Systematic review

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Early urinary catheter removal after rectal surgery: systematic review and meta-analysis

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Background: **Urinary catheters are placed after rectal surgery to prevent urinary retention, but prolonged use may increase the risk of urinary tract infection (UTI). This review evaluated the non-inferiority of early urinary catheter removal compared with late removal for acute urinary retention risk after rectal surgery.**

Methods: **MEDLINE, Embase and the Cochrane Central Register of Controlled Trials were searched from January 1980 to February 2019. RCTs comparing early *versus* late catheter removal after rectal surgery were eligible. Primary outcomes were acute urinary retention and UTI; the secondary outcome was length of hospital stay. Early catheter removal was defined as removal up to 2 days after surgery, with late removal after postoperative day 2. The non-inferiority margin from an included trial was used for analysis of change in urinary retention ($\Delta_{NI} = 15$ per cent). Pooled estimates of risk differences (RDs) were derived from random-effects models. Risk of bias was assessed using a modified Cochrane risk-of-bias tool.**

Results: **Four trials were included, consisting of 409 patients. There was insufficient evidence to conclude non-inferiority of early *versus* late catheter removal for acute urinary retention (RD 9 (90 per cent c.i. −1 to 19) per cent; $P_{NI} = 0{\cdot}31$). Early catheter removal was superior for UTI (RD −11 (95 per cent c.i. −17 to −4) per cent; $P = 0{\cdot}001$). Results for length of stay were mixed. There were insufficient data to conduct subgroup analyses.**

Conclusion: **The existing literature is inconclusive for non-inferiority of early *versus* late urinary catheter removal for acute urinary retention. Early catheter removal is superior in terms of reducing the risk of UTI.**

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Introduction

Acute urinary retention (AUR) is common after abdominopelvic surgery, affecting up to 24 per cent of men and 15 per cent of women[1]. Older patients are at increased risk of AUR from age-related neuronal degeneration[2,3], and men are at increased risk as a result of benign prostatic hyperplasia[4]. The mechanism by which pelvic surgery results in AUR is unclear, but two theories have been proposed[3]. Pelvic dissection can stimulate a reflex involving the pudendal nerve, sacral spinal cord and sympathetic pelvic nerves, resulting in inhibition of the detrusor muscle[3,5]. Postoperative sympathetic drive can cause bladder outlet obstruction by activating α-adrenergic receptors at the bladder neck[3,6].

Transurethral urinary catheters are placed during rectal surgery to prevent AUR and allow accurate measurement of perioperative urine output[7]. Urinary catheters are, however, not without risk. Transurethral catheterization is associated with a risk of urinary tract infection (UTI) that increases with duration of catheterization[8]. Historically, catheters have been left in place for 3–5 days after rectal surgery, but this practice restricts mobility, results in potentially avoidable UTIs requiring antimicrobial therapy, and may increase length of hospital stay (LOS)[7–9]. Several randomized[10,11] and non-randomized[12,13] studies have attempted to determine the optimal duration of catheterization after rectal surgery. The results of these studies have varied, and the risk–benefit trade-off of early catheter removal remains uncertain.

A recent systematic review[14] compared catheter removal on day 1 with removal on days 3 and 5 for AUR using a superiority approach. Despite pooling of RCTs and observational studies, this review did not demonstrate a statistically significant difference in AUR rates between day 1 and day 3 removal. The review[14] had important methodological limitations, with implications for the conclusions drawn. Superiority approaches to the analysis of a single trial or pooled estimates in the context of a meta-analysis are appropriate where an intervention plausibly improves an outcome compared with the standard of care[15]. In the setting of catheter removal, it is not physiologically plausible that earlier catheter removal improves AUR. Furthermore, an evaluation of the effectiveness of early catheter removal must acknowledge that the intervention involves trading off AUR for UTI. Superiority approaches do not inherently consider efficacy trade-offs.

In contrast with the superiority approach, the non-inferiority approach acknowledges that the novel treatment (early catheter removal) is not expected to improve the primary efficacy outcome for which catheters are used (AUR)[16]. Furthermore, it assumes that the novel treatment is associated with potential secondary benefits (reducing UTI, increasing mobility, decreasing LOS) that make it worth accepting a prespecified reduction in the primary efficacy outcome compared with the existing treatment (late catheter removal). This diminution in efficacy for the primary outcome is termed the non-inferiority margin[16]. Given the clinical context, a non-inferiority approach is therefore more appropriate to determine the optimal timing for urinary catheter removal after rectal surgery.

The aim of this review was to synthesize the existing evidence evaluating the effect of early transurethral urinary catheter removal after rectal surgery in adults on AUR, UTI and LOS using a non-inferiority meta-analytical approach.

Methods

This systematic review and meta-analysis was registered on PROSPERO, the international Prospective Register of Systematic Reviews (CRD42019121059), and is reported according to the PRISMA guidelines[17].

Searches

The search strategy was developed with a senior information specialist. Observational studies were initially eligible, but were subsequently excluded as sufficient RCTs were identified. MEDLINE, Embase and the Cochrane Central Register of Controlled Trials were searched from January 1980 to February 2019, including studies in English, French and Portuguese. Owing to limited access to professional translation services, language restrictions were applied, although considered unlikely to introduce bias[18]. Citation lists of included articles and the first ten pages of Google Scholar results were also searched. The search strategy was reviewed by a second information specialist in accordance with the Peer Review of Electronic Search Strategies (PRESS) guidelines[19]. The final MEDLINE search strategy is shown in *Appendix S1* (supporting information).

Two investigators independently screened study titles and abstracts before completing independent full-text reviews of remaining studies. Discrepancies were resolved by discussion and mediated by a third investigator as required. Screening was performed using DistillerSR™ software[20].

Eligibility criteria

RCTs of adults aged 18 years or over undergoing rectal surgery for benign or malignant indications were eligible. Studies must have included an experimental group consisting of transurethral urinary catheter removal on postoperative day (POD) 1 or 2, with or without premedication with an α-blocker, and a control group of removal on POD 3 or later. Studies with fewer than 20 patients, conference abstracts, studies not reporting the present outcomes of interest, studies that included only patients in the ICU, and studies for which the full text was not available despite interlibrary loan requests were excluded.

Outcomes

The primary outcomes were the incidence of postoperative AUR and UTI during the index hospital admission. The secondary outcome was LOS.

Definitions

Rectal surgery was defined as any colorectal operation including rectal dissection below the peritoneal reflection. For all studies, patients who had urinary catheters removed on POD 1 or 2 were combined to form the early removal group, and those who had catheters removed on POD 3 or later were combined to form the late removal group. AUR was defined as the inability to void adequately after catheter removal, requiring recatheterization with either intermittent or indwelling catheters. UTI was defined in the primary analysis as the presence of a positive urine culture with or without UTI symptoms (any of dysuria, frequency, urgency, suprapubic pain, haematuria or testicular pain). A sensitivity analysis included trials that failed to differentiate between symptomatic and asymptomatic bacteriuria. LOS was restricted to the index hospital admission.

Data extraction

Two investigators independently extracted study-level data using piloted data extraction forms. Discrepancies were resolved by discussion and mediated by a third investigator as required. Study authors were contacted for clarification as necessary. Data extracted included study and patient-level characteristics. Data for both intention-to-treat and per-protocol analyses were extracted when possible, in keeping with the non-inferiority approach[16].

Assessment of bias

Study quality was assessed using the Cochrane risk-of-bias tool[21], supplemented by additional assessments of bias specific to non-inferiority studies for the primary outcome of AUR[16]. Two investigators independently completed the risk-of-bias assessment for each outcome. Discrepancies were resolved by discussion and mediated by a third investigator as required. A funnel plot was not constructed as fewer than ten studies were included.

Statistical analysis

Descriptive synthesis was used to summarize study characteristics, patient characteristics and study results. The included trials did not present per-protocol data, and the meta-analyses were therefore performed with the available modified intention-to-treat data. The pooled risk difference (RD) was calculated for the primary outcome of AUR. To test for non-inferiority of early catheter removal for AUR, a one-sided Z test with $\alpha = 0{\cdot}05$ was used. The pooled risk difference is presented with its 90 per cent confidence interval. One of the included trials[6] was a non-inferiority trial and used a consensus between three surgeons to determine a non-inferiority margin increase (Δ_{NI}) of 15 per cent in absolute risk of AUR associated with early catheter removal (personal communication). This non-inferiority margin was used for the meta-analysis.

A standard meta-analytical superiority approach was used for the remaining outcomes. Pooled RDs were calculated and 95 per cent c.i. estimated from weights in a Mantel–Haenszel random-effects model. LOS was extracted with all reported measures of variance and central tendency. Analyses stratified by sex and epidural use were planned *a priori*, but were unable to be performed owing to a paucity of data.

Statistical heterogeneity was quantified using I^2 scores and Forest plots. I^2 scores of 25 per cent or less were considered as low heterogeneity, 25–50 per cent as moderate, and above 50 per cent as high[22]. $P < 0{\cdot}050$ was considered statistically significant. Statistical analyses were performed using the *metafor* package in R Studio® v1.0.136 (RStudio, Boston, Massachusetts, USA), RevMan® 5 (The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark) and SAS® version 9.4 (SAS Institute, Cary, North Carolina, USA).

Results

The search strategy identified 3904 unique articles. After screening and full-text review, four RCTs[6,10,11,23] involving 409 patients were included in the final analysis (*Fig. 1*). Study characteristics are presented in *Table 1*.

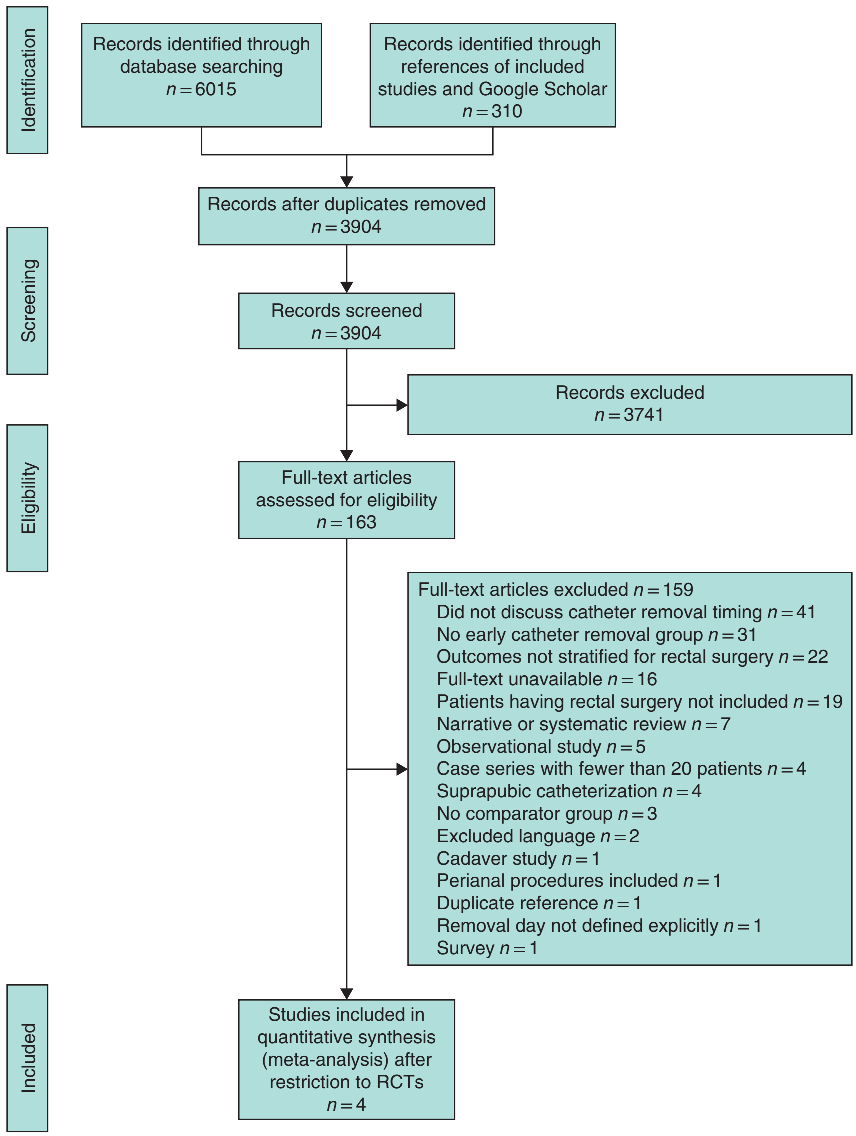
Patient characteristics are described in *Table 2*. In three RCTs[10,11,23], the majority of patients had surgery for cancer, whereas in the remaining trial[6] only 30 (21·1 per cent) of the 142 patients underwent cancer surgery. With the exception of one RCT[23], in which men comprised 20 (91 per cent) of the 22 patients in the early removal arm and ten of the 22 (45 per cent) of those in the delayed removal arm, all RCTs were well balanced with respect to patient sex. Epidural analgesia was used for all patients in one RCT[23], whereas the others either excluded patients who required epidural analgesia or made no reference to epidural analgesia.

Of four RCTs, three[10,11,23] used a superiority approach and one[6] used a non-inferiority approach to AUR. Patients in the non-inferiority trial were younger and had rectal surgery for inflammatory bowel disease more often than those in the other trials[6,10,11,23]. One trial[23] included patients undergoing colonic and rectal surgery, but reported AUR by group, so was included in the analysis.

Risk of bias

The risk-of-bias assessment for AUR showed that all trials[6,10,11,23] were at low risk of bias for sequence generation, and none of the trials blinded participants and personnel to treatment allocation. With regard to specific risk

Fig. 1 PRISMA diagram for the systematic review



of bias for non-inferiority trials, all four trials had a low risk of bias for participant selection bias, where inconsistent application of inclusion/exclusion criteria could lead to anticipated non-response to the intervention. Two trials[6,23] were found to be at high risk of performance bias. Patel and colleagues[6] changed the definition of AUR between the trial protocol[24] and final manuscript, and Coyle and co-workers[23] had less precision around catheter removal timing in the late compared with the early removal arm (12 h after epidural removal *versus* 48 h after surgery). Owing to the subjective nature of AUR assessment among unblinded study personnel, all trials[6,10,11,23] were considered at high risk of measurement bias. Two[11,23] were at high risk of attrition bias for failure to use and report intention-to-treat and per-protocol analyses. Risk-of-bias results for UTI and LOS are shown in *Tables S1* and *S2* (supporting information).

Study interventions

Patel *et al.*[6] randomized participants to catheter removal on POD 1 with an α-blocker (prazosin 1 mg orally)

Table 1 Characteristics of included RCTs comparing early *versus* late urinary catheter removal

Reference	Setting	Study definition of rectal surgery	Trial design	Intervention groups	Outcomes and definitions	No. of randomized patients: Early removal	No. of randomized patients: Late removal
Patel *et al.*[6] (2018)	Single centre	Dissection of infraperitoneal portion of rectum	Non-inferiority	POD 1 catheter removal with α-blocker *versus* POD 3 removal	AUR: inability to urinate 8 h after catheter removal or difficulty voiding with PVR > 300 ml*, managed by catheterization UTI: positive urine culture with symptoms LOS: days	71	71
Coyle *et al.*[23] (2015)	Single centre	Anterior resection/proctectomy, low anterior resection, APR	Superiority	Catheter removal at 48 h after surgery *versus* removal within 12 h of withdrawal of epidural analgesia	AUR: inability to pass urine requiring reinsertion of urethral catheter with residual > 400 ml after catheter reinsertion UTI: positive urine culture	10	13
Zmora *et al.*[11] (2010)	Multicentre	Any abdominal surgery involving mobilization of rectum below level of sacral promontory	Superiority	POD 1 *versus* POD 3 *versus* POD 5 catheter removal	AUR: inability to void despite urge and attempting for at least 30 min or failure to void 8 h after catheter removal with > 250 ml urine residual on catheter reinsertion UTI: positive urine culture with symptoms	41	77
Benoist *et al.*[10] (1999)	Single centre	Total or subtotal proctectomy with dissection of infraperitoneal rectum	Superiority	POD 1 *versus* POD 5 catheter removal	AUR: inability to void after catheter removal with full bladder or 12 h after catheter removal, even after single IOC UTI: positive routine urine culture LOS: days	64	62

*Acute urinary retention (AUR) definition changed from registered protocol definition of inability to void 6 h after removal or postvoid residual (PVR) greater than 200 ml. POD, postoperative day; UTI, urinary tract infection; LOS, length of stay; APR, abdominoperineal resection; IOC, in-and-out catheterization.

given 6 h before catheter removal on POD 3. Zmora and colleagues[11] randomized participants to catheter removal on POD 1, 3 or 5. The POD 3 and POD 5 arms were combined to calculate the pooled estimates for late catheter removal. Benoist and co-workers[10] randomized participants to catheter removal on POD 1 or 5. Coyle *et al.*[23] randomized participants to catheter removal on POD 2 or delayed removal 12 h after epidural removal. The latter group had catheter removal a median of 85 h after surgery.

Acute urinary retention

All included RCTs reported AUR. Among the four studies[6,10,11,23], 35 (18·8 per cent) of 186 patients in the early catheter removal group experienced AUR, compared with 21 (9·4 per cent) of 223 patients in the late removal group. The pooled RD between groups was inconclusive for non-inferiority of early *versus* late catheter removal for AUR (RD 9 (90 per cent c.i. −1 to 19) per cent; $\Delta_{NI} = 15$ per cent; $P_{NI} = 0{\cdot}31$) (*Fig. 2*). Statistical heterogeneity was high ($I^2 = 63$ per cent). Only one trial[6] included an α-blocker in the experimental group. As this could be considered a substantively different intervention from that in the other trials, a sensitivity analysis was performed excluding this trial. This analysis was also inconclusive (RD 14 (5 to 23) per cent; $\Delta_{NI} = 15$ per cent; $P_{NI} = 0{\cdot}46$) (*Fig. 3*), with low statistical heterogeneity ($I^2 = 22$ per cent). Relative measures of effect were similarly inconclusive.

Table 2 Characteristics of patients in included RCTs comparing early and late urinary catheter removal

Reference	No. of randomized patients	Male sex (%)	Age (years)*	Epidural use (%)	Cancer (%)	IBD (%)
Patel *et al*.[6]						
Early removal	71	56	43 (31·5–56·5)	0	15	77
Late removal	71	52	44 (29·0–60·0)	0	27	68
Coyle *et al*.[23]						
Early removal	22	91¶	63·5¶	100¶	73¶	14¶
Late removal	22	46¶	62¶	100¶	77¶	14¶
Zmora *et al*.[11]						
Early removal	41	56	57 (18–85)†	Unclear	73	2
Late removal	77	58	54 (22–81)†		74	8
Benoist *et al*.[10]						
Early removal	64	52	55(18)‡	0	69	13
Late removal	62	47	56(17)‡	0	63	26

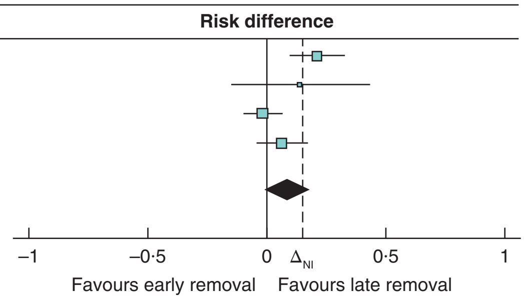
*Values are median (i.q.r.) unless indicated otherwise; †values are mean (range); ‡values are mean (s.d.). ¶Characteristic as randomized, including patients undergoing both colon and rectal surgery; some patients were excluded after randomization and the authors did not differentiate baseline characteristics by type of surgery. IBD, inflammatory bowel disease.

Fig. 2 Forest plot showing non-inferiority meta-analysis of acute urinary retention on the risk difference scale in patients who had rectal surgery with early or late urinary catheter removal

Reference	Early removal	Late removal	Weight (%)	Risk difference
Benoist *et al*.[10]	20 of 64	6 of 62	27·6	0·22 (0·10, 0·33)
Coyle *et al*.[23]	3 of 10	2 of 13	9·3	0.15 (–0·14, 0·44)
Patel *et al*.[6]	6 of 71	7 of 71	33·8	–0·01 (–0·09, 0·07)
Zmora *et al*.[11]	6 of 41	6 of 77	29·3	0·07 (–0·04, 0·17)
Total	35 of 186	21 of 223	100·0	0·09 (–0·01, 0·19)

Heterogeneity: $\tau^2 = 0{\cdot}01$; $\chi^2 = 8{\cdot}16$, 3 d.f., $P = 0{\cdot}04$; $I^2 = 63\%$

Test for overall effect: $Z = -0{\cdot}49$, $P = 0{\cdot}31$



A Mantel–Haenszel random-effects model was used for meta-analysis. Risk differences are shown with 90 per cent confidence intervals. The dashed line indicates the risk difference non-inferiority margin set at 15 per cent (Δ_{NI}).

Urinary tract infection

All four trials reported UTI as an outcome and were included in the primary analysis. Among these trials[6,10,11,23], 18 (9·7 per cent) of the 186 patients in the early removal group were diagnosed with a UTI, compared with 47 (21·1 per cent) of the 223 in the late group. The pooled analysis showed early catheter removal to be superior to late removal for risk of UTI (RD −11 (95 per cent c.i. −17 to −4) per cent; $P = 0{\cdot}001$ (*Fig. 4*). The statistical heterogeneity was low ($I^2 = 12$ per cent). Relative measures of effect demonstrated similar findings.

Coyle and colleagues[23] observed a single UTI in the late removal group. Although the authors reported AUR stratified by colonic or rectal surgery, they failed to do so for UTI. Thus, a sensitivity analysis excluding this trial was performed, the results of which did not differ from the primary analysis (*Fig. S1*, supporting information).

Two trials[6,11] defined UTI as the presence of typical symptoms and a positive urine culture, and did not include asymptomatic bacteriuria in the outcome definition. The result of a second sensitivity analysis restricted to these two trials did not differ from the primary analysis (*Fig. S2*, supporting information).

Length of hospital stay

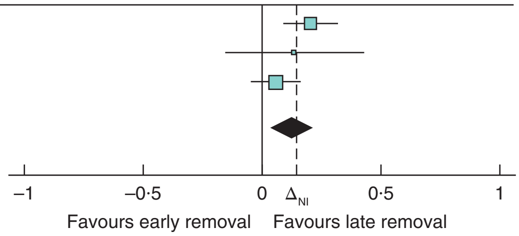
Two RCTs[6,10] reported LOS as an outcome. Because the trials were conducted nearly 20 years apart, the findings were considered too heterogeneous for quantitative meta-analysis. One study[10] reported mean(s.d.) LOS of 13(5) days in the early removal group and 15(11) days in

Fig. 3 Forest plot showing non-inferiority meta-analysis of acute urinary retention as a sensitivity analysis excluding Patel *et al.*[6] on the risk difference scale in patients who had rectal surgery with early or late urinary catheter removal

Reference	Early removal	Late removal	Weight (%)	Risk difference
Benoist *et al.*[10]	20 of 64	6 of 62	42·8	0·22 (0·10, 0·33)
Coyle *et al.*[23]	3 of 10	2 of 13	8·8	0.15 (–0·14, 0·44)
Zmora *et al.*[11]	6 of 41	6 of 77	48·4	0·07 (–0·04, 0·17)
Total	29 of 115	14 of 152	100·0	0·14 (0·05, 0·23)

Heterogeneity: $\tau^2 = 0{\cdot}00$; $\chi^2 = 2{\cdot}55$, 2 d.f., $P = 0{\cdot}28$; $I^2 = 22\%$

Test for overall effect: $Z = -0{\cdot}11$, $P = 0{\cdot}46$



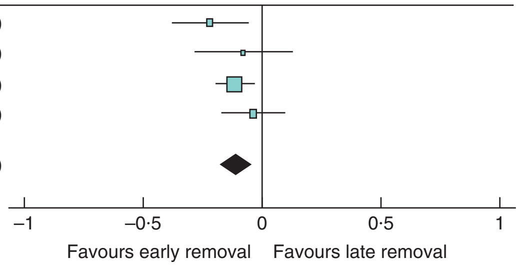
A Mantel–Haenszel random-effects model was used for meta-analysis. Risk differences are shown with 90 per cent confidence intervals. The dashed line indicates the risk difference non-inferiority margin set at 15 per cent (Δ_{NI}).

Fig. 4 Forest plot showing meta-analysis of urinary tract infection on the risk difference scale in patients who had rectal surgery with early or late urinary catheter removal

Reference	Early removal	Late removal	Weight (%)	Risk difference
Benoist *et al.*[10]	13 of 64	26 of 62	15·8	–0·22 (–0·37, –0·06)
Coyle *et al.*[23]	0 of 10	1 of 13	9·8	–0.08 (–0·28, 0·13)
Patel *et al.*[6]	0 of 71	8 of 71	51·7	–0·11 (–0·19, –0·04)
Zmora *et al.*[11]	5 of 41	12 of 77	22·7	–0·03 (–0·16, 0·09)
Total	18 of 186	47 of 223	100·0	–0·11 (–0·17, –0·04)

Heterogeneity: $\tau^2 = 0{\cdot}00$; $\chi^2 = 3{\cdot}42$, 3 d.f., $P = 0{\cdot}33$; $I^2 = 12\%$

Test for overall effect: $Z = 3{\cdot}22$, $P = 0{\cdot}001$



A Mantel–Haenszel random-effects model was used for meta-analysis. Risk differences are shown with 95 per cent confidence intervals.

the late removal group (mean difference −2·00 (95 per cent c.i. −5·00 to 1·00) days; $P = 0{\cdot}19$). The other trial[6] reported a median LOS of 4 (i.q.r. 3–6) days in the early and 5 (4–7) days in the late removal group ($P = 0{\cdot}03$).

Discussion

This systematic review and non-inferiority meta-analysis of four RCTs[6,10,11,23] comparing early *versus* late catheter removal after rectal surgery could not conclude non-inferiority of early removal for the risk of AUR. Early catheter removal resulted in a significantly reduced risk of UTI compared with late removal. In one of two trials[6,10] reporting LOS, this was shortened by early catheter removal.

A recent systematic review and meta-analysis[14] concluded that catheter removal on POD 1 may be as safe as removal on POD 3. The present review differs from that analysis in a number of ways. This review used a non-inferiority rather than a superiority approach to account for the clinical trade-off inherent to early catheter removal, did not pool RCTs and observational studies, performed a risk-of-bias assessment specific for non-inferiority trials, presented risk-of-bias assessments for each outcome[25], and performed multiple sensitivity analyses around the definition of UTI.

The findings of this non-inferiority meta-analysis differ subtly, but importantly, from those of the earlier study[14]. On the basis of the superiority analysis, it was concluded that early catheter removal on POD 1 may be as safe as removal on POD 3 based on the absence of a significant difference in AUR rates between day 1 and day 3 removal (relative risk 1·36, 95 per cent c.i. 0·83 to 2·21)[14]. That conclusion could be interpreted as supporting recommendations of catheter removal within 2 days of mid/lower rectal resection[26]. Null results from superiority analysis must be interpreted cautiously, as readers cannot conclude, based on the absence of a significant difference in AUR rates between catheter removal on POD 1 and POD 3, that the two treatments are similar for AUR, only that they had insufficient power to detect a difference.

In contrast, a non-inferiority approach allows conclusions to be drawn about whether or not early catheter removal results in an acceptable increase in AUR. The results of the present review indicate that there is insufficient evidence to conclude early removal on days 1–2 is non-inferior to removal on days 3–5. Instead of supporting recommendations for catheters to be removed within 2 days of rectal surgery, the present results suggest that the recommendations of existing perioperative care pathways[7,26] for patients having rectal surgery should reflect greater uncertainty around the safety of early catheter removal.

In contrast to the findings of this non-inferiority meta-analysis, the sole non-inferiority trial[6] concluded that early catheter removal was non-inferior to late catheter removal for AUR. In that study, patients in the early removal arm were pretreated with α-blockers, which may have resulted in a lower risk of AUR after early catheter removal. Additionally, the median age of patients was lower than in the other trials, and most operations were performed for inflammatory bowel disease rather than cancer. These factors may reduce the risk of AUR in both groups, leading to underestimation of the difference between groups and a higher likelihood of a non-inferiority conclusion[4,27]. Because of the paucity of data found in the present systematic review, subgroup analyses stratified by age and surgical indication could not be conducted, and thus the influence of surgical indication and age on AUR rates could not be assessed quantitatively.

That early catheter removal after rectal surgery is superior to late removal for avoiding UTI is an important finding. Although previous studies[7,9,28] have found a positive association between the risk of UTI and duration of catheterization in other surgical contexts, rectal surgery is associated with a particularly high risk of AUR[26], which may itself contribute to UTI through recatheterization. An observational study[12] of 205 patients undergoing rectal surgery did not find an association between UTI and earlier catheter removal. In contrast, the present analysis indicated that, in the setting of an RCT, catheter removal on or before POD 2 decreased the risk of UTI. This review has demonstrated the robustness of this finding through sensitivity analyses that accounted for heterogeneity in trial definitions of UTI and uncertainty about whether the single UTI observed in one trial[23] occurred in a patient who had rectal surgery.

Strengths of this review include the systematic nature of the search and quantitative synthesis of the existing evidence. Heterogeneity in interventions and outcome definitions was accounted for through several sensitivity analyses. The non-inferiority approach acknowledges the trade-off between AUR and beneficial outcomes of reduced UTI risk, increased patient comfort and earlier ambulation. In addition, the analysis used the non-inferiority margin previously defined by Patel *et al.*[6], which was derived by consensus, and a risk-of-bias framework specific to non-inferiority trials was used.

This meta-analysis does have limitations. All trials were deemed to be at high risk of bias owing to issues with blinding as well as poorly described secondary exposures, such as epidural analgesia, that may have altered the effect of early removal on AUR. Acknowledging the subjective nature of voiding 'urge' and some UTI symptoms, all trials in the primary analysis did include objective criteria to assess AUR and UTI, such as postvoid residual volume and urine culture. Although the presence of measurement bias cannot be excluded completely, objective criteria likely minimized these biases. Limited data meant that interactions between early removal and known risk factors for AUR could not be examined, nor could a meta-regression be undertaken to explore quantitatively the influence of patient sex and epidural use on outcomes. Future RCTs should report their results in a manner that allows stratification of results by sex, surgical indication and epidural use. Ideally, such RCTs would also be powered to identify differences between these subgroups. Additional RCT data are also needed to determine the optimal α-blocker regimen in patients who have early catheter removal.

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M.C. and C.S. contributed equally and share first authorship.

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References

1 Eveno C, Lamblin A, Mariette C, Pocard M. Sexual and urinary dysfunction after proctectomy for rectal cancer. *J Visc Surg* 2010; **147**: e21–e30.

2 Baldini G, Bagry H, Aprikian A, Carli F. Postoperative urinary retention: anesthetic and perioperative considerations. *Anesthesiology* 2009; **110**: 1139–1157.

3 Toyonaga T, Matsushima M, Sogawa N, Jiang SF, Matsumura N, Shimojima Y *et al.* Postoperative urinary retention after surgery for benign anorectal disease: potential risk factors and strategy for prevention. *Int J Colorectal Dis* 2006; **21**: 676–682.

4 Berry SJ, Coffey DS, Walsh PC, Ewing LL. The development of human benign prostatic hyperplasia with age. *J Urol* 1984; **132**: 474–479.

5 Church JM, Raudkivi PJ, Hill GL. The surgical anatomy of the rectum – a review with particular relevance to the hazards of rectal mobilisation. *Int J Colorectal Dis* 1987; **2**: 158–166.

6 Patel DN, Felder SI, Luu M, Daskivich TJ, Zaghiyan KN, Fleshner P. Early urinary catheter removal following pelvic colorectal surgery: a prospective, randomized, noninferiority trial. *Dis Colon Rectum* 2018; **61**: 1180–1186.
7 Gustafsson UO, Scott MJ, Hubner M, Nygren J, Demartines N, Francis N *et al.* Guidelines for perioperative care in elective colorectal surgery: Enhanced Recovery After Surgery (ERAS®) Society recommendations: 2018. *World J Surg* 2019; **43**: 659–695.
8 Nagle D, Curran T, Anez-Bustillos L, Poylin V. Reducing urinary tract infections in colon and rectal surgery. *Dis Colon Rectum* 2014; **57**: 91–97.
9 Okrainec A, Aarts M-A, Conn LG, McCluskey S, McKenzie M, Pearsall EA *et al.*; members of the iERAS Group. Compliance with urinary catheter removal guidelines leads to improved outcome in enhanced recovery after surgery patients. *J Gastrointest Surg* 2017; **21**: 1309–1317.
10 Benoist S, Panis Y, Denet C, Mauvais F, Mariani P, Valleur P. Optimal duration of urinary drainage after rectal resection: a randomized controlled trial. *Surgery* 1999; **125**: 135–141.
11 Zmora O, Madbouly K, Tulchinsky H, Hussein A, Khaikin M. Urinary bladder catheter drainage following pelvic surgery – is it necessary for that long? *Dis Colon Rectum* 2010; **53**: 321–326.
12 Kwaan MR, Lee JT, Rothenberger DA, Melton GB, Madoff RD. Early removal of urinary catheters after rectal surgery is associated with increased urinary retention. *Dis Colon Rectum* 2015; **58**: 401–405.
13 Lee SY, Kang S-B, Kim D-W, Oh H-K, Ihn MH. Risk factors and preventive measures for acute urinary retention after rectal cancer surgery. *World J Surg* 2015; **39**: 275–282.
14 Lee Y, McKechnie T, Springer JE, Doumouras AG, Hong D, Eskicioglu C. Optimal timing of urinary catheter removal following pelvic colorectal surgery: a systematic review and meta-analysis. *Int J Colorectal Dis* 2019; **34**: 2011–2021.
15 Mauri L, D'Agostino RB. Challenges in the design and interpretation of noninferiority trials. *N Engl J Med* 2017; **377**: 1357–1367.
16 Treadwell J, Uhl S, Tipton K, Singh S, Santaguida L, Sun X *et al. Assessing Equivalence and Noninferiority*. US Agency for Healthcare Research and Quality: Rockville, 2012.
17 Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JPA *et al.* The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *J Clin Epidemiol* 2009; **62**: e1–e34.
18 Morrison A, Polisena J, Husereau D, Moulton K, Clark M, Fiander M *et al.* The effect of English-language restriction on systematic review-based meta-analyses: a systematic review of empirical studies. *Int J Technol Assess Health Care* 2012; **28**: 138–144.
19 McGowan J, Sampson M, Salzwedel DM, Cogo E, Foerster V, Lefebvre C. PRESS peer review of electronic search strategies: 2015 guideline statement. *J Clin Epidemiol* 2016; **75**: 40–46.
20 Evidence Partners. *DistillerSR*. https://www.evidencepartners.com/ [accessed 13 March 2019].
21 Higgins JPT, Altman DG, Gøtzsche PC, Jüni P, Moher D, Oxman AD *et al.*; Cochrane Bias Methods Group; Cochrane Statistical Methods Group. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *BMJ* 2011; **343**: d5928.
22 The Cochrane Collaboration. *Cochrane Handbook for Systematic Reviews of Interventions*; version 5.1.0, 2011. http://handbook-5-1.cochrane.org/ [accessed 28 January 2019].
23 Coyle D, Joyce KM, Garvin JT, Regan M, McAnena OJ, Neary PM *et al.* Early post-operative removal of urethral catheter in patients undergoing colorectal surgery with epidural analgesia – a prospective pilot clinical study. *Int J Surg* 2015; **16**: 94–98.
24 ClinicalTrials.gov. *Optimal Duration of Indwelling Urinary Catheter Following Pelvic Surgery*. https://clinicaltrials.gov/ct2/show/NCT01923129 [accessed 31 May 2019].
25 Dekkers OM, Vandenbroucke JP, Cevallos M, Renehan AG, Altman DG, Egger M. COSMOS-E: guidance on conducting systematic reviews and meta-analyses of observational studies of etiology. *PLoS Med* 2019; **16**: e1002742.
26 Carmichael JC, Keller DS, Baldini G, Bordeianou L, Weiss E, Lee L *et al.* Clinical practice guidelines for enhanced recovery after colon and rectal surgery from the American Society of Colon and Rectal Surgeons and Society of American Gastrointestinal and Endoscopic Surgeons. *Dis Colon Rectum* 2017; **60**: 761–784.
27 Lange MM, Maas CP, Marijnen CAM, Wiggers T, Rutten HJ, Kranenbarg EK *et al.*; Cooperative Clinical Investigators of the Dutch Total Mesorectal Excision Trial. Urinary dysfunction after rectal cancer treatment is mainly caused by surgery. *Br J Surg* 2008; **95**: 1020–1028.
28 Nicolle LE. Catheter-related urinary tract infection. *Drugs Aging* 2005; **22**: 627–639.

Supporting information

Additional supporting information can be found online in the Supporting Information section at the end of the article.