



Review Article

Evidence-based Prevention and Treatment of Postoperative Catheter-related Bladder Discomfort: A Comprehensive Review

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Abstract

Catheter-related bladder discomfort (CRBD) represents a highly prevalent postoperative complication following general anesthesia. Characterized by suprapubic pain, urinary urgency, and involuntary bladder contractions, CRBD significantly impairs patient recovery and satisfaction. This comprehensive review systematically examines the pathophysiological mechanisms, risk stratification, and evidence-based prevention and treatment strategies for CRBD. The underlying pathogenesis involves muscarinic receptor activation, inflammatory responses, and nociceptor sensitization. Established risk factors encompass patient characteristics, surgical variables, anesthetic factors, and device-related aspects. Multimodal interventions demonstrate superior efficacy, including pharmacological agents such as dexmedetomidine, gabapentin, nefopam, and antimuscarinics; regional anesthesia techniques including pudendal nerve block and sacral erector spinae plane block; and non-pharmacological approaches like transcutaneous electrical nerve stimulation and acupuncture. Technological innovations in catheter design and early removal protocols further enhance recovery outcomes. Future research priorities include external validation of machine learning prediction tools, large-scale comparative effectiveness trials of multimodal bundles, and development of smart catheter systems with integrated biosensing capabilities.

Keywords

Catheter-related Bladder Discomfort, General Anesthesia, Postoperative Complications, Multimodal Analgesia, Prevention Strategies

1. Introduction

CRBD affects 47% to 90% of patients undergoing surgery with intraoperative urinary catheterization, representing a significant source of postoperative morbidity [1, 2]. The condition is characterized by burning sensations in the suprapubic region, persistent urge to void, and involuntary bladder contractions that persist despite adequate bladder emptying [3].

Beyond immediate discomfort, CRBD correlates with increased emergence agitation, prolonged hospitalization, and diminished patient satisfaction [4, 5]. As enhanced recovery after surgery (ERAS) protocols gain widespread adoption, systematic CRBD prevention has become integral to perioperative quality improvement initiatives.

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2. Pathophysiological Mechanisms

The pathogenesis of CRBD centers on muscarinic receptor activation and inflammatory responses [3]. Mechanical irritation from the indwelling catheter triggers M3 receptor-mediated detrusor muscle contractions, while foreign body reactions generate local inflammation with prostaglandin release and nociceptor sensitization [6]. Surgical trauma, anesthetic residual effects, and inadequate postoperative analgesia further amplify these responses. Recent investigations have additionally implicated bladder adenosine triphosphate release in modulating postoperative urinary dysfunction [7, 8].

3. Risk Prediction

Mitobe et al. [1] systematically categorized CRBD predictors into patient characteristics (male gender, advanced age, elevated body mass index, preoperative anxiety), surgical variables (urological procedures, prolonged operative duration), anesthetic factors (general anesthesia, long-acting opioids), and device-related aspects (excessive catheter diameter, suboptimal insertion technique). Wang et al. [4] further demonstrated that CRBD independently predicts emergence agitation in elderly surgical patients, with odds ratios exceeding those of postoperative pain or prolonged fasting.

4. Pharmacological Interventions

4.1. Antimuscarinic Agents

Antimuscarinic medications constitute foundational CRBD therapy. A comprehensive meta-analysis of eleven randomized controlled trials encompassing 1,165 patients confirmed significant reductions in CRBD incidence at all measured postoperative intervals through six hours, without appreciable increases in dry mouth, nausea, facial flushing, or visual disturbances [9]. Notably, rescue analgesic requirements decreased substantially with antimuscarinic prophylaxis.

Among specific agents, tolterodine demonstrates consistent efficacy across the early postoperative period and favorable safety profiling [2, 10]. Solifenacin appears effective primarily at immediate postoperative assessment with attenuated longer-term benefit [2]. The selective β_3 -adrenoceptor agonist mirabegron offers comparable efficacy to conventional antimuscarinics with reduced anticholinergic burden, representing a viable alternative particularly for patients with cognitive vulnerability or cardiovascular comorbidity [11, 12].

4.2. Alpha-2 Adrenergic Agonists

Dexmedetomidine has emerged as a cornerstone intervention through dual anxiolytic and sympatholytic mechanisms. Meta-analytic evidence from five randomized trials demonstrates significant reductions in CRBD incidence and severity

at zero, one, two, and six hours postoperatively, accompanied by decreased moderate-to-severe episode rates [13]. Pooled analysis of seven trials further confirms these benefits with improved postoperative pain scores and minimal side effect liability [14].

Dose optimization research identifies 0.5 micrograms per kilogram as the optimal intravenous bolus, achieving maximal protective effect without clinically significant hypotension or bradycardia [15]. For rescue therapy of established severe CRBD in the post-anesthesia care unit, the ninety percent effective dose is 0.55 micrograms per kilogram [16]. Intramuscular administration offers comparable efficacy with practical advantages in specific surgical populations [17].

Combination regimens have recently gained attention. Concurrent administration of dexmedetomidine with butorphanol achieves superior response rates compared to dexmedetomidine-sufentanil combinations, with enhanced hemodynamic stability and reduced respiratory depression [18]. This synergistic approach capitalizes on distinct receptor mechanisms while minimizing individual agent doses.

4.3. NMDA Receptor Antagonists

Sub-anesthetic dose ketamine significantly reduces CRBD incidence at two and six hours postoperatively, with particular efficacy in diminishing moderate-to-severe episodes during the early recovery phase [19]. The purified S-enantiomer esketamine demonstrates comparable benefit at 0.25 milligrams per kilogram, with favorable pharmacokinetic properties and reduced psychotomimetic potential [20].

4.4. Non-opioid Analgesics

Nefopam, a non-opioid central analgesic with NMDA antagonist and serotonergic properties, has garnered substantial recent interest. Meta-analysis of five trials involving 405 patients demonstrates significant reductions in both short-term and long-term CRBD incidence, with pronounced effects on moderate-to-severe episode prevention [21]. Network meta-analytic ranking identifies nefopam as having the highest probability of optimal performance among all evaluated pharmacological interventions [22]. Single-dose intravenous administration before transurethral prostate resection substantially reduces six-hour CRBD rates and improves patient satisfaction metrics [23].

Scheduled acetaminophen administration following bladder tumor resection significantly lowers eight-hour discomfort scores and decreases supplemental analgesic requirements between four and twelve hours postoperatively [24].

4.5. Opioid Agents

Butorphanol, characterized by κ -opioid receptor agonism and μ -receptor antagonism, demonstrates particular efficacy for CRBD management. Intravenous administration at 0.02 to

0.03 milligrams per kilogram significantly reduces both shivering and CRBD incidence in elderly surgical patients, with concurrent improvements in recovery quality metrics [25]. Direct comparison with tramadol reveals faster onset, superior comfort relief, and more favorable sedation profiles [26]. Relative to nalbuphine, butorphanol exhibits superior early postoperative efficacy with reduced rescue analgesic requirements [27].

Nalbuphine dose-response relationships have been precisely characterized, with the median effective dose of 0.03 milligrams per kilogram and ninety-five percent effective dose of 0.108 milligrams per kilogram established through rigorous probit analysis [28].

Tapentadol demonstrates advantages over conventional tramadol for pre-emptive administration, with significantly reduced two-hour postoperative CRBD rates, attenuated surgical stress responses as measured by cortisol levels, and diminished adverse effect profiles including nausea and sedation [29].

4.6. Adjunctive Pharmacotherapy

Preoperative oral gabapentin significantly reduces moderate-to-severe CRBD risk across all postoperative timepoints through six hours, with concurrent postoperative analgesic benefits and minimal side effects [10]. Perioperative magnesium sulfate infusion comparably decreases CRBD incidence and severity while reducing intraoperative and postoperative opioid requirements [30, 31].

Novel agents under investigation include melatonin, which significantly reduces CRBD incidence at multiple postoperative assessments following prostate resection surgery when administered as five milligram oral doses preoperatively [32]. Intravenous vitamin C similarly demonstrates efficacy in reducing immediate and early postoperative moderate-to-severe CRBD with improved patient satisfaction [33].

5. Regional Anesthesia and Local Anesthetic Techniques

5.1. Systemic and Intravesical Lidocaine

Lidocaine possesses multimodal properties including anti-muscarinic, anti-inflammatory, and analgesic effects that render it particularly suitable for CRBD prevention. Comprehensive meta-analysis with trial sequential analysis and GRADE evaluation confirms that both intravenous and intravesical administration significantly reduce moderate-to-severe CRBD at zero, one, and two hours postoperatively, with high certainty evidence [34]. Six-hour efficacy appears attenuated, suggesting optimal utility for early postoperative management.

Intravesical instillation of dilute lidocaine solution achieves nearly eighty percent reduction in early postoperative moderate-to-severe CRBD following transurethral procedures [35, 36]. Intravenous infusion throughout complex spinal surgery

similarly decreases post-anesthesia care unit and one-hour CRBD rates while reducing cumulative opioid consumption and improving global satisfaction scores [37].

5.2. Neural Blockade

Pudendal nerve block substantially reduces CRBD incidence and severity throughout the first twelve postoperative hours, with particular efficacy during the immediate recovery period [38, 39]. Ultrasound-guided techniques at Alcock's canal entrance bilaterally achieve these benefits while concomitantly decreasing postoperative pain scores and analgesic requirements without technique-related complications [40].

Sacral erector spinae plane block demonstrates comparable efficacy to pudendal nerve block with significantly reduced performance time, offering practical advantages in clinical workflow [41]. Ilioinguinal and iliohypogastric nerve blockade similarly mitigate early CRBD while decreasing intraoperative opioid consumption and accelerating extubation [42]. Penile nerve block effectively reduces zero to eight-hour discomfort and pain scores following prostate resection, with multivariate analysis identifying this intervention as the sole independent CRBD-modifying factor [39].

6. Non-pharmacological Interventions

6.1. Neurostimulation Techniques

Transcutaneous electrical nerve stimulation applied from surgical conclusion through one hour postoperatively dramatically reduces immediate moderate-to-severe CRBD incidence with a number needed to treat of only 2.3, accompanied by improved pain scores and substantially enhanced patient satisfaction [5]. Transcutaneous tibial nerve stimulation similarly decreases moderate-to-severe episode rates at zero, one, and two hours while improving twenty-four hour quality of recovery metrics without adverse effects [43].

6.2. Acupuncture-based Therapies

Transcutaneous electrical acupoint stimulation at standardized bladder-related meridian points significantly reduces CRBD incidence and severity at multiple postoperative assessments, improves early recovery quality scores, and decreases supplemental analgesic requirements [6, 7]. Wrist-ankle acupuncture with prolonged needle retention comparably attenuates discomfort and pain scores following prostate surgery [44]. Acupoint injection at classical Chinese medicine loci demonstrates superior efficacy to tramadol for established CRBD, with faster onset and reduced nausea incidence [45].

6.3. Anesthetic Technique Modification

General anesthesia combined with epidural anesthesia significantly decreases CRBD occurrence and severity compared

to general anesthesia alone, with enhanced effects in male patients and those aged fifty years or older [46].

7. Catheter Technology and Management

Innovative catheter designs incorporating open-ended tips reduce six-hour postoperative CRBD incidence by approximately thirty-eight percent compared to conventional Foley catheters, with particular efficacy in non-transurethral resection populations [47]. Multi-porous silicone catheters enabling continuous local anesthetic infusion demonstrate dose-dependent CRBD reduction without increased complication rates [48, 49]. Disposable painless catheter systems with integrated lidocaine delivery comparably decrease early postoperative incidence and severity while improving global satisfaction [50].

Early catheter removal at twenty-four hours following prostate resection, compared to standard seventy-two hour protocols, achieves equivalent safety profiles with reduced pain and CRBD scores and shortened hospitalization [51].

8. Evidence Synthesis and Comparative Effectiveness

Systematic review and network meta-analysis of forty-five studies involving thirty-one distinct pharmacological interventions identifies dexmedetomidine, gabapentin, tolterodine, tramadol, ketamine, nefopam, oxybutynin, pregabalin, and pudendal nerve block as consistently superior to control conditions [2]. Integrated assessment of efficacy and adverse event profiles ranks dexmedetomidine and gabapentin as optimal choices. A subsequent network meta-analysis specifically identifies nefopam as having the highest probability of best performance for moderate-to-severe CRBD prevention [22].

9. Conclusions and Future Directions

Catheter-related bladder discomfort represents a preventable source of postoperative morbidity amenable to systematic multimodal intervention. Current evidence supports risk-stratified approaches incorporating preoperative gabapentin or melatonin for high-risk patients, intraoperative dexmedetomidine or magnesium with regional anesthesia integration, and postoperative lidocaine-based strategies with neurostimulation adjuncts. Technological innovations in catheter design and early removal protocols further enhance recovery quality.

Future priorities include external validation of machine learning prediction tools, large-scale comparative effectiveness trials of multimodal bundles, and development of smart catheter systems with integrated biosensing and automated drug delivery. Standardization of CRBD outcomes and integration into ERAS protocols will ultimately eliminate this complication as a barrier to optimal surgical recovery.

Abbreviations

CRBD	Catheter-related Bladder Discomfort
ERAS	Enhanced Recovery After Surgery
NMDA	N-Methyl-D-aspartate

Author Contributions

Xin Wei: Conceptualization, Formal Analysis, Writing – original draft

Dan Zhou: Conceptualization, Methodology, Writing – review & editing, Supervision

Conflicts of Interest

The authors report no conflicts of interest in this work.

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