Considerations in ureteral stent selection in order to minimize symptoms

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RAMKUMAR RR, VEREECKEN S, WILLIAMS T, DE S. Considerations in ureteral stent selection in order to minimize symptoms. *Can J Urol* 2022;29(4): 11231-11242.

Introduction: *Ureteral stent-related symptoms are common after stent placement. Various characteristics of stent design have been previously investigated to mitigate this issue. Our review summarizes available literature on stent design parameters (diameter, material, position, length, distal loop modifications) and their effect on stent-related symptoms, including pain.*

Materials and methods: *We identified articles from PubMed, Medline, EMBASE, Web of Science, and Grey Literature using a search strategy employing MESH search headings (i.e, ureteral stent diameter, length, composition, material, durometer, and stent-related pain).*

Results: *Out of 2,970 identified studies, 26 met eligibility criteria. Most diameter studies found patients with > 6Fr stents reported significantly increased stent-related symptoms. A few did report more migration with thinner stents. Almost half of durometer studies found composition made no difference in symptoms. Distal loop modification studies found minimizing intravesical material decreased stent-related pain. All studies on positioning found patients reported more severe urinary, pain and quality of life symptoms when stents crossed the bladder midline. No difference in stent-related symptoms was seen between multi-length and standard stents patients.*

Conclusion: *Adverse symptoms occur commonly after ureteral stent placement. No definitive recommendations on the model stent can be provided due to the heterogeneity of studies. Though the number of robust studies is limited, data suggest stents crossing midline, larger diameters, and those without distal material-reduction modifications may worsen stent-related symptoms. Future studies are needed to better understand the ideal stent design.*

Key Words: ureteral stent, stent diameter, durometer, multi-length, USSQ, stent pain

Introduction

The lifetime prevalence of kidney stones is 10%-12% according to the most recent National Health and Nutrition Examination Survey, and more than 20% of stone formers require surgical intervention for stone management.[1,2] This includes extracorporeal shockwave lithotripsy, ureteroscopy, percutaneous nephrolithotomy, or laparoscopic or open surgery. Of these, ureteroscopy is the most common accounting for 63% of annual stone procedures in the United States, or roughly 92,000 surgeries in 2017 alone.[1] Though ureteroscopy is a widely used minimally invasive intervention, it is not without risks. A well-known adverse effect of ureteroscopy with stent placement is stent-related discomfort, with more than 80% of patients reporting bothersome symptoms or pain in some studies.[3,4] Unsurprisingly, these symptoms contribute to a poor quality of life (QoL), which almost always recovers after stent removal.[4]

Accepted for publication May 2022

Acknowledgement
We thank Dr. Anna Zampini for her critical review of our paper.

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Considerable literature has been published with recommendations on minimizing stent-related symptoms. Medical treatment typically consists of alpha-receptor antagonists (tamsulosin or alfuzosin), which can be used alone or in combination with antimuscarinics (oxybutynin, solifenacin, tolterodine) or nonsteroidal anti-inflammatory drugs (ketorolac).[5-8] Other medications such as belladonna and opium suppositories and phenazopyridine have been used successfully in practice though trials did not demonstrate significant differences in reducing stent-related pain.[9,10]

Active areas of investigation seek to understand how stent-related pain can be prevented rather than treated. While symptoms are likely multifactorial and may include patient and operative factors, several trials have been published recently that have sought to optimize stent design. Relevant variables include stent diameter, composition, distal loop modifications, length, and position. Here, we review the literature on trials comparing various characteristics of stent design and their effect on patients' symptoms.

Materials and methods

Search strategy

A systematic search of PubMed, Medline, Embase, Web of Science, and Grey Literature databases was conducted to identify all studies published in English that compared different ureteral stent designs. We did not include unpublished studies as there was not sufficient access to data to see if they met inclusion

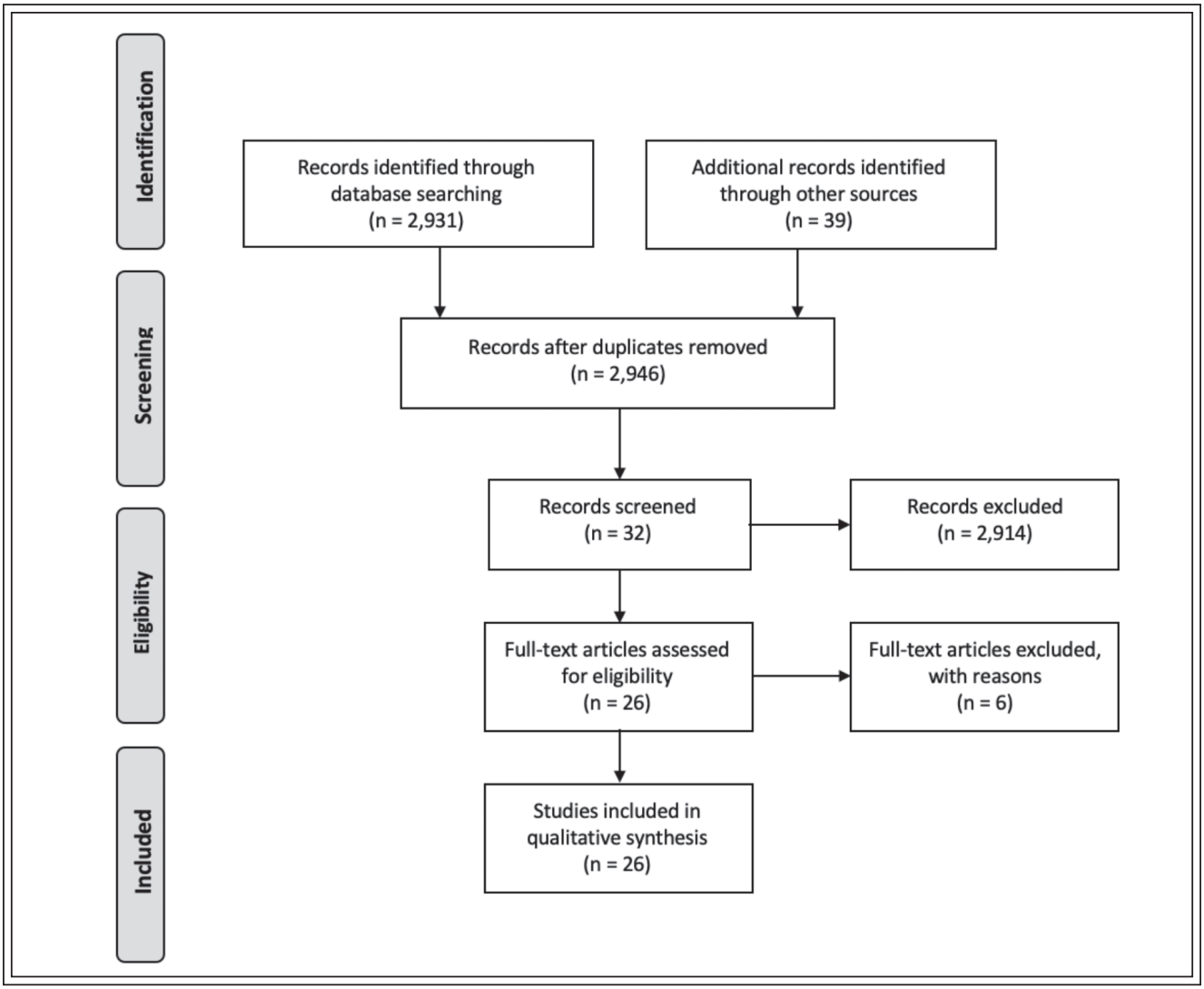

Figure 1. Search strategy flow diagram.

criteria. Searches included studies from 1997 to December 2020. This narrative literature review was performed with reference to PRISMA guidelines. The following MESH search headings were used: ([ureteral stent diameter OR length OR composition OR material OR durometer; ureteral stent; urinary symptoms] AND ([stents] OR adverse effects OR [ureter] OR [stent-related pain] OR [pain]). Results were limited to full-text availability and duplicate records were removed. Reference lists and related articles from retrieved documents were also searched. Computer searches were supplemented with a manual search. An independent screening of all citations and abstracts were selected by the search strategy to identify potentially eligible studies. Figure 1 shows a flow diagram that details the main steps of the search phase.

Eligibility criteria

Study inclusion criteria were as follows: 1) adult patients requiring a ureteral stent related to ureteroscopy for stone disease 2) comparison of at least one factor of stent design (length, diameter, position, durometer, composition, and/or distal loop modification), and 3) report of at least one outcome of interest including Ureteral Stent Symptom Questionnaire (USSQ), Overactive Bladder Symptom Score (OABSS), International Prostate Symptom Score (IPSS), irritative urinary symptoms, mean pain score, visual analog scale, mean irritation score, hematuria, flank pain, quality of life (QoL), and related data.

Studies were excluded if they involved ureteral stricture disease, extrinsic ureteral obstruction, the pediatric population, endopyelotomy, or cancer given stents may fail in many of these patient populations, there may be confounding effects from the underlying disorder (i.e. cancer-related pain) and specific stent types are often indicated (i.e. a softer, thinner stent is likely not appropriate after an endopyelotomy).

Data extraction and outcomes of interest

Two reviewers independently retrieved the following data from articles: first author, publication year, country of interest, study population and design, number of patients, and outcome(s) of interest. Any disagreement between both reviewers of a study's eligibility was initially resolved after a discussion and then by involvement of a third reviewer. The following additional outcomes were also collected if available: mean indwelling stent time, unscheduled removal, stent migration, urinary tract infection (UTI) rate, auxiliary procedure, readmission, stone-free-rates, and any other related complications.

Results

Through our database searches, we retrieved 2,931 records. A total of 2,970 studies were identified from the literature search and narrowed to 32 studies after screening. Six of these were excluded as ureteral stent placement was performed for a cause other than related to ureteroscopy, Figure 1. Studies included (n = 26) were further reviewed and separated based on the area of stent design investigated in the study. Areas of ureteral stent design included diameter, length, position, composition, and distal loop modifications. Tables 1-4 summarize these findings.

Stent diameter

One of the first studies to explore the effect of stent diameter on patient-reported stent outcomes was Candela et al in 1997. Sixty patients were randomized to receive a 4.8Fr or 6Fr stent. No significant differences were found in any of the irritative voiding symptoms, including dysuria, urgency, frequency, nocturia, hematuria, pain, or incontinence.[11] A few years later, Erturk et al randomized 46 post ureteroscopy patients to 4.7Fr or 7Fr ureteral stents, or no ureteral stent. Patients with the 7Fr stent reported higher pain and irritative voiding scores compared to the smaller diameter stent; however, the 4.7Fr stents tended to migrate distally and dislodge more frequently than the 7Fr stents (32% vs. 10%, $p = 0.19$).[12] In a similar study, Damiano et al randomized 55 patients to either 4.8Fr or 6Fr stents, versus no ureteral stent. The study found no significant difference in QoL between the 4.8Fr and the 6Fr stent groups. The smaller diameter stent group also had a higher percentage of stent migration (23.5% vs. 10%), similar to the Erturk study.[13] Since then, new validated measurement tools, such as the USSQ, IPSS, and OABSS, have been developed. Most applicable to this review is the USSQ, a stent-specific QoL questionnaire, developed by Joshi et al in 2003. In this study, a total of 309 patients participated in various study phases from interviews and drafting the new questionnaires to field testing and validation. The final result was a 38-item questionnaire covering six domains of health affected by ureteral stents (urinary symptoms, pain, work performance, general health, sexual matters, and additional problems) that had discriminative capability between healthy controls and also patients with urinary calculi without stents.[14]

Three recent studies reported the USSQ as an outcome measure. One study that did not use the USSQ was a randomized controlled trial by Prasanchiamontri et al where 60 patients received either a 4.8Fr or 6Fr ureteral stent. No significant difference was found

TABLE 1. **Comparing stent diameter studies**

Author/year	Study design	Intervention	Outcomes measured	Results	Conflict of interest
Candela et al, US, 1997	RCT	6Fr stent without hydrogel (n = 20) 6Fr hydrogel stent (n = 20) 4.8Fr hydrogel stent (n = 20) Total n = 60	Flank pain, hematuria, dysuria, urgency	No statistically significant results	Unknown
Erturk et al, US, 2003	RCT	4.7Fr stent (n = 24) 6Fr stent (n = 23) Total n = 46	Flank pain, irritative symptoms, migration	No statistically significant results	Unknown
Damiano et al, Italy, 2005	RCT	No stent (n = 21) 4.7Fr stent (n = 17) 6Fr stent (n = 17) Total n = 55	QoL, VPAS, migration	No statistically significant results between different diameter stents	No
Prasanchaimontri et al, Thailand 2017	RCT	No stent (n = 20) 4.7Fr stent (n = 20) 6Fr stent (n = 20) Total n = 60	OABSS, flank pain, hematuria, febrile UTI, asymptomatic pyuria, post operative mean pain score, post operative analgesic use	No statistically significant results between different diameter stents	No
Cubuk et al, Turkey, 2018	RCT	No stent (n = 62) 4.8Fr stent (n = 63) 6Fr stent (n = 63) Total n = 188	USSQ, migration, post operative analgesic use	Significantly lower total USSQ scores in 4.8Fr over 6Fr ureteral stent group after procedure with indwelling stent ($p = 0.01$) and after stent removal ($p = 0.010$). Significantly increased improvement in sexual dysfunction domain of USSQ for 6Fr vs. 4.8Fr stent group after stent removal ($p < 0.001$)	No
Nestler et al, Germany, 2019	RCT	4.7Fr stent (n = 48) 6Fr stent (n = 66) 7Fr stent (n = 67) Total n = 181	USSQ domains (urinary, work performance, general health), febrile UTIs, antibiotic use, readmission, surgical success of second ureteroscopy	Significantly improved "urinary index score" ($p < 0.001$), "pain index score" ($p = 0.03$), "general health index" ($p = 0.01$) and "work performance score" ($p < 0.001$) with 4.7Fr vs. 7Fr ureteral stent group. Significantly improved "work performance score" ($p = 0.04$) with 6Fr vs. 7Fr stent	No

TABLE 1 (Cont'd). **Comparing stent diameter studies**

Author/year	Study design	Intervention	Outcomes measured	Results	Conflict of interest
Taguchi et al, Japan, 2019	RN-R	4.7Fr stent (n = 17) 6Fr stent (n = 54) Total n = 71	OABSS, IPSS	Significantly lower OABSS score with 4.7Fr vs. 6Fr ureteral stent (p = 0.045), including urgency subscore (p = 0.002). Significantly higher IPSS score with 6Fr vs. 4.7Fr stents (p = 0.02) including more intermittency (p = 0.009), urgency (p = 0.008), voiding symptoms (p = 0.046), and storage symptom (p = 0.017). Multivariate analysis showed that increasing stent diameter was significantly associated with total IPSS (p = 0.007) and OABSS (p = 0.036)	No
Kim et al, Korea, 2020	RCT	5Fr stent (n = 55) 6Fr stent (n = 55) Total n = 110	USSQ domains (urinary symptom score, body pain), analgesic use	Significantly lower urinary symptoms score in USSQ with 5Fr over 6Fr stent group (p = 0.014)	No

RCT = randomized controlled trial; RN-R = retrospective non-randomized; USSQ = Ureteral Stent Symptom Questionnaire; VPAS = Visual Pain Analog Scale; QoL = quality of life; IPSS = International Prostate Symptom Score

for OABSS, flank pain, asymptomatic pyuria, febrile UTI, hematuria, or stone free rates.[15] The other was a retrospective study by Taguchi et al, which did report significantly worse OABSS and IPSS for the 6Fr compared to the 4.7Fr stent (p = 0.045).[16]

The three studies that used the USSQ all reported statistically significant results favoring the use of smaller diameter stents. Cubuk et al compared patients with 4.8Fr vs. 6Fr vs. no stent, just as was done in the earlier Damiano et al study. Patients with 6Fr stents had significantly higher total USSQ scores when compared to the 4.8Fr group (p = 0.01).[17] This is in contrast to the Damiano et al study where no difference between groups was found. Nestler et al found statistical significance in the work performance and urinary index scores of the USSQ giving preference to the use of the 4.8Fr stents.[18] Unlike previous studies, the rate of stent migration in the 4.8Fr group was low, 4.2% vs. 1.5% in the 7Fr group. Kim et al found that patients randomized to the 5Fr stent group had fewer urinary symptoms compared to those with a 6Fr stent (p = 0.014) though other sections of the USSQ (body pain, general health, work performance score) did not show statistical significance.[19]

In summary, seven of the eight studies that looked at stent diameter were randomized controlled trials. There was considerable heterogeneity in outcomes investigated. These included the USSQ, OABSS, IPSS, QoL, flank pain, hematuria, dysuria, urgency, irritative symptoms, febrile UTIs, asymptomatic UTIs, use of antibiotics, readmissions, and stent dislodgement. More than half of studies (5 of 8) reported significant differences between stent diameter in at least one of the listed domains, but less than half (3 of 8) showed significant results among studies for the same outcome. Overall, most studies found smaller stents (4.7Fr, 4.8Fr,

TABLE 2. **Comparing stent diameter studies**

Author/year	Study design	Intervention	Outcomes measured	Results	Conflict of interest
Pryor et al, US, 1991	PN-R	Four different durometer stents: 98A, 91A, 90A, 65A Total n = 72	Urinary symptoms, pain	No statistically significant results	Unknown
Lennon et al, Ireland, 1995	RCT	Firm polyurethane stent (n = 78) Softer stent (n = 77) Total n = 155	Positional stability, degree of bladder inflammation, stent encrustation, patient tolerance, dysuria, renal pain, suprapubic pain	Significantly higher incidence of dysuria, renal, and suprapubic pain with firmer stent ($p < 0.01$)	Unknown
Joshi et al, UK, 2005	RCT	Firm stents (> 64A) (n = 61) Softer stents (64A) (n = 55) Total n = 116	USSQ	No statistically significant results	No
Davenport et al, UK 2011	RCT	Proprietary composition (firm material that softens with temperature((n = 45) Dual durometer stent (firm shaft, soft tail) (n = 53) Total n = 98	USSQ, readmission, antibiotic use, dysuria, hematuria	No statistically significant results	No
Lee et al, Korea, 2015	RCT	Firm stent (n = 30) Less firm stent (n = 30) Dual durometer stent (n = 30) Total n = 90	OABSS, QoL, IPSS, flank pain, lower abdominal pain, urethral pain, gross hematuria	Significantly increased IPSS (13.03, 11.5, 7.2, $p = 0.008$), flank pain (4.03, 2.77, 2.63, $p < 0.001$), lower abdominal pain (3.12, 2.48, 2.03, $p < 0.001$), urethral pain (3.21, 2.63, 2.07, $p = 0.001$), and gross hematuria (73%, 46%, 36%, $p = 0.013$) for firm stent > less firm > dual durometer stent respectively	No
Park et al, Korea, 2015	RCT	Softer tail stent (n = 64) Firm tail polyurethrane stent (n = 80) Total n = 128	USSQ domains, VPAS, antibiotic use, UTIs, readmission, outpatient visit due to discomfort	Significantly increased scores for specific questions on USSQ domains including presence of pain ($p = 0.000$), frequency of painkiller use ($p = 0.035$), difficulties with hard physical activity ($p = 0.030$), fatigue ($p = 0.037$), antibiotic use ($p = 0.031$) and outpatient visits for discomfort ($p = 0.036$) with the firmer tail stent group	No

TABLE 2 (Cont'd). **Comparing stent diameter studies**

Author/year	Study design	Intervention	Outcomes measured	Results	Conflict of interest
Chew et al, Canada, 2017	PN-R	Flexible helical stent (n = 15) Polyurethane stent (n = 30) Total n = 45	VPAS analgesic use	Significantly less analgesics required with the more flexible stent compared with the polyurethane stents to achieve similar VPAS scores (p = 0.0035)	No
Gadzhiev et al, US, 2018	PN-R	Polyurethane stent (n = 20) Silicone stent (n = 30) Total n = 50	VPAS	Significantly lower mean VPAS scores with silicone ureteral stent after procedure (p = 0.023) and immediately before stent removal (p = 0.014)	No
Wiseman et al, UK, 2020	RCT	Polyurethane stent (n = 73) Silicone stent (n = 68) Total n = 141	USSQ, VPAS QoL	Significantly lower USSQ mean body pain scores (p = 0.015) and urinary symptom scores (p < 0.001) in the silicone stent group	Yes

RCT = randomized controlled trial; PN-R = prospective non-randomized; USSQ = Ureteral Stent Symptom Questionnaire; VPAS = Visual Pain Analog Scale; QoL = quality of life; IPSS = International Prostate Symptom Score; UTIs = urinary tract infections
Durometer (A) is a material's hardness on a scale of 0 to 100

TABLE 3. **Comparing distal stent modification studies**

Author/year	Study design	Intervention	Outcomes measured	Results	Conflict of interest
Dunn et al, US, 2000	RCT	7Fr distal pigtail (n = 31) 7Fr distal straight tail (n = 29) Total n = 60	Irritative urinary symptoms, obstructive urinary symptoms, flank pain, fever, UTIs, ER visits, pain medication use, antispasmodic use	Significantly less irritative voiding symptoms with straight tail stent (p = 0.048)	Unknown
Lingeman et al, US, 2009	RCT	Short loop 3Fr tail (n = 60) Long loop 3Fr tail (n = 59) 6Fr firm distal pigtail (n = 64) Dual durometer 6Fr soft disal pigtail (n = 53) Total n = 236	USSQ, analgesic use, pain, and migration	Significantly lower mean analgesic use with short loop tail stents (p = 0.035)	Yes

TABLE 4. **Comparing position and length studies**

Author/year	Study design	Intervention	Outcomes measured	Results	Conflict of interest
Position					
Abt et al, Switzerland, 2015	Case series	Distal loop ipsilateral (n = 13) Crossing midline (n = 20) Distal loop contralateral (n = 40) Total n = 73	USSQ, morbidity	No statistically significant results	None
Al-Kandari et al, Kuwait, 2007	RCT	Longer stent (proximal end in upper calix, distal end crosses bladder midline) (n = 60) Standard length stent (proximal end in renal pelvis, distal end just beyond UVJ) (n = 60) Total n = 120	QoL, flank pain, dysuria, urgency	Significantly worse dysuria ($p < 0.001$), urgency ($p < 0.001$), and QoL ($p < 0.001$) with longer stents crossing the bladder midline	None
Giannarini et al, Italy, 2010	Case series	Distal loop crosses midline (n = 40) Does not cross midline (n = 46) Total n = 86	USSQ domains, analgesic use	Significantly lower scores for urinary symptoms, body pain, general health, work performance, and sexual matters domains on USSQ ($p < 0.00$) and significantly decreased analgesic use if stent did not cross bladder midline ($p < 0.01$)	None
Inn et al, Malaysia, 2019	Cross sectional study	Distal loop is ipsilateral bladder (n = 24). Distal loop is contralateral in bladder (n = 22) Total n = 46	USSQ	Significantly lower USSQ score ($p < 0.003$), including urinary symptoms ($p < 0.002$), body pain ($p < 0.013$), and general health score ($p < 0.056$), for patients with distal stent loop that did not cross bladder midline	None
Taguchi et al, Japan, 2017	Case series	Tail crosses midline (n = 51) Does not cross midline (n = 57) Total n = 130	OABSS	Significantly higher OABSS ($p < 0.001$) if distal tail crossed midline	
Multi-length					
Calvert et al, UK, 2013	RCT	6Fr x 24 cm stent (n = 81) 6Fr x 22-30 cm multi-length (n = 81) Total n = 162	USSQ	No statistically significant results	Yes

USSQ = Ureteral Stent Symptom Questionnaire; UTIs = urinary tract infections; ER = emergency room

5Fr) had improved stent-related discomfort when compared with larger stents (6Fr, 7Fr).

Stent material

Stent material composition is an important design factor to consider when discussing stent-related pain. Material for stents include metal, polymeric and biodegradable. In clinical practice the most common stents are polymeric (i.e., silicone, polyurethane, Silitek, Percuflex, C-Flex, or dual durometer).[20] Depending on stent composition, the durometer or hardness of a stent will vary. Firmer stents have a higher durometer (A) than softer, more flexible stents. A dual durometer stent has a firm proximal curl and shaft with a softer distal curl.

Whether this affects stent-related pain is debated. A total of 11 studies were included (3 were non-randomized and 8 were randomized prospective controlled trials). Two early studies from the 1990s differed in their results. In a trial by Pryor et al, 72 patients undergoing ureteroscopy were delegated in a non-randomized fashion to four different stent types of varying durometer (98A, 91A, 90A, and 65A). No significant difference in urinary symptoms or pain was found between groups.[21] Lennon et al enrolled more patients, 155, and found those with firm stents had significantly increased dysuria as well as renal and suprapubic pain than their soft stent counterparts.[22] In the last 20 years, additional studies have investigated this question with inconsistent results. In a trial of 130 patients receiving high or low durometers stents, Joshi et al found no difference in USSQ scores between groups.[23] Similarly, Davenport et al found of the 98 patients randomized to a dual durometer stent or a proprietary material stent that softened at body temperature, there was no significant difference in USSQ score.[24]

Other studies however have found that stent composition and durometer do significantly affect patients' stent-related pain. In 2015, Lee et al randomized 90 patients undergoing ureteroscopy to firm, soft, or dual durometer stents. Patients had significantly increased flank and abdominal pain in the firm stent group ($p < 0.001$) and significantly lower total IPSS scores in the dual durometer group ($p = 0.016$).[25] No significant difference in QoL or OABSS was observed.[25] In the following year, Park et al observed among 128 patients undergoing ureteroscopy that those randomized to a softer tail stent had improved scores on some USSQ parameters, including the frequency of additional NSAID use ($p = 0.035$), and fatigue ($p = 0.037$), as well as fewer outpatient visits related to discomfort ($p = 0.036$) when compared to firmer tail stents.[26] A few years later, two separate smaller studies had similar conclusions. Chew et al compared VPAS scores, analgesia use, and unscheduled visits between a firm shaft stent and a more flexible version in 45 patients. Patients with the more flexible stents used significantly less pain medications ($p = 0.0035$) though no difference was observed in VPAS score or unscheduled visits.[27] Alternatively, Gadhiev et al found that VPAS scores were significantly decreased in patients who received a softer, more flexible stent ($p = 0.014$).[28] Most recently, Wiseman et al conducted a larger study with 141 patients requiring stent placement. Based on USSQ scores, patients with the softer stent had significantly decreased pain compared to those with firmer stents ($p < 0.001$).[29]

Distal loop modifications

Distal stent modification is another design modification to alleviate stent-related symptoms. It is thought that the constant rubbing of the stent material on the urothelium may induce inflammation leading to discomfort. By minimizing the intravesical portion of a ureteral stent, the degree of inflammation and thus pain should theoretically decrease as well.[3] This theory was supported by a study by Dunn et al where 60 patients were randomized to either a 7Fr tail stent (7Fr shaft and 3Fr lumenless straight distal tail) or a standard 7Fr double pigtail stent. Patients with less intravesical stent material (tail stent) reported significantly lower urinary frequency and had a statistically significant decrease of 21% in overall irritative voiding symptoms. Flank symptoms, however, were not significantly different between groups.[30] Lingeman et al had similar findings in their 4-arm multicenter study. A total of 238 adults requiring retrograde unilateral stent placement were randomized in a 1:1:1:1 fashion to a short loop tail (n = 60), long loop tail (n = 59), dual durometer (n = 64), or standard stent (n = 53). Patients with short loop tail stents had the lowest pain scores on the USSQ on postoperative day 4 and required the least pain medication on postoperative day 1. There was also a uniform peak in pain scores across all groups on postoperative day 1 suggesting that having less material in the bladder may be related to lower pain scores.[31]

Stent length and position

Finally, stent position and length are two important factors of stent design that can impact stent related pain. Six studies met inclusion criteria including two RCT, one cross sectional study, and three case series.

In terms of stent position, it is theorized that stents that cross the bladder midline distally may cause increased stent symptoms. This was first investigated by Al Kandari et al in 2007 in a randomized controlled trial with 120 patients. The study demonstrated that patients with stents crossing the bladder midline experienced significantly more bothersome lower urinary tract symptoms (urgency, dysuria) and worse QoL when compared to patients whose stents did not cross midline ($p < 0.001$), though no difference in flank pain was seen between the proximal stent curl residing in the upper renal calyx versus renal pelvis.[32] Studies by Giannarini et al, Taguchi et al, and Inn et al thereafter had similar conclusions as all three found that patients with stents crossing the bladder midline distally reported significantly more stent-related issues.[33-35] Inn et al reported worse scores for urinary symptoms ($p < 0.002$), body pain ($p < 0.013$), and general health ($p < 0.056$) as measured by the USSQ as well as worse total USSQ score ($p < 0.003$) though no difference in the work performance and sexual matter domains were seen.[34] In contrast, in a small case series with 86 patients, Giannarini et al noted significantly worse scores across all five USSQ domains (urinary, body pain, general health, work, sexual matters, $p < 0.001$).[33] Taguchi et al used the OABSS instead of the USSQ as an outcome measure but still found among a case series with 130 patients that those with stents crossing the bladder midline had worse scores ($p < 0.001$).[35] Although not statistically significant, a small case series by Abt et al found that patients with stents with an intravesical portion that remained ipsilateral in the bladder had lower USSQ scores compared with distal portions of stents that were positioned tangential or contralateral.[36]

With respect to stent length, there was only a single prospective randomized controlled trial evaluating multilength versus single length stents. Calvert et al randomized 162 patients with upper urinary tract stones to a 6Fr x 24 cm stent or a 6Fr x 22-30 cm multi-length stent. Despite a difference of 6 cm in stent length between both groups (of which the excess is incorporated into the curls), there was no significant difference seen on USSQ scores.[37]

Discussion

Any urologist who places stents as a part of their practice is familiar with the many calls and messages regarding stent-related symptoms. Per the literature, up to 84% of patients experience bothersome urinary symptoms, with 32% also describing sexual dysfunction and over one-half reporting reduced work capacity.[3]

From our review of the literature, we would suggest placing smaller diameter stents (< 6Fr) to minimize stent-related symptoms, though this is based on studies with great heterogeneity. Stent size could potentially affect reflux-related symptoms but not all patients with stents have reflux and there was no data discussing this in the included studies.[38] Yossepowitch et al did not find a correlation between stent diameter and reflux in 100 consecutive patients who had a cystogram after being stented for a variety of reasons.[38] As expected, mathematical models of reflux in stented ureters indicate a host of variables including bladder pressures and ureteral size, to be important. Efforts are underway to design non-refluxing stents.[38] In our review, stent migration was seen more with thinner stents though the range was large among studies, 4.2% to 35%, raising concern for the possibility of poorly placed or sized ureteral stents at the time of surgery.[12,13,18] No studies specifically addressed stricture formation or adequate stent dilation with respect to stent diameter. However, Nestler et al did report that in their study group, unsuccessful secondary ureteroscopy was mostly due to a still narrow ureter with similar case numbers between different diameter stents placed during the initial ureteroscopy (3 patients with 4.7Fr, 7 with 6Fr, 4 with 7Fr).[18] Ureteral stent migration, need for dilation on subsequent endoscopic procedures, and/or stricture formation should be noted in future, appropriately powered, randomized trials to fully comment on these areas. Considerations should also be given to improvements in stents over time (i.e., mechanical strength, flexibility, biocompatibility, and surface coating) that have likely improved stent symptoms as well.[39]

In general, it was found that less material in the bladder led to a more satisfactory experience for patients, specifically it is important to ensure that the intravesical stent does not cross bladder midline and a short loop or tail stent is used. This is in line with the theory that bladder nociceptors are uniquely sensitive to material rubbing against the urothelium. Based on this, it would be expected that a multi-length stent should incite greater discomfort than a standard stent, particularly when the patient has a shorter ureteral length whereby there may be excess multi length stent coiled in the bladder. However, in the only randomized controlled trial looking at symptoms due to a multi-length versus standard stents, no significant difference was found in pain between the groups.

In regards to stent durometer, no consensus was found among the publications reviewed here. This may partially be due to the fact that there was no publicly available durometer for each stent brand

type used at the time of the relevant studies. Prior benchtop studies have evaluated the durometer for several commercially available stents but it was not possible to correlate these findings with the stents used in the clinical trials due to a lack of corresponding identifiers, variability in stent diameter, or potential for updated manufacturing practices over time. Thus, only descriptive terms of firmness and flexibility could be used to characterize stents within a given study and conclusions could not be broadly drawn.

More recently, novel therapies such as placing drug-eluting stents have shown promising results. Krambeck et al found ketorolac-loaded stents significantly reduced mean pain pill use postoperatively compared to using standard stents while Mendez-Probst et al reported that placing an anti-microbial triclosan-eluting stent decreased lower flank pain, possibly via combating biofilm-precipitated inflammation.[40] Another interesting area is the use of pigtail suture stents (PSS) where the distal curl is replaced by a thin suture. Studies in animals have shown that there is significantly less ureteral inflammation observed grossly and microscopically when a PSS is used versus a double pigtail stent.[41,42] Theoretically less inflammation translates to fewer urinary symptoms for patients.[42] Advances such as these are important as they may translate into economic as well as QoL benefits. One study calculated the average reduced wages due to stent-related symptoms to be $338 per person per day unable to work. Nearly half of employed patients missed at least 1 day of work due to stent-related discomfort, and the median duration of work incapacitation was 6 days.[43]

Strengths and limitations

The greatest weakness of our review is that no recommendations can truly be given due to the heterogeneity of the trials, overall small samples sizes, and wide range of outcome measures. The most specific of these measures, the USSQ, was used in less than half of studies. In addition, certain areas of stent design lacked enough robust studies to provide a thorough review of the topic. The variability of brands with different stent compositions also precluded comparisons across studies. There was also considerable variability in follow up schedules for when outcomes were assessed, and most trials did not enforce a standard pain medication protocol or include this metric in their results. Each study also had various degrees of bias. Lastly, while the older studies reviewed provide a historical perspective, they may not represent current practices.

Conclusion

Ureteral stent placement is a common part of ureteroscopy for practicing U.S. urologists. Practitioners should seek to minimize stent-related discomfort if a stent is required given the significant QoL and economic effects. While the etiology of stent-related pain is likely multi-factorial, stent design remains an area where there is an abundance of variables that could potentially be optimized to achieve this goal. Trends in the literature in regards to stent diameter, composition, positioning, length and distal modifications are able to suggest which stent type may cause the least patient discomfort but overall the ideal stent design remains unknown. Urologists may consider such data when placing stents for patients, especially for patients who have a history of stent intolerance. Stents with smaller diameters and minimal material in the bladder may provide relief in some patients. □

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