase of stents/catheters, cystoscopy and other equipment needs, and estimated cost of the urologist's time, US studies have reported mean additional expenses of \$1504.32–\$2000, for standard or lighted ureteric stent/catheter insertion [8, 34, 40]. A German study, estimated lower total additional costs of €410 for bilateral stent insertion [31]. An Indian study [39], and a US study of lighted stents [35] calculating overall operating room charges, reported these to be similar whether or not prophylactic stents were used. One study assessed the overall hospital costs of colorectal patients in whom prophylactic ureteric stents were used and estimated them to be \$7538 greater than those in non-stented patients [37].

The mean time reported for the insertion of bilateral prophylactic ureteric stents/catheters ranged 8–22 min [29, 31–33]. The average overall time for stent insertion and repositioning and redraping of the patient as necessary ranges 10–31.53 min [[18, 26, 34], [28, 33]], with figures on the lower end of this scale reported where the colorectal case is beginning in the lithotomy position, abolishing the need for repositioning [18]. Time savings are demonstrated when stent insertion is performed simultaneously with commencement of the colorectal procedure [28, 29]. Several studies reported on the overall operating time increase in cases where prophylactic stents were used, and reported average total increases between 15 and 69.3 min [3, 27, 30, 35–37, 39].

Discussion

Use of ureteric stents

Prophylactic ureteric stents are generally used at the discretion of the colorectal surgeon. Some geographical variation likely exists, Chiu et al. [8], in a US national series, noted differing

patterns of prophylactic stent use across the USA. This was postulated due to differing training practices, and possibly a 'defensive' approach of colorectal surgeons—rates of preoperative ureteric stent placement were noted to be highest in Northeast USA, where population-adjusted medical-malpractice rates are highest [8]. Certainly, 'failing to place temporary ureteral stents before performing the surgery' has been quoted by legal representation as grounds for negligence in the situation of iatrogenic ureteric injury during a colorectal resection [45]. Presumably, the availability of a urologist also plays a role. Whilst centralisation of cancer care in many countries means elective colorectal cancer cases are likely to take place in large centres with diverse specialties, emergency colorectal cases may not.

Ureteric injury

The data demonstrates an overall low rate of IUI. Pooled results demonstrate a higher rate of IUI in patients with prophylactic ureteric stents in situ (1.49% versus 0.17% of patients without them). Several possible explanations underlie this, including surgeons potentially being overly reassured by the presence of stents and being less meticulous in conduction of dissection. We feel, however, it is more likely due to a strong selection bias, with stents generally used at surgeon discretion, presumably on anticipation of a challenging resection. As such, the use of ureteric stents likely serves as a proxy marker of a difficult, high-risk colorectal procedure. This opinion is admittedly not supported by the findings of a 1.1% (1/89) IUI rate in the only study that attempted stent insertion routinely in the study cohort [31]. This was, however, by nature a somewhat high-risk cohort as only distal colorectal resections were included, and the injury rate is similar to the 1% IUI rate in laparoscopic resections for rectal cancer in a large Danish study [5]. In this review, the overall rate of IUI in minimally invasive surgery appears lower than that in open procedures, which is inconsistent with the literature [1, 5, 11]. It is also inconsistent with the findings of an included study that was discussed with regard to recognition and outcomes of ureteric injuries but excluded from the analysis of IUI incidence due to inability to assess which patients had ureteric stents [44]. We would be mindful in interpretation that analysis of the rates of IUI in laparoscopic versus open surgery was not an intended outcome measure, and that rates may be skewed by selection bias of studies meeting the inclusion criteria.

Data was interpreted on an intention-to-treat (intention-to-stent) basis as this was thought more reflective of everyday practice, and ensured that iatrogenic injuries from attempted stent placement itself would be included in the 'stented' group even if insertion failed.

Limitations of reporting included a lack of consistent clarity regarding the laterality of the injured ureter in cases of unilateral stenting cases, emergency versus elective cases,

Table 6 Stent type, timing of insertion/removal and cost analysis

Study	Type of stent/catheter	Inserted by	Timing of insertion	Timing of removal	Cost estimate of stent insertion	Additional time due stent insertion
Bothwell [41]	Catheter, not specified	Urologist	Start of operation	Staged: 1 removed postoperatively, 1 on day 1	>\$2000 all factors included	Unknown
Beraldo [32]	Ureterschiene, Polyamid, Coloplast GmbH	Urologist	Post induction of anaesthesia	Immediately postoperatively	€€ 410 bilateral, all factors included	Mean 16 min (7–35) unilateral, 22 min (10–30) bilateral
Boyan [34]	Size 5 Fr lighted LED stents	Urologist	Post induction of anaesthesia	Immediately postoperatively (pre-extubation)	\$167.01 for illuminated stent, additional costs not calculated	Mean 8 min for stent insertion, 28 min including redraping
Chahin [35]	Polyurethane Bard 6 lighted ureteral catheter	Urologist	Not specified	Immediately postoperatively	\$1504.32 (stents \$236.80 each)	Mean 26 min total added
Chiu [8]	Not specified (mix—national study)	Not specified	Not specified	Not specified	\$1983 estimate	Not specified
Coakley [3]	Not specified (mix—national study)	Not specified	Not specified	Not specified	Not specified	Operative time mean 69.3 min longer with stents
Chong [29]	5 or 6 Fr whistle tip catheters	Urology resident	Post induction of anaesthesia	Not specified	Not calculated	Mean 31.53 min from 'anaesthetic ready' to commencing colorectal procedure in sequential group. Simultaneous insertion of catheters and abdominal incision = 11.82 min saving ($p = 0.005$) between catheter insertion and start time
Hassinger [38]	6Fr straight temporary ureteral stent	Urologist	Following induction of anaesthesia	At completion of the surgical case	Estimated mean \$7538 extra total hospital costs in stent group	Not assessed
Kyzer [33]	Size 5Fr Bard ureteral catheters in 91% (86/118), remainder size 4-8Fr Bard	Not specified	Following induction of anaesthesia, or under local anaesthesia a few hours pre procedure	Unilateral catheters—removed immediately post op Bilateral—majority removed simultaneously (64/71), 7/71 removed in staged fashion	Not calculated	Mean 23 min (10–55)
Leff [19]	Size 5Fr Bard ureteral catheters	Urologist	Following induction of anaesthesia	Initially at completion of surgical case, practice changed to staged removal over 24 h during course of study	Not evaluated	Estimated 10 min (left colon and rectal procedures started in lithotomy—no repositioning)
Luks [39]	Not specified	Not reported	Not reported	Typically (>95%) removed on first postoperative day	Not evaluated	Mean 15 min additional operative time
Merola [28]	Stents, not specified	Not reported	Not reported	Not reported	Not evaluated	Mean 55 min longer procedure time overall ($p = 0.16$), stent insertion not timed specifically
Nam [27]	5Fr ureteric catheters	Urologist	Post induction of anaesthesia	Immediately post colorectal procedure	Not reported	Mean 11.35 min extra to procedure time
Pathak [42]	5Fr ×70cm TigerTail (Bard) localization stents*	Resident under supervision of staff surgeon (specialty not specified)	In the colorectal theatre	Generally immediately post-procedure but discretion of CR surgeon	Not reported	Not reported
Palaniappa [45]	Stents, not specified	Not reported	Not reported	Not reported	Not reported	Not reported

Table 6 (continued)

Study	Type of stent/catheter	Inserted by	Timing of insertion	Timing of removal	Cost estimate of stent insertion	Additional time due stent insertion
Pokala [30]	Stents, not specified	Sequential: resident urologist. Simultaneous: 1 by staff urologist, 2nd by resident	Sequential: after induction of anaesthesia prior to colorectal procedure Simultaneous: simultaneously with commencement of colorectal procedure	Not reported	Not reported	Catheter insertion time sequential group mean 17.6, simultaneous group mean 17.9 min Induction to entry to abdominal cavity time reduced in simultaneous group by mean 19 min $p = 0.0001$
Sahoo [40]	Size 5Fr lighted ureteric catheters	Urologist	After induction of anaesthesia	Immediately post-procedure	Not specified (overall cost similar to no stents)	Overall operative time increased by 20 ± 5 min
Senagore [36]	7Fr Cook lighted ureteral catheter and 6Fr Rousch lighted ureteral catheter	Not specified	Immediately pre-procedure?	Immediately post-procedure	Overall costs estimated similar between groups	Mean 24 ± 7.2 min Overall operative time increased (with catheter mean 192 ± 11.3 min, without catheter 161.4 ± 9.5 min) Not assessed
Sheikh [43]	5Fr ureteral catheters	Not specified	Not specified	Of 3 cases of transient ureteric obstruction studied: removed in recovery room in 2 patients, removed staged over 24 h in 1	Not assessed	Not assessed
Speicher [31]	Stents Not specified	Not specified	Not specified	Not specified	Not specified	Median 44-min increase in operative time with stents
Tsujinaka [37]	Ureteric catheters not specified	Staff urologist	After induction of anaesthesia	Immediately post colorectal procedure	Not specified	Overall procedure time longer in catheter group (200.2 ± 72 min) versus control (147.2 ± 69.8) $p = 0.0001$

*Routinely placed without a guidewire or fluoroscopy

and rates of laparoscopic converted to open cases. Furthermore, in laparoscopic surgery, reduced tactile feedback may increase the need to visualise stents for them to serve a purpose [46], and most studies do not report on whether visualisation was achieved. A further limitation is that certain ureteric injuries, particularly devascularisation and thermal injuries may not have been identified peri-operatively, and any role of stenting in their prevention is unknown.

Timing of recognition

Data shows a possible trend towards increased intraoperative recognition of IUIs in patients with ureteric stents in situ (62.5%) versus those without (52.94%); however, this failed to demonstrate statistical significance. It should be noted that numbers of ureteric injuries with enough data to analyse this endpoint were low ($n = 33$), and we would stress the need for large-scale prospective data collection to clarify this question. We also acknowledge that injuries presenting very late, for example devascularisation injuries with late ureteric stricture formation, were unlikely captured in the studies evaluated, and it is impossible to draw conclusions as to the role of stenting in prevention or detection of these.

Complications

Complications of prophylactic ureteric stent placement were low overall. Heterogeneity in reporting of complications was recognised, and it is possible that under-reporting existed. Haematuria was not reported by many authors, perhaps due to its acceptance as a known complication, thought insignificant when ‘its presence [does] not deviate from the normal post-operative course’ [41]. Urinary tract infection occurred in 3.92% of patients with stents. This rate was similar to controls where evaluated in 4 studies, although higher than controls in 1 study. It is similar to the identified overall rate of 3.7% (1764/47,781) of urinary tract infection following colorectal cancer surgery in a study of the American College of Surgeons National Surgical Quality Improvement Program [47]. The use of a urinary catheter, typically employed following major abdominal surgery whether or not stents are used, has been proposed as a key variable in this equation [48]. There was a lack of conformity in studies regarding diagnostic criteria for urinary tract infection. No incidence of pyelonephritis was described, but it is unclear if this were evaluated as distinct from ‘UTIs’ in most studies. Furthermore, the choice and timing of perioperative antibiotics was not consistently reported. The approach to reporting of acute kidney injury (AKI) also varies throughout the literature. Whilst some authors had a clear definition, for example a serum creatinine ≥ 1.5 times the preoperative level [37], and others differentiated between ‘renal insufficiency’ and ‘renal failure’ [30], this was not uniform, and rates of milder renal impairment may be underreported. It is

noteworthy that a previous systematic review has identified overall rates of AKI of approximately 13% following major abdominal surgery [49]. Transient ureteric obstruction following stent removal is sometimes termed ‘reflex anuria’, and defined as ‘cessation of urine output from both kidneys in response to irritation or trauma to one kidney or its ureter, or severely painful stimuli to the other organs’ [50]. This is an uncommon but significantly morbid complication associated with ureteric stenting. As all cases described involved the use of bilateral ureteric stenting, and the vast majority involved simultaneous removal of stents, potential approaches to minimise its incidence include unilateral stenting where only one ureter is believed to be at increased risk of injury, and staggered removal of the ureteric stents. Further research is required to conclude benefit of these strategies.

A thought-provoking finding of this review was the 0.12% ureteric injury rate identified with attempted prophylactic stent placement from the pooled results of 14 studies. Although low, it is quite similar to the 0.17% ureteric injury rate apparent in non-stented patients. Both cases of IUI from stent placement (2/1716) involved initial cystoscopic catheter placement without the use of guidewires or fluoroscopy, which are postulated to potentially increase safety [41] and/or success rates, although with limited evidence in this context. Furthermore, arguably, IUI incurred during attempted stent placement may be easier to identify and address immediately with retrograde uretero-pyelography, than IUI sustained during a colorectal procedure. Nonetheless, it is an uncomfortable thought that a planned prophylactic intervention may result in the very complication it is intended to prevent, particularly when the incidence appears comparable. We feel this is a compelling argument against the routine insertion of prophylactic ureteric stents, and serves as a reminder to evaluate the risk–benefit equation on a case-by-case basis. Our results suggest that colorectal resections in the presence of specific patient- and/or disease-related risk factors likely have an IUI rate in excess of 1%, and we believe that in this patient cohort, judicious use of prophylactic ureteric stents may be justified. In cases where only one ureter, most frequently the left, is deemed at increased risk, we advocate stenting only on this side, to minimise unnecessary instrumentation.

The failure rate of stent placement in at least one ureter of 7.47% is noteworthy. Possibly, this rate reflects altered ureteric anatomy in the setting of factors making stenting desirable, such as prior radiotherapy or bulky pelvic tumours. It is important for urologists and colorectal surgeons to acknowledge the possibility of failed stent placement preoperatively, and to discuss this with patients during the consent process.

Cost and time

Cost estimates vary significantly, likely related to healthcare systems and local agreements. A large variable is the cost of

service of the attending urologist, who may bill for this service specifically versus covering it amongst general duties whilst on site at a state-funded hospital. Reports of markedly increased overall operative time and overall hospital costs are likely confounded by the increased clinical complexity of patients receiving prophylactic ureteric stents.

Future direction

Certainly, further evidence is needed to draw strong conclusions on the role of prophylactic ureteric stents. Whilst a randomised controlled trial in this area may be unfeasible, multi-institution detailed data collection in prospectively maintained databases would allow further evaluation, including more stringent retrospective case-control analysis. In this minimally invasive era, variables reported must include whether and by what means stents were identified intraoperatively to further characterise their role. Lighted ureteric stents offer an interesting and potentially effective means of ureteric identification during laparoscopic/robotic-assisted procedures. They are, however, more costly, and an early *ex vivo* study showed variable luminance of the distal ureter between models [51]. More evidence is required to confirm a benefit of lighted stents and to clarify reliability of *in vivo* visualisation. An alternative emerging novel technique is the use of systemically administered dye that can be visualised by fluorescence under a specific light source intraoperatively as it is renally excreted and travels down the ureter. Successful ureteric identification has been demonstrated in *ex vivo* porcine models (using IRDye800CW-CA) [52] and rat models (using sodium fluorescein) [53]. More recent years have shown potential efficacy of this technique in small human studies with the use of methylene blue [54, 55]. Whilst a much greater body of evidence is needed in relation to this application of dye, incorporating both surgeons' subjective assessment of intraoperative utility and objective outcomes, this may appear on the horizon as a useful, and possibly even safer, alternative to stenting.

Conclusions

The placement of prophylactic ureteric stents has a low complication rate, which may be further improved by the use of guidewires and fluoroscopy in stent/catheter insertion and sequential removal of stents, although further research is needed to confirm this. It should be noted that the IUI rate from attempted stent insertion is low but not negligible, and this must be factored into the risk–benefit equation when determining if a stent is warranted. Prophylactic ureteric stents do not entirely prevent ureteric injuries, and in fact, higher rates of IUI are reported in stented versus non-stented patients. In the absence of a randomised controlled trial, however, this is

assumed due to a marked selection bias, with stents being requested at surgeon discretion for anticipated high-risk resections. Prophylactic ureteric stents may improve intraoperative detection of ureteric injuries; however, current evidence is inadequate to confirm this. The medico-legal climate may be a future driver for increased stent use, albeit with limited evidence. Small to moderate increases in cost and operative time are seen with the use of prophylactic stents. The authors feel that selected rather than routine stenting along with careful dissection and a high index of suspicion minimises reoperation for inadvertent ureteric injury. Future developments may see greater use of novel technologies including lighted ureteric stents and fluorescent dye for ureteric identification, particularly in minimally invasive cases.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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