



A Comprehensive Systematic Review of The Relationship between Long-Term Urinary Catheter Use and the Incidence of Recurrent Urinary Tract Infections

¹ Andi Dedi Pradana Putra, ² Khaeriah B

¹ Prima Husada Sengkang Regional General Hospital, Indonesia

² University of Puangrimaggalatung, Indonesia

Corresponding Email : dedibugis29@gmail.com

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ABSTRACT

Background: Long-term urinary catheterization (≥ 30 days) is widely used but strongly associated with recurrent urinary tract infections (UTIs). However, the magnitude of risk, comparative safety of catheter types, efficacy of preventive strategies, and trade-offs such as antimicrobial resistance remain debated.

Methods: This systematic review synthesized evidence from 80 studies (including randomized controlled trials, cohort studies, meta-analyses, and systematic reviews) examining the relationship between long-term catheter use and recurrent UTIs. Primary outcomes included UTI incidence rates, risk ratios, and the effects of catheter duration, catheter type, coatings, antibiotic prophylaxis, care bundles, irrigation protocols, and non-antibiotic strategies.

Results: A dose-dependent relationship was identified, with UTI risk increasing approximately 5% per catheterization day and reaching near-certainty at 30 days (OR 3.03 for long-term indwelling catheters in kidney recipients). Early catheter removal

(≤ 3 weeks) reduced UTI odds by 47–59%. Antimicrobial-coated catheters showed modest benefit (OR 0.80), but noble metal alloy catheters reduced CAUTI by 69% (IRR 0.31). Hydrophilic intermittent catheters significantly lowered UTI risk (OR 0.36). Continuous antibiotic prophylaxis reduced symptomatic UTIs by 48% but increased resistance to nitrofurantoin (24% vs 9%) and trimethoprim (67% vs 33%). Nurse-driven protocols and reminder systems reduced CAUTI by 52–56%, and twice-weekly bladder irrigation was optimal (IRR 0.40). Probiotics showed no significant benefit, while D-mannose and bowel management in spina bifida were promising.

Discussion: The evidence confirms a strong duration–risk relationship, supports coated catheters for long-term use, highlights the efficacy–resistance trade-off of antibiotic prophylaxis, and emphasizes institutional protocols as the most consistently effective interventions. Indwelling versus intermittent catheterization shows no clear infection-related superiority when confounders are considered.

Conclusion: Early catheter removal remains the most effective strategy. For long-term users, coated catheters, antibiotic prophylaxis (in selected patients), and optimized irrigation (twice weekly) reduce UTI risk. Future research should focus on non-antibiotic strategies and implementation science.

Keywords: Long-term urinary catheter, recurrent urinary tract infection, catheter-associated UTI, antibiotic prophylaxis, catheter coating, care bundle

INTRODUCTION

Urinary tract infection (UTI) is one of the most common healthcare-associated infections, and the use of urinary catheters is the leading modifiable risk factor (1). Long-term urinary catheterization, typically defined as duration ≥ 30 days, is frequently required in patients with neurogenic bladder, spinal cord injury (SCI), multiple sclerosis, benign prostatic hyperplasia, or after urologic surgery (2,3). However, the prolonged presence of a foreign body in the urinary tract inevitably leads to biofilm formation, bacterial colonization, and recurrent episodes of symptomatic infection (4).

Background: Recurrent UTIs in long-term catheter users are associated with increased morbidity, hospitalizations, antimicrobial resistance, reduced quality of life, and significant healthcare costs (5,6). Despite decades of research, substantial controversy remains regarding several key questions: whether indwelling catheters truly cause more UTIs than intermittent catheterization, what the optimal catheter material or coating is, whether antibiotic prophylaxis provides net benefit given resistance risks, and which non-pharmacological strategies are most effective (7,8).

Problem statement: Current clinical guidelines provide inconsistent recommendations, partly because previous studies have been heterogeneous in design, populations, definitions of long-term use, and outcomes. Moreover, many studies fail to distinguish between asymptomatic bacteriuria and symptomatic UTI, and few directly compare the full range of preventive strategies (9,10).

Research gap: No single systematic review has comprehensively synthesized evidence across all relevant domains—catheter duration, catheter type, coatings, antibiotic prophylaxis, care bundles, irrigation, and other preventive strategies—in long-term catheter users. Furthermore, the relative importance of these factors and their interactions remain poorly understood.

Novelty: This review is the first to integrate findings from 80 studies covering diverse populations (SCI, nursing home residents, renal transplant recipients, neurogenic bladder patients)

and interventions, with a focus on clinically significant outcomes (symptomatic recurrent UTI) and moderating factors such as neurologic diagnosis, setting, and duration thresholds.

Objectives: To systematically review the relationship between long-term urinary catheter use and the incidence of recurrent UTIs, quantify the duration–risk relationship, compare catheter types and coatings, evaluate antibiotic and non-antibiotic preventive strategies, and assess institutional interventions.

Hypothesis: Long-term catheterization is associated with a dose-dependent increase in recurrent UTI risk, but the magnitude of effect varies significantly by catheter type, coating, patient population, and the use of prophylactic or care bundle interventions.

Benefits: This review provides evidence-based guidance for clinicians, hospital administrators, and policymakers to reduce UTI burden in long-term catheter users while minimizing antimicrobial resistance.

METHODS

Protocol

The study strictly adhered to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 guidelines to ensure methodological rigor and accuracy. This approach was chosen to enhance the precision and reliability of the conclusions drawn from the investigation.

Criteria for Eligibility

This systematic review aims to evaluate The Relationship between Long-Term Urinary Catheter Use and the Incidence of Recurrent Urinary Tract Infections.

Screening

We screened in sources based on their abstracts that met these criteria:

- **Catheter Duration:** Does the study include patients with long-term urinary catheter use (≥ 30 days)?

- **Recurrent UTI Outcomes:** Does the study report on recurrent urinary tract infections as a primary or secondary outcome with clear definitions using established clinical or laboratory criteria?
- **Adult Population:** Does the study include adult patients (≥ 18 years)?
- **Quantitative Data:** Does the study provide quantitative data on UTI incidence rates or frequencies?
- **Study Design:** Is the study design a randomized controlled trial, cohort study, case-control study, cross-sectional study, systematic review, or meta-analysis?
- **UTI Classification:** Does the study clearly distinguish between catheter-associated UTIs and other types of UTIs?
- **Study Size and Design Quality:** Is the study NOT a case report or case series with fewer than 10 patients?
- **Human Clinical Data:** Is the study conducted in human patients (not laboratory or animal models)?

We considered all screening questions together and made a holistic judgement about whether to screen in each paper.

Search Strategy

The keywords used for this research based PICO :

Element	P (Population)	I (Intervention/Exposure)	C (Comparison/Context)	O (Outcome)
Keyword 1	Adult patients	Long-term urinary catheter use	Short-term catheter use	Recurrent urinary tract infection incidence

Keyword 2	Adult population	Prolonged catheterization	Intermittent catheterization	Catheter-associated UTI (CAUTI)
Keyword 3	Patients ≥ 18 years	Chronic catheter dwell time	Non-catheterized patients	Repeated symptomatic bacteriuria
Keyword 4	Adult individuals	Long-term bladder catheterization	Alternative bladder management	Frequent UTI episodes

The Boolean MeSH keywords inputted on databases for this research are: (*"Adult patients" OR "Adult population" OR "Patients ≥ 18 years" OR "Adult individuals"*) AND (*"Long-term urinary catheter use" OR "Prolonged catheterization" OR "Chronic catheter dwell time" OR "Long-term bladder catheterization"*) AND (*"Short-term catheter use" OR "Intermittent catheterization" OR "Non-catheterized patients" OR "Alternative bladder management"*) AND (*"Recurrent urinary tract infection incidence" OR "Catheter-associated UTI (CAUTI)" OR "Repeated symptomatic bacteriuria" OR "Frequent UTI episodes"*)

Data extraction

- **Catheter Duration Definition:**

Extract how the study defines 'long-term' catheter use and what specific durations were examined in relation to recurrent UTIs, including:

- Definition of long-term catheterization (e.g., >14 days, >30 days, permanent)
- Actual duration ranges studied (minimum, maximum, mean)
- Whether duration was analyzed as continuous or categorical variable
- Any duration thresholds identified as critical for UTI risk

- **Study Population:**

Extract characteristics of the population studied for the catheter-UTI relationship, including:

- Setting (nursing home, ICU, hospital ward, community, etc.)
- Sample size for catheter-UTI analysis
- Age range and mean age
- Gender distribution
- Baseline health status and comorbidities
- Indication for catheterization
- Any exclusion criteria that might affect generalizability

- **Catheter Characteristics:**

Extract details about the urinary catheters examined in relation to recurrent UTI incidence, including:

- Catheter type (indwelling, intermittent, suprapubic)
- Material and coating (silicone, latex, silver-coated, antimicrobial, etc.)
- Size/caliber
- Insertion method and sterility protocols
- Maintenance and changing schedules
- Any catheter care bundles or protocols used

- **UTI Definition:**

Extract how recurrent urinary tract infections were defined and measured in relation to long-term catheter use, including:

- Diagnostic criteria for UTI (symptomatic vs asymptomatic bacteriuria)
- Definition of 'recurrent' (number of episodes, time frame)
- Laboratory thresholds (colony counts, specific pathogens)
- Clinical symptoms included in diagnosis
- Follow-up period for UTI detection
- Method of urine collection for diagnosis

- **Primary Relationship Findings:**

Extract the main findings about the relationship between long-term catheter use and recurrent UTI incidence, including:

- Direction of association (positive, negative, no association)
- Quantitative measures (incidence rates, risk ratios, odds ratios, hazard ratios)
- Statistical significance and confidence intervals
- Dose-response relationship if analyzed (UTI risk by duration categories)
- Comparison groups used (short-term vs long-term, catheterized vs non-catheterized)

- **Moderating Factors:**

Extract factors that modify the relationship between long-term catheter use and recurrent UTIs, including:

- Patient factors (age, gender, immune status, comorbidities)

- Catheter factors (type, material, coating) that influence the duration-UTI relationship
- Care factors (insertion technique, maintenance protocols, staff training)
- Setting factors (ICU vs ward, nursing home vs hospital)
- Any subgroup analyses showing differential effects

- **Study Methodology:**

Extract methodological details relevant to assessing the catheter duration-UTI relationship, including:

- Study design (RCT, etc)
- Prospective vs retrospective data collection
- Blinding of outcome assessment
- Loss to follow-up rates and reasons
- Adjustment for confounders in analysis
- Risk of bias assessment results if available

Table 1. Article Search Strategy

Database	Keywords	Hits
Pubmed	<i>("Adult patients") AND ("Long-term urinary catheter use") AND ("Recurrent urinary tract infection incidence" OR "Catheter-associated UTI (CAUTI)" OR "Repeated symptomatic bacteriuria" OR "Frequent UTI episodes")</i>	1
Semantic Scholar	<i>("Adult patients" OR "Adult population" OR "Patients ≥18 years" OR "Adult individuals") AND ("Long-term urinary catheter use" OR "Prolonged catheterization" OR "Chronic catheter dwell time" OR "Long-term bladder catheterization") AND ("Short-term catheter use" OR "Intermittent catheterization" OR "Non-catheterized patients" OR "Alternative bladder management") AND ("Recurrent urinary tract infection incidence" OR "Catheter-associated UTI (CAUTI)" OR "Repeated symptomatic bacteriuria" OR "Frequent UTI episodes")</i>	250
Springer	<i>"Adult patients" AND "Long-term urinary catheter use" AND "Recurrent urinary tract infection incidence" OR "Catheter-associated UTI (CAUTI)" OR "Repeated symptomatic bacteriuria" OR "Frequent UTI episodes"</i>	94
Google Scholar	<i>("Adult patients" OR "Adult population" OR "Patients ≥18 years" OR "Adult individuals") AND ("Long-term urinary catheter use" OR "Prolonged catheterization" OR "Chronic catheter dwell time" OR "Long-term bladder catheterization") AND ("Short-term catheter use" OR "Intermittent catheterization" OR "Non-catheterized patients" OR "Alternative bladder management") AND ("Recurrent urinary tract infection incidence" OR "Catheter-associated UTI (CAUTI)" OR "Repeated symptomatic bacteriuria" OR "Frequent UTI episodes")</i>	92
Wiley Online Library	<i>"Adult patients" AND "Long-term urinary catheter use" AND "Recurrent urinary tract infection incidence" OR "Catheter-associated UTI (CAUTI)" OR "Repeated symptomatic bacteriuria" OR "Frequent UTI episodes"</i>	50

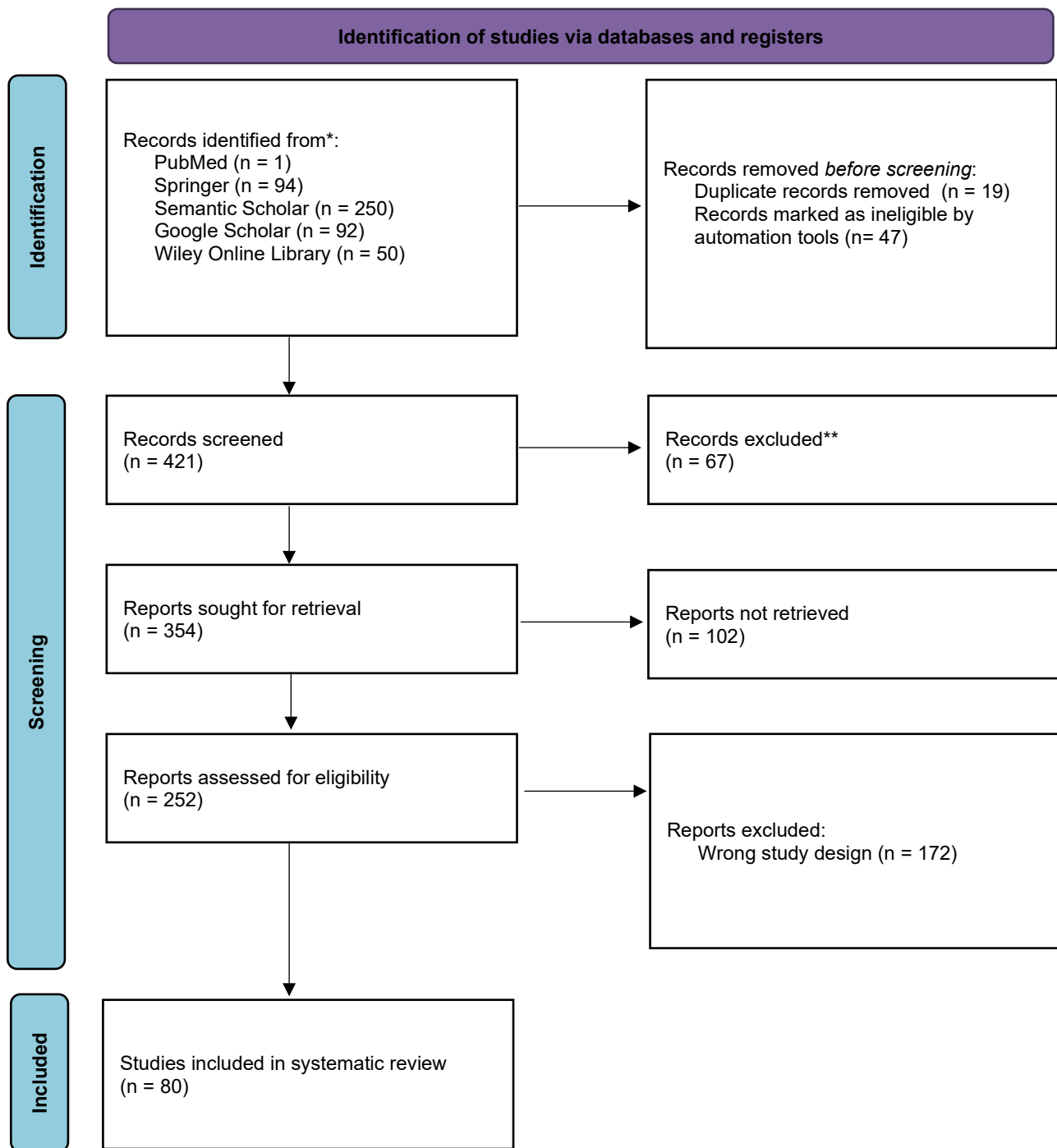


Figure 1. Article search flowchart

Risk of Bias Summary Table – All Included Studies

Author (Year)	Randomization (D1)	Deviation from Intended Intervention (D2)	Missing Outcome Data (D3)	Measurement of Outcome (D4)	Selection of Reported Result (D5)	Overall Risk of Bias
R. Pickard et al., 2018	Low	Low	Low	Low	Low	Low
M. Wilde et al., 2015	Low	Moderate	Low	Low	Low	Moderate
H. Fisher et al., 2018	Low	Low	Low	Low	Low	Low
T. Kessler et al., 2019	Low	Low	Low	Low	Low	Low
Mohamed Abdel-fattah et al., 2024	Low	Low	Low	Low	Low	Low
A. Dinh et al., 2019	Low	Moderate	Low	Moderate	Low	Moderate
L. Mody et al., 2015	Low	Low	Low	Low	Low	Low
J. Meddings et al., 2010	Moderate	Moderate	Low	Low	Low	Moderate

Author (Year)	Randomization (D1)	Deviation from Intended Intervention (D2)	Missing Outcome Data (D3)	Measurement of Outcome (D4)	Selection of Reported Result (D5)	Overall Risk of Bias
K. Gibson et al., 2019	Low	Moderate	Moderate	Low	Low	Moderate
D. Cardenas et al., 2009	Low	Moderate	Low	Moderate	Low	Moderate
R. Darouiche et al., 2014	Low	Low	Low	Low	Low	Low
V. Neumeier et al., 2023	Moderate	Moderate	Low	Low	Low	Moderate
Mikolaj Jankowski et al., 2025	Unclear	Moderate	Unclear	Moderate	Unclear	Unclear
S. Bermingham et al., 2013	Moderate	Moderate	Moderate	Low	Low	Moderate
X. Bonfill et al., 2017	Low	Low	Low	Low	Low	Low
J. Salomon et al., 2006	Moderate	Moderate	Low	Moderate	Low	Moderate

Author (Year)	Randomization (D1)	Deviation from Intended Intervention (D2)	Missing Outcome Data (D3)	Measurement of Outcome (D4)	Selection of Reported Result (D5)	Overall Risk of Bias
Dominique Thomas et al., 2017	Unclear	Moderate	Moderate	Moderate	Moderate	Moderate
T. Ziadeh et al., 2021	Moderate	Moderate	Low	Low	Low	Moderate
B. B. Lee et al., 2016	Low	Low	Low	Low	Low	Low
V. Gauhar et al., 2022	Low	Low	Low	Low	Low	Low
Mohamed H Gad et al., 2021	Moderate	Moderate	Moderate	Low	Low	Moderate
Fei Li et al., 2018	Low	Low	Low	Low	Low	Low
D. de Ridder et al., 2005	Low	Moderate	Low	Low	Low	Moderate
H. Leek et al., 2019	Low	Low	Low	Moderate	Low	Moderate

Author (Year)	Randomization (D1)	Deviation from Intended Intervention (D2)	Missing Outcome Data (D3)	Measurement of Outcome (D4)	Selection of Reported Result (D5)	Overall Risk of Bias
R. Darouiche et al., 2006	Low	Low	Low	Low	Low	Low
L. Su et al., 2024	Moderate	Moderate	Low	Low	Low	Moderate
Jing Tian et al., 2017	Unclear	Moderate	Moderate	Moderate	Unclear	Moderate
Zhang Ruijuan et al., 2023	Unclear	Unclear	Moderate	Moderate	Unclear	Unclear
S. Shamout et al., 2016	Moderate	Moderate	Low	Low	Low	Moderate
Masoumeh Hosseinpour et al., 2023	Low	Low	Low	Low	Low	Low
Na Li et al., 2025	Low	Low	Low	Low	Low	Low
A. Leuck et al., 2015	Low	Moderate	Moderate	Low	Low	Moderate

Author (Year)	Randomization (D1)	Deviation from Intended Intervention (D2)	Missing Outcome Data (D3)	Measurement of Outcome (D4)	Selection of Reported Result (D5)	Overall Risk of Bias
A. Yuan et al., 2014	Unclear	Moderate	Moderate	Moderate	Unclear	Moderate
Y. Kai-Larsen et al., 2021	Low	Low	Low	Low	Low	Low
Hani Salwan AL et al., 2025	Unclear	Moderate	Moderate	Moderate	Unclear	Moderate
C. Jia et al., 2013	Low	Moderate	Low	Low	Low	Moderate
J. Pannek et al., 2019	Low	Moderate	Moderate	Moderate	Low	Moderate
H. Giamarellou et al., 2007	Unclear	Moderate	Moderate	Moderate	Unclear	Moderate
H. Dong et al., 2019	Low	Low	Low	Low	Low	Low
J. M. Arreola Guerra et al., 2022	Low	Low	Low	Low	Low	Low

Author (Year)	Randomization (D1)	Deviation from Intended Intervention (D2)	Missing Outcome Data (D3)	Measurement of Outcome (D4)	Selection of Reported Result (D5)	Overall Risk of Bias
Michelle Fang et al., 2021	Unclear	Moderate	Moderate	Moderate	Unclear	Moderate
J. Meddings et al., 2017	Low	Low	Low	Low	Low	Low
M. Hafizi et al., 2019	Low	Moderate	Low	Low	Low	Moderate
Rachel Vopni et al., 2021	Low	Low	Low	Low	Low	Low
Li Li et al., 2013	Low	Low	Low	Low	Low	Low
M. Beattie et al., 2011	Moderate	Moderate	Low	Low	Low	Moderate
J. Stensballe et al., 2007	Low	Low	Low	Low	Low	Low
R. Kyriakides et al., 2020	Low	Low	Low	Low	Low	Low

Author (Year)	Randomization (D1)	Deviation from Intended Intervention (D2)	Missing Outcome Data (D3)	Measurement of Outcome (D4)	Selection of Reported Result (D5)	Overall Risk of Bias
Ashgan Tolba Elgohary et al., 2020	Unclear	Moderate	Moderate	Moderate	Unclear	Moderate
G. Ahmed et al., 2020	Unclear	Moderate	Moderate	Moderate	Unclear	Moderate
Lauren E. Corona et al., 2020	Unclear	Moderate	Moderate	Moderate	Unclear	Moderate
Nicholas Pryor et al., 2024	Low	Low	Low	Low	Low	Low
M. Stillman et al., 2018	Moderate	Moderate	Low	Low	Low	Moderate
B. Welk et al., 2022	Low	Low	Low	Low	Low	Low
Hui-ying Sun et al., 2011	Unclear	Moderate	Moderate	Moderate	Unclear	Moderate
J. Penders et al., 2003	Unclear	Moderate	Moderate	Moderate	Unclear	Moderate

Author (Year)	Randomization (D1)	Deviation from Intended Intervention (D2)	Missing Outcome Data (D3)	Measurement of Outcome (D4)	Selection of Reported Result (D5)	Overall Risk of Bias
Jeanette Fiveash et al., 2020	Unclear	Moderate	Moderate	Moderate	Unclear	Moderate
X. Bonfill et al., 2013	Low	Low	Low	Low	Low	Low
Yulong Cao et al., 2018	Low	Low	Low	Low	Low	Low
Maria Regina Rachmawati et al., 2016	Unclear	Moderate	Moderate	Moderate	Unclear	Moderate
Luisa De Palma et al., 2023	Low	Low	Low	Low	Low	Low
R. Lan et al., 2013	Low	Low	Low	Low	Low	Low
A. Westgeest et al., 2024	Low	Low	Low	Low	Low	Low

Author (Year)	Randomization (D1)	Deviation from Intended Intervention (D2)	Missing Outcome Data (D3)	Measurement of Outcome (D4)	Selection of Reported Result (D5)	Overall Risk of Bias
C. Theobald et al., 2017	Moderate	Moderate	Low	Low	Low	Moderate
F. D'Ambrosio et al., 2022	Low	Low	Low	Low	Low	Low
M. Plata et al., 2022	Low	Low	Low	Low	Low	Low
N. Nassikas et al., 2020	Moderate	Moderate	Low	Low	Low	Moderate
Bindu R. Potugari et al., 2020	Unclear	Moderate	Moderate	Moderate	Unclear	Moderate
Jin-Sook Kim et al., 2017	Low	Low	Low	Low	Low	Low
Z. Radojicic et al., 2018	Low	Low	Low	Low	Low	Low
Swee-Ling Toh et al., 2019	Low	Low	Low	Low	Low	Low

Author (Year)	Randomization (D1)	Deviation from Intended Intervention (D2)	Missing Outcome Data (D3)	Measurement of Outcome (D4)	Selection of Reported Result (D5)	Overall Risk of Bias
M. G. Meneguetti et al., 2019	Moderate	Moderate	Low	Low	Low	Moderate
Matthew Davis et al., 2023	Low	Low	Low	Low	Low	Low
D. Gould et al., 2017	Moderate	Moderate	Low	Low	Low	Moderate
Peter Darmawan et al., 2026	Low	Low	Low	Low	Low	Low
W. et al., 2012	Moderate	Moderate	Low	Low	Low	Moderate
S. Chandramohan et al., 2018	Unclear	Moderate	Moderate	Moderate	Unclear	Moderate
Danielle J. Durant et al., 2017	Low	Low	Low	Low	Low	Low

Author (Year)	Randomization (D1)	Deviation from Intended Intervention (D2)	Missing Outcome Data (D3)	Measurement of Outcome (D4)	Selection of Reported Result (D5)	Overall Risk of Bias
X. Saenz-Montoya et al., 2020	Low	Low	Low	Low	Low	Low
Xiaohui Wu et al., 2016	Low	Low	Low	Low	Low	Low

RESULTS

Characteristics of Included Studies

This review synthesized evidence from 80 sources examining the relationship between long-term urinary catheter use and recurrent urinary tract infections (UTIs). The included studies span a diverse range of designs, populations, settings, and intervention types, including randomized controlled trials, etc. The studies address multiple dimensions of the catheter-UTI relationship, including the effect of catheterization duration, catheter type and material, antibiotic prophylaxis, non-antibiotic prevention strategies, care bundles, and institutional protocols.

Study	Primary Focus	Population / Setting	Sample Size
R. Pickard et al., 2018	Antibiotic prophylaxis in CISC users [12]	Community, adults performing CISC with recurrent UTIs [12]	404 [12]

Study	Primary Focus	Population / Setting	Sample Size
M. Wilde et al., 2015	Self-management intervention for indwelling catheter users [15]	Community, long-term indwelling catheter users [15]	202 [15]
H. Fisher et al., 2018	Antibiotic prophylaxis in CISC users (AnTIC trial) [13]	Community, CISC users with recurrent UTIs, 51 UK NHS sites [13]	404 [13]
T. Kessler et al., 2019	Expert summary of AnTIC trial [16]	CISC users with recurrent UTIs, 51 UK NHS sites [16]	404 [16]
Mohamed Abdel-fattah et al., 2024	Catheter washout policies for LTC users [17]	UK community, adults with LTC ≥ 28 days [17]	80 [17]
A. Dinh et al., 2019	Weekly cyclic antibiotic prophylaxis in SCI [18]	SCI patients with neurogenic bladder using CISC [18]	45 [18]
L. Mody et al., 2015	Targeted infection prevention in nursing homes [19]	Community-based nursing homes, residents with indwelling devices [19]	418 [19]
J. Meddings et al., 2010	Reminder systems to reduce CAUTI [8]	Hospitalized adults [8]	14 studies [8]

Study	Primary Focus	Population / Setting	Sample Size
K. Gibson et al., 2019	Urethral vs suprapubic catheters in nursing homes [20]	Nursing home residents, mean age 74.1 years [20]	208 [20]
D. Cardenas et al., 2009	Hydrophilic vs noncoated catheters for IC [21]	Community, SCI patients on self-IC with recurrent UTIs [21]	56 [21]
R. Darouiche et al., 2014	Short vs long antibiotic course for CA-UTI in SCI [22]	Medical center, SCI patients with CA-UTI [22]	61 [22]
V. Neumeier et al., 2023	Indwelling vs intermittent catheterization and UTI [7]	Tertiary neuro-urology department, NLUTD patients [7]	505 [7]
Mikołaj Jankowski et al., 2025	UTI risk associated with nephrostomy [23]	Adults undergoing PCN [23]	35 studies [23]
S. Bermingham et al., 2013	Catheter types for intermittent self-catheterization [24]	Community, primarily SCI patients, 80% male [24]	8 studies [24]
X. Bonfill et al., 2017	Silver alloy-coated catheters in SCI [25]	Hospitalized (43%) and outpatients (57%) with SCI, 72% male [25]	489 [25]

Study	Primary Focus	Population / Setting	Sample Size
J. Salomon et al., 2006	Weekly cyclic antibiotic prophylaxis in SCI [26]	SCI patients with neurogenic bladder using CISC [26]	Not specified [26]
Dominique Thomas et al., 2017	Cranberry supplement for CA-UTI [27]	Tertiary outpatient facilities, mean age 77.22 years [27]	22 completers [27]
T. Ziadeh et al., 2021	Bladder instillation for UTI prevention in neurogenic bladder [28]	Neurogenic bladder patients using IC [28]	346 [28]
B. B. Lee et al., 2016	Probiotics for UTI prevention in SCI [29]	SCI patients in New South Wales, Australia [29]	Not specified [29]
V. Gauhar et al., 2022	Coated vs non-coated indwelling catheters [11]	Hospital (various wards including ICU) [11]	36,783 [11]
Mohamed H Gad et al., 2021	Preventive and interventional protocols for CA-UTI [1]	Various healthcare settings [1]	59 studies [1]
Fei Li et al., 2018	Risk factors for CAUTI in hospitalized patients [30]	Hospitalized patients [30]	8,785 [30]
D. de Ridder et al., 2005	Hydrophilic-coated vs uncoated PVC catheters [31]	Multi-center, male SCI patients [31]	123 [31]

Study	Primary Focus	Population / Setting	Sample Size
H. Leek et al., 2019	Single-use vs multiple reuse of IC catheters [32]	CISC users, average age 60, 73% female [32]	23 [32]
R. Darouiche et al., 2006	StatLock securing device and CA-UTI [33]	Multicenter, SCI or MS patients with indwelling catheters [33]	118 [33]
L. Su et al., 2024	Nurse-driven protocols for CAUTI prevention [9]	Not specified [9]	58,195 [9]
Jing Tian et al., 2017	Bladder irrigation and UTI in long-term catheter users [34]	Not specified [34]	1,722 [34]
Zhang Ruijuan et al., 2023	Catheter tracking management in SCI [35]	Hospital, SCI patients [35]	92 [35]
S. Shamout et al., 2016	Self-intermittent catheterization approaches in neurogenic patients [36]	Primarily SCI and MS patients [36]	2,188 [36]
Masoumeh Hosseinpour et al., 2023	UTI prevalence and risk factors in kidney recipients [3]	Kidney transplant recipients, mean age 48.7 years [3]	72,600 [3]
Na Li et al., 2025	Effective interventions to prevent CAUTI [37]	Hospitalized adult patients [37]	12 studies [37]

Study	Primary Focus	Population / Setting	Sample Size
A. Leuck et al., 2015	Silver-impregnated catheter system [38]	University hospital, neurosurgical patients [38]	95 [38]
A. Yuan et al., 2014	Bladder irrigation frequency in long-term catheter users [39]	Not specified [39]	275 [39]
Y. Kai-Larsen et al., 2021	Noble metal alloy-coated catheter for CAUTI prevention [40]	Six hospitals in India, urology/surgery/ICU [40]	1,000 [40]
Hani Salwan AL et al., 2025	Methenamine prophylaxis for recurrent UTIs [41]	Large academic medical center, median age 80 [41]	134 [41]
C. Jia et al., 2013	Botulinum toxin A and UTI in SCI [42]	National rehabilitation center, China, male SCI patients [42]	41 [42]
J. Pannek et al., 2019	Homeopathy for UTI prophylaxis in SCI [43]	Rehabilitation center, Switzerland, SCI patients [43]	35 [43]
H. Giamarellou et al., 2007	Long-term quinolone therapy and bacteriuria in elderly [44]	Institutionalized elderly patients [44]	132 [44]

Study	Primary Focus	Population / Setting	Sample Size
H. Dong et al., 2019	Multifunctional vs conventional suprapubic catheter [45]	Hospital, permanent suprapubic cystostomy patients [45]	91 [45]
J. M. Arreola Guerra et al., 2022	Screening/treatment of asymptomatic bacteriuria post-renal transplant [46]	Post-renal transplant patients, mean age 29.8 years [46]	80 [46]
Michelle Fang et al., 2021	Antibiotic treatment duration for UTI in SCI/D [47]	VA San Diego, SCI/D unit [47]	107 patients, 241 events [47]
J. Meddings et al., 2017	Interventions to reduce UTI in nursing home residents [48]	Nursing homes [48]	19 interventions [48]
M. Hafizi et al., 2019	Mupirocin/betadine-impregnated catheters and UTI [49]	Clinical setting, patients aged 18–75 [49]	150 [49]
Rachel Vopni et al., 2021	Antimicrobial-coated catheters and CAUTI/bacteriuria [50]	Not specified [50]	15 studies [50]
Li Li et al., 2013	Hydrophilic catheters and UTI in SCI [10]	SCI patients using IC [10]	462 [10]

Study	Primary Focus	Population / Setting	Sample Size
M. Beattie et al., 2011	Silver alloy vs uncoated catheters and CAUTI [51]	Hospital adult inpatients [51]	11 papers [51]
J. Stensballe et al., 2007	Nitrofurazone-impregnated catheters in trauma patients [52]	Level 1 trauma center, Copenhagen [52]	~212 planned [52]
R. Kyriakides et al., 2020	D-Mannose for prevention of recurrent UTIs [53]	Catheter and non-catheter users [53]	695 individuals across 6 clinical studies [53]
Ashgan Tolba Elgohary et al., 2020	Educational programs to reduce UTI in catheterized patients [54]	Urology department, Benha University Hospitals [54]	60 patients, 30 nurses [54]
G. Ahmed et al., 2020	Catheter care maintenance bundle and UTI [55]	Neurological department, Assuit University Hospital [55]	60 [55]
Lauren E. Corona et al., 2020	CIC vs pharmacologic treatment and UTI in MS [56]	Institutional database, MS patients with LUTS [56]	37 [56]

Study	Primary Focus	Population / Setting	Sample Size
Nicholas Pryor et al., 2024	Female external urine wicking devices vs IUCs [57]	Various hospital units, primarily female patients [57]	50 studies [57]
M. Stillman et al., 2018	Bladder management and UTI post-SCI discharge [5]	Community, SCI Model System center, mean age 41 [5]	169 [5]
B. Welk et al., 2022	Antibiotic prophylaxis efficacy by neurologic disease [58]	Community, IC users with neurologic disease [58]	138 [58]
Hui-ying Sun et al., 2011	Bladder irrigation necessity in indwelling catheter users [59]	Not specified [59]	120 [59]
J. Penders et al., 2003	Urine culture utility in SCI patients [60]	Ghent University Hospital, SCI patients [60]	74 [60]
Jeanette Fiveash et al., 2020	Resident distraction to reduce CAUTI in LTC [61]	116-bed long-term care facility [61]	~12 CAUTIs baseline [61]
X. Bonfill et al., 2013	Silver alloy-coated catheters in SCI (ESCALE protocol) [62]	Rehabilitation/spinal units in Spain [62]	742 planned [62]

Study	Primary Focus	Population / Setting	Sample Size
Yulong Cao et al., 2018	Urethral cleaning vs disinfection for CAUTI prevention [63]	Hospitalized patients [63]	6,490 [63]
Maria Regina Rachmawati et al., 2016	CIC effect on UTI in SCI [64]	Community dormitories, SCI patients aged 22–62 [64]	26 [64]
Luisa De Palma et al., 2023	CISC training timing and infection [65]	Outpatient spinal unit, Bari, Italy [65]	100 [65]
R. Lan et al., 2013	Long-acting antibacterial material JUC and CAUTI [66]	Hospital settings [66]	3,172 [66]
A. Westgeest et al., 2024	Catheter replacement in CAUTI treatment [67]	Medical/geriatric centers, nursing homes [67]	4 studies [67]
C. Theobald et al., 2017	Multifaceted QI strategy for CAUTI reduction [68]	Hospital ward, medical inpatient veterans [68]	Not specified [68]
F. D'Ambrosio et al., 2022	UTI frequency in IC users [69]	Adult population with various conditions [69]	43 studies [69]

Study	Primary Focus	Population / Setting	Sample Size
M. Plata et al., 2022	Hydrophilic vs non-hydrophilic catheters and UTI [70]	Adults using CIC [70]	525 [70]
N. Nassikas et al., 2020	ICU rounding checklist for CAUTI reduction [71]	Academic community hospital 16-bed ICU [71]	9,288 catheter days [71]
Bindu R. Potugari et al., 2020	Multimodal intervention for CAUTI reduction [72]	Rural 504-bed tertiary care facility [72]	16,195 catheter-days (pre) [72]
Jin-Sook Kim et al., 2017	Periurethral cleaning (water vs antiseptic) and UTI [73]	Not specified [73]	Not specified [73]
Z. Radojicic et al., 2018	Bowel management and UTI frequency in spina bifida [74]	Clinical setting, spina bifida patients [74]	70 [74]
Swee-Ling Toh et al., 2019	Probiotics for UTI prevention in SCI [75]	Spinal units in NSW, Australia, mean age 49.1 [75]	207 [75]
M. G. Meneguetti et al., 2019	Educational program and daily checklist for CAUTI [14]	ICU, tertiary-care hospital [14]	12-year period [14]

Study	Primary Focus	Population / Setting	Sample Size
Matthew Davis et al., 2023	Bladder management and infection risk in SCI [6]	SCI populations [6]	24 studies [6]
D. Gould et al., 2017	Clinical guidelines for CAUTI prevention in nursing homes [76]	Nursing homes and long-term care [76]	8 studies [76]
Peter Darmawan et al., 2026	Catheterization duration and UTI risk post-ureteroplasty [4]	Diverse clinical contexts [4]	66 studies [4]
W. et al., 2012	UTI prevention bundle in neuro ICU [77]	Adult neurological ICU [77]	20,394 catheter-days [77]
S. Chandramohan et al., 2018	Multidisciplinary infection prevention in LTACH [78]	76-bed LTACH, Southeast Michigan [78]	Not specified [78]
Danielle J. Durant et al., 2017	Nurse-driven protocols and CAUTI prevention [79]	US hospital settings [79]	29 studies [79]

Study	Primary Focus	Population / Setting	Sample Size
X. Saenz-Montoya et al., 2020	Non-pharmacological interventions during catheter insertion [80]	Hospitalized non-immunocompromised adults [80]	8,718 [80]
Xiaohui Wu et al., 2016	UTI prevalence and risk factors in renal transplant [2]	Renal transplant recipients [2]	6,671 [2]

Populations most commonly studied included spinal cord injury patients, nursing home residents, hospitalized patients in ICU or surgical wards, and renal transplant recipients. The primary catheter types examined were indwelling urethral, intermittent (clean and sterile), and suprapubic catheters, with a range of coating materials including silver alloy, noble metal alloy, nitrofurazone, hydrophilic polymer, and antibiotic-impregnated surfaces.

Effects

Given the breadth of the evidence, findings are organized thematically by intervention category: (1) catheterization duration and UTI risk, (2) catheter type comparisons, (3) catheter coatings and materials, (4) antibiotic prophylaxis, (5) care bundles, institutional protocols, and behavioral interventions, (6) bladder irrigation and washouts, and (7) other preventive strategies.

Catheterization Duration and UTI Risk

Intervention / Comparison	Key Finding	Effect Estimate	Statistical Significance
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Intervention / Comparison	Key Finding	Effect Estimate	Statistical Significance
Prolonged catheterization as risk factor (meta-analysis of observational studies) [30]	Average CAUTI incidence 13.79 per 1000 catheter-days; prolonged duration is a risk factor [30]	Prevalence 9.33% [30]	Significant [30]
Duration of catheter in renal transplant (meta-analysis) [2]	Longer catheter duration increases UTI risk [2]	OR 1.52 (95% CI 1.03–2.03) [2]	Significant [2]
Long-term indwelling catheter in kidney recipients (meta-analysis) [3]	Long-term indwelling catheter use is a significant risk factor [3]	OR 3.03 (95% CI 1.59–6.59) [3]	P < 0.001 [3]
Early vs late stent/catheter removal post-ureteroplasty (systematic review) [4]	Early removal (≤ 3 weeks) reduces UTI [4]	ORs 0.41–0.53 [4]	Significant [4]

Intervention / Comparison	Key Finding	Effect Estimate	Statistical Significance
Duration risk thresholds (qualitative systematic review) [1]	Risk increases ~5%/day; 35% at 7 days, 70% at 14 days, ~100% at ≥30 days [1]	Dose-dependent [1]	Significant [1]
Nephrostomy catheter dwell time (systematic review) [23]	UTI risk increases beyond 7–14 days of catheterization [23]	CAUTI incidence 8%–40% [23]	Not specified [23]
IC-associated UTI frequency (systematic review) [69]	UTI range of 26%–63% in IC users [69]	Range reported [69]	Not specified [69]
Bladder management post-SCI discharge [5]	Indwelling catheter: 57% UTI; IC: 37%; spontaneous voiding: 22% [5]	$p < 0.001$ among strategies [5]	$p < 0.01$ for voiding vs catheterized [5]

The evidence consistently demonstrates a dose-dependent relationship between catheterization duration and UTI risk. Meta-analytic data from renal transplant populations show that each increment in catheter duration increases UTI odds (OR 1.52) [2], while in kidney recipients with long-term indwelling catheters, the risk is threefold (OR 3.03) [3]. The comprehensive systematic review by Darmawan et al. (2026) identified threshold effects at 7, 14, and 30 days, with early removal (≤ 3 weeks) yielding odds ratios of 0.41–0.53 compared to later removal [4]. The qualitative review by Gad et al. (2021) described an approximate daily risk

increase of 5%, reaching near-certainty of bacteriuria at 30 days [1]. Among SCI patients followed for one year post-discharge, cumulative UTI incidence reached 71%, with indwelling catheter users experiencing significantly more UTIs (57%) than intermittent catheterization users (37%) or spontaneous voiders (22%) [5].

Catheter Type Comparisons: Indwelling vs Intermittent vs Suprapubic

Comparison	Key Finding	Effect Estimate	Statistical Significance
Indwelling vs IC in NLUTD (cross-sectional) [7]	No significant difference in UTI frequency [7]	8% prevalence in both groups at visit [7]	p = 0.782 [7]
Indwelling vs IC in SCI (systematic review) [6]	No significant difference; studies favoring IC had critical risk of bias [6]	Not quantified [6]	Not significant [6]
CIC vs pharmacologic therapy in MS [56]	CIC associated with 7-fold higher UTI odds [56]	OR 6.8 [56]	p = 0.01 [56]
CIC vs control in SCI [64]	CIC reduced UTI incidence (38.5% vs 84.6%) [64]	Incidence difference [64]	p = 0.016 [64]

Comparison	Key Finding	Effect Estimate	Statistical Significance
Urethral vs suprapubic in nursing homes [20]	Suprapubic associated with lower CAUTI (6.6 vs 8.8 per 1000 device-days) [20]	HR 0.73 (95% CI 0.53–1.00) [20]	p = 0.05 [20]
Multifunctional vs conventional suprapubic [45]	No influence on catheter-related UTI [45]	Not significant [45]	p = 0.540 [45]
Female external wicking devices vs IUCs (meta-analysis) [57]	IUC utilization decreased 14%; CAUTI decreased up to 54% with protocols [57]	IRR 0.46 (95% CI 0.32–0.66) with protocols [57]	p < 0.001 (with protocols) [57]

The comparison between indwelling and intermittent catheterization produced heterogeneous results. The systematic review by Davis et al. (2023) found that only 3 of 24 studies reported significantly higher UTI risk with indwelling catheters, and all three had critical risk of bias [6]. The cross-sectional study by Neumeier et al. (2023) found no relevant difference in UTI frequency between indwelling and IC groups (8% prevalence in both) [7], though the indwelling group was older and had higher comorbidity [7]. In contrast, Rachmawati et al. (2016) found that CIC significantly reduced UTI incidence compared to no CIC in SCI patients (38.5% vs 84.6%, p = 0.016) [64], while Corona et al. (2020) found CIC was associated with increased UTI risk (OR 6.8, p = 0.01) compared to pharmacologic treatment in MS patients [56]. Suprapubic catheters showed a marginal advantage over urethral catheters in nursing home residents (6.6 vs 8.8 CAUTIs per 1000

device-days, $p = 0.05$), though the suprapubic group had higher rates of multidrug-resistant organism colonization [20]. Female external wicking devices significantly reduced CAUTI rates when implemented with standardized protocols (IRR 0.46, $p < 0.001$) [57].

Catheter Coatings and Materials

Coating / Material	Key Finding	Effect Estimate	Statistical Significance
Coated vs non-coated (meta-analysis, 12 RCTs) [11]	No overall significant difference; benefit for long-term use (>14 days) [11]	Overall: RR 0.87 (95% CI 0.75–1.00); >14 days: RR 0.82 (95% CI 0.68–0.99) [11]	$p = 0.06$ overall; $p = 0.04$ for >14 days [11]
Antimicrobial-coated catheters (meta-analysis, 15 RCTs) [50]	Significant negative association with CAUTI [50]	OR 0.80 (95% CI 0.74–0.88) [50]	$p < 0.001$ [50]
Noble metal alloy (BIP Foley) vs uncoated (RCT, n=1000) [40]	69% reduction in CAUTI [40]	6.5 vs 20.8 CAUTI/1000 catheter-days; IRR 0.31 (95% CI 0.21–0.46) [40]	$p < 0.001$ [40]
Silver alloy-coated vs standard in SCI (RCT, n=489) [25]	No difference in symptomatic UTI [25]	OR 0.96 (95% CI 0.49–1.87) [25]	Not significant [25]

Coating / Material	Key Finding	Effect Estimate	Statistical Significance
Silver alloy catheters (systematic review) [51]	Emerging pattern favoring silver alloy, but inconclusive [51]	Not quantified [51]	Heterogeneity precluded meta-analysis [51]
Silver-impregnated catheter (pilot RCT, n=95) [38]	Trend toward longer time to bacteriuria [38]	Not quantified [38]	p = 0.03 (evaluable); p = 0.08 (ITT) [38]
Nitrofurazone-impregnated vs standard silicone (RCT) [52]	Reduced bacteriuria/funguria and need for antibiotic changes [52]	Not quantified in abstract [52]	Not specified [52]
Mupirocin/betadine-impregnated vs conventional (RCT, n=150) [49]	Conventional group: 56% UTI; Mupirocin: 24% [49]	Incidence difference [49]	p < 0.004 [49]
Hydrophilic vs non-hydrophilic IC (meta-analysis, 5 RCTs) [10]	Lower UTI incidence with hydrophilic [10]	OR 0.36 (95% CI 0.24–0.54) [10]	p < 0.0001 [10]

Coating / Material	Key Finding	Effect Estimate	Statistical Significance
Hydrophilic vs non-hydrophilic IC (meta-analysis, 9 RCTs) [70]	Lower UTI risk with hydrophilic [70]	RR 0.78 (95% CI 0.62–0.97) [70]	Significant [70]
Hydrophilic vs uncoated PVC IC (RCT, n=123) [31]	Fewer patients with ≥ 1 UTI in hydrophilic group (64% vs 82%) [31]	Incidence difference [31]	$p = 0.02$ [31]
Hydrophilic vs noncoated IC in SCI (RCT, n=56) [21]	Fewer treated UTIs with hydrophilic [21]	Not quantified [21]	$p < 0.05$ [21]
Gel reservoir/hydrophilic vs sterile non-coated (systematic review) [24]	Fewer patients reporting ≥ 1 UTI; but no difference in mean monthly UTIs [24]	149–153 fewer per 1000; mean difference 0.01 [24]	$p = 0.04$ for ≥ 1 UTI; $p = 0.84$ for monthly rate [24]
JUC antibacterial material (meta-analysis, 20 studies) [66]	Significant CAUTI reduction [66]	RD = -0.15 (95% CI -0.18 to -0.13) [66]	$p < 0.05$ [66]

Coating / Material	Key Finding	Effect Estimate	Statistical Significance
Single-use vs multiple reuse IC (crossover RCT, n=23) [32]	No difference in UTI rates [32]	Not quantified [32]	p = 0.26 [32]

The evidence on catheter coatings and materials is substantial but reveals important nuances. For indwelling catheters, antimicrobial coatings collectively demonstrate a modest benefit (OR 0.80, 95% CI 0.74–0.88) [50], but this aggregate masks considerable variation by coating type and population. The noble metal alloy-coated BIP Foley catheter showed a striking 69% reduction in CAUTI in a large Indian multicenter trial [40], whereas silver alloy-coated catheters showed no benefit in SCI patients (OR 0.96) [25]. The meta-analysis by Gauhar et al. (2022) found that coated catheter benefits were statistically significant only for long-term use (>14 days; RR 0.82, p = 0.04) but not for short-term use [11].

For intermittent catheterization, hydrophilic-coated catheters consistently demonstrated reduced UTI incidence across multiple meta-analyses. Li Li et al. (2013) reported an OR of 0.36 (95% CI 0.24–0.54, p < 0.0001) [10], and Plata et al. (2022) found an RR of 0.78 (95% CI 0.62–0.97) [70]. However, the cost-effectiveness analysis by Bermingham et al. (2013) found that while gel reservoir catheters were most effective, they cost >£54,350 per QALY gained [24], and the difference in mean monthly UTI rates between hydrophilic and sterile non-coated catheters was not significant (p = 0.84) [24]. Single-use versus multiple reuse of IC catheters showed no significant difference in UTI rates [32].

Antibiotic Prophylaxis

Intervention	Key Finding	Effect Estimate	Statistical Significance

Intervention	Key Finding	Effect Estimate	Statistical Significance
Continuous low-dose antibiotic prophylaxis in CISC users (AnTIC RCT, n=404) [12]	48% reduction in symptomatic UTI [12]	IRR 0.52 (95% CI 0.44–0.61) [12]	$p < 0.0001$ [13]
Antibiotic prophylaxis by neurologic disease (secondary analysis of AnTIC) [58]	Overall IRR 0.59; most protective in SCI (IRR 0.23); least in spina bifida (IRR 0.85) [58]	IRR 0.59 (95% CI 0.46–0.76) [58]	Significant overall [58]
WOCA prophylaxis in SCI (RCT, n=45) [18]	Median 1.0 vs 2.5 UTIs; no febrile UTI in WOCA vs 45% in control [18]	Not formally calculated [18]	$p = 0.0241$ [18]
WOCA prophylaxis in SCI (observational, 2-year follow-up) [26]	UTI decreased from 9.4 to 1.8 per patient-year [26]	~81% reduction [26]	Significant [26]
Methenamine prophylaxis in chronic catheter users [41]	Reduced from 3.5 to 2.1 UTIs/year in catheter users [41]	~40% reduction [41]	$p = 0.0004$ [41]

Intervention	Key Finding	Effect Estimate	Statistical Significance
Short (5-day) vs long (10-day) antibiotics for CA-UTI in SCI [22]	100% clinical cure in both; higher recurrence with short course [22]	Not quantified [22]	Not specified [22]
≤7 vs >7 day antibiotic treatment for UTI in SCI/D [47]	No significant difference in recurrence at 30 or 90 days [47]	Not significant [47]	Not significant [47]
Screening/treatment of asymptomatic bacteriuria post-transplant (RCT, n=80) [46]	Treatment group had more UTIs and pyelonephritis [46]	Intervention higher: 25% vs 10% UTI [46]	p = 0.07 (UTI); p = 0.04 (pyelonephritis) [46]

The AnTIC trial, the largest RCT in this area, demonstrated that continuous low-dose antibiotic prophylaxis reduced symptomatic UTI by 48% (IRR 0.52, 95% CI 0.44–0.61, $p < 0.0001$) in CISC users [12, 13]. However, increased antimicrobial resistance was a significant concern: resistance to nitrofurantoin (24% vs 9%), trimethoprim (67% vs 33%), and co-trimoxazole (53% vs 24%) was significantly higher in the prophylaxis group [13, 16]. A secondary analysis revealed that prophylaxis efficacy varied by neurologic diagnosis, with the greatest benefit in SCI (IRR 0.23) and no significant benefit in spina bifida (IRR 0.85) [58].

The weekly oral cyclic antibiotic (WOCA) regimen demonstrated substantial benefit in SCI patients, with the observational study showing an 81% reduction in UTIs over 2 years and no

emergence of multidrug-resistant bacteria [26], and the RCT confirming a reduction in symptomatic UTIs (median 1.0 vs 2.5, $p = 0.024$) and elimination of febrile UTIs [18]. Methenamine prophylaxis also showed unexpected effectiveness in chronic catheter users, reducing UTIs from 3.5 to 2.1 per year ($p = 0.0004$) [41]. Notably, screening and treating asymptomatic bacteriuria in post-renal transplant patients was counterproductive, with higher UTI and pyelonephritis incidence in the intervention group [46].

Care Bundles, Institutional Protocols, and Behavioral Interventions

Intervention	Key Finding	Effect Estimate	Statistical Significance
Reminder systems/stop orders for catheter removal (meta-analysis) [8]	52% reduction in CAUTI rate [8]	37% decrease in catheterization duration [8]	$p < 0.001$ [8]
Nurse-driven protocols (meta-analysis, 10 studies) [9]	55.91% reduced CAUTI risk [9]	Catheter utilization 34.84% vs 49.40% [9]	Significant [9]
Nurse-driven protocols (systematic review, 29 studies) [79]	All studies reported CAUTI reductions; 1 showed no change [79]	Not quantified [79]	High risk of bias noted [79]

Intervention	Key Finding	Effect Estimate	Statistical Significance
Targeted infection prevention in nursing homes (RCT, n=418) [19]	Reduced CAUTI (HR 0.54 for first; HR 0.69 for all) [19]	HR 0.54 (95% CI 0.30–0.97) [19]	Significant [19]
UTI prevention bundle in neuro ICU [77]	CAUTI reduced from 13.3 to 4.0 per 1000 catheter-days [77]	Linear relationship ($r^2 = 0.79$) with catheter utilization [77]	$p < 0.001$ [77]
Multimodal intervention in rural tertiary care [72]	SIR reduced by 60.2%; catheter days reduced by 17.6% [72]	SIR from 1.524 to 0.607 [72]	$p < 0.05$ [72]
Multifaceted QI strategy in veterans [68]	Catheter use declined 35%; days between CAUTIs increased from 101 to >400 [68]	Not formally tested [68]	Not specified [68]
ICU rounding checklist [71]	CAUTI rate from 4.62 to 0.45 in year 2 [71]	~90% reduction by year 2 [71]	$p = 0.028$ (year 2) [71]
Educational program and daily checklist (12-year quasi-experimental) [14]	CAUTI density from 14.9 to 1.1 per 1000 catheter-days [14]	~93% reduction [14]	Not specified [14]

Intervention	Key Finding	Effect Estimate	Statistical Significance
Catheter care maintenance bundle [55]	Significant reduction in UTI incidence [55]	Not quantified [55]	$p < 0.003$ [55]
Nursing education program [54]	Control group UTI rate 86% vs study group 6.6% [54]	~93% reduction [54]	Not specified [54]
Catheter follow-up management in SCI [35]	UTI incidence 17.78% in intervention vs control [35]	Not quantified [35]	$p = 0.003$ [35]
Resident distraction during perineal care in LTC [61]	73% reduction in CAUTI [61]	1.86 to 0.51 per 1000 catheter-days [61]	$p = 0.02$ [61]
Multidisciplinary infection prevention in LTACH [78]	CAUTI rate did not decrease during intervention [78]	CAUTI rate 4.36 during vs 2.49 pre-intervention [78]	Not significant [78]

Intervention	Key Finding	Effect Estimate	Statistical Significance
Interventions in nursing homes (systematic review, 19 studies) [48]	5 studies showed CAUTI reduction (1 significantly); 9 showed UTI reduction (none significantly) [48]	Not quantified [48]	Mostly not significant [48]

Care bundles and institutional protocols represented the most consistently applied category of interventions. Reminder systems and stop orders reduced CAUTI rates by 52% [8], and nurse-driven protocols achieved a 55.91% risk reduction [9]. The most dramatic sustained reductions came from long-term, multi-component programs: Menegueti et al. (2019) documented a decline from 14.9 to 1.1 CAUTIs per 1000 catheter-days over a 12-year period combining education and daily checklists [14], and the neuro ICU bundle reduced rates from 13.3 to 4.0 per 1000 catheter-days with a strong linear relationship to catheter utilization ($r^2 = 0.79$) [77]. However, the systematic review of nursing home interventions found that most studies were underpowered, with only 1 of 5 studies showing significant CAUTI reduction [48]. One LTACH study found that CAUTI rates paradoxically increased during intervention, though this may reflect denominator effects from rapid catheter day reduction [78].

Bladder Irrigation and Washouts

Intervention	Key Finding	Effect Estimate	Statistical Significance

Intervention	Key Finding	Effect Estimate	Statistical Significance
Bladder irrigation vs none (meta-analysis, 9 RCTs) [34]	Irrigation reduces UTI; twice/week optimal [34]	Not quantified [34]	Not specified [34]
Irrigation frequency (RCT, n=275) [39]	Twice/week: 17.14% UTI at day 21; no irrigation: 40.58% [39]	Significant difference at days 7, 14, 21 [39]	$p < 0.05$ [39]
Frequent vs no irrigation (RCT, n=120) [59]	Frequent irrigation (2×/day) increased UTI to 56.67% vs 13.33% without irrigation [59]	$\chi^2 = 18.73$ [59]	$p < 0.01$ [59]
Saline vs acidic vs no washout (RCT, n=80) [17]	Saline washout reduced S-CAUTI (IRR 0.40) [17]	IRR 0.40 (97.5% CI 0.20–0.80) [17]	$p = 0.003$ [17]
Bladder instillation in neurogenic bladder (systematic review) [28]	Gentamicin, hyaluronic acid, and Lactobacillus rhamnosus reduce UTI [28]	Not quantified [28]	Not specified [28]

A notable finding regarding bladder irrigation is the non-linear dose-response relationship: twice-weekly irrigation was superior to both more frequent (daily or twice daily) and no irrigation

[34, 39]. Strikingly, Sun et al. (2011) found that twice-daily irrigation actually increased UTI rates to 56.67%, compared to 13.33% with no irrigation at all [59], suggesting that overly frequent irrigation disrupts protective mechanisms or introduces infection. Weekly saline washouts showed the most favorable profile, with significant S-CAUTI reduction (IRR 0.40, $p = 0.003$) [17].

Other Preventive Strategies

Intervention	Key Finding	Effect Estimate	Statistical Significance
Probiotics (RC14-GR1 and/or LGG-BB12) in SCI (RCT, n=207) [75]	No significant effect on UTI prevention [75]	HR 0.67 (95% CI 0.39–1.18) for RC14-GR1 [75]	$p = 0.17$ [75]
D-Mannose for recurrent UTI prevention (systematic review) [53]	Reduced recurrent UTIs and improved QoL in catheter and non-catheter users [53]	Not quantified [53]	Not specified [53]
Cranberry supplement in long-term catheter users (pre/post, n=22) [27]	Reduced symptomatic CA-UTIs; antibiotic resistance reduced 28% [27]	Not quantified [27]	No controls [27]
Botulinum toxin A in SCI with NDO (n=41) [42]	UTIs decreased from 1.39 to 0.78 per 6 months [42]	~44% reduction [42]	$p = 0.023$ [42]

Intervention	Key Finding	Effect Estimate	Statistical Significance
Homeopathy adjunct in SCI (n=35) [43]	Significant decrease in UTIs in homeopathy group [43]	Not quantified [43]	Significant [43]
Bowel management in spina bifida (n=70) [74]	Mean UTIs 0.3 vs 1.1 with bowel management [74]	~73% reduction [74]	$p < 0.001$ [74]
Urethral cleaning method comparison (network meta-analysis, n=6490) [63]	No significant differences among methods; chlorhexidine ranked first [63]	Not significant [63]	$p > 0.05$ for all [63]
CIC self-management training adherence [65]	Adherence to prescribed frequency reduces infection risk [65]	Not quantified [65]	Infections more frequent in MS ($p < 0.03$) [65]
StatLock securing device (RCT, n=118) [33]	45% reduction in symptomatic UTI (not significant) [33]	RR 0.55 (95% CI 0.25–1.22) [33]	$p = 0.16$ [33]

Intervention	Key Finding	Effect Estimate	Statistical Significance
Catheter replacement vs retention in CAUTI (systematic review) [67]	Conflicting evidence; one RCT favors replacement, another retainment [67]	Recurrence 11% vs 26% (one RCT); 32% vs 11% (another) [67]	Inconclusive [67]

Among non-antibiotic strategies, probiotics did not demonstrate significant benefit in a well-designed double-blind RCT in SCI patients (HR 0.67, $p = 0.17$ for RC14-GR1) [75], though a post-hoc analysis suggested possible benefit for one probiotic strain alone [75]. D-Mannose showed promise across multiple clinical studies, reducing recurrent UTIs and improving quality of life [53]. An unexpected finding was the significant benefit of bowel management in spina bifida patients, reducing mean UTIs from 1.1 to 0.3 per year ($p < 0.001$) [74], highlighting the role of cross-system interactions. Detrusor botulinum toxin A injection significantly reduced UTI in SCI patients with neurogenic detrusor overactivity ($p = 0.023$), with the effect linked to decreased detrusor pressure [42]. The question of whether to replace catheters during CAUTI treatment remains unresolved, with two RCTs yielding opposing results [67].

Synthesis

Reconciling the Indwelling vs Intermittent Catheterization Debate

The most persistent controversy in this literature concerns whether indwelling catheters genuinely cause more UTIs than intermittent catheterization. The conventional recommendation favoring intermittent catheterization is challenged by the systematic review of Davis et al. (2023), which found that all three studies reporting significantly higher UTI risk with indwelling catheters had critical risk of bias, and most studies showed less than 20% difference between methods [6]. The cross-sectional comparison by Neumeier et al. (2023) similarly found no difference (8% UTI prevalence in both groups) [7].

This apparent equivalence may be explained by confounding by indication: patients prescribed indwelling catheters tend to be older, have higher comorbidity indices [7], and have more severe neurological impairment [5]. The significant difference observed by Stillman et al. (2018) — indwelling 57% vs IC 37% — may partially reflect these population differences rather than a pure catheter-type effect [5]. The finding by Corona et al. (2020) that CIC was associated with 7-fold higher UTI odds in MS patients [56] is likely influenced by the fact that CIC patients had more severe bladder dysfunction requiring catheterization, while pharmacologic therapy patients had milder symptoms.

The weight of higher-quality evidence suggests that catheter type per se is a less important determinant of UTI risk than was historically assumed, and that clinician and patient preference, functional status, and quality of catheter care may be more influential factors.

The Duration-Risk Relationship: Thresholds and Dose-Response

The evidence converges on a strong, dose-dependent relationship between catheterization duration and UTI risk, with identifiable thresholds at approximately 7, 14, and 30 days [1, 4]. The mechanism underlying this relationship involves progressive biofilm formation on catheter surfaces, which provides a scaffold for bacterial colonization and ascension [23]. The finding that coated catheters provide benefit specifically in long-term (>14 day) use [11] is mechanistically consistent: antimicrobial coatings may delay but not prevent biofilm formation, yielding a window of protection that becomes meaningful only when catheterization extends beyond the initial high-risk period.

The clinical implication is that early catheter removal remains the most powerful intervention, as consistently demonstrated by the 52% CAUTI reduction with reminder systems [8], the 55.91% reduction with nurse-driven protocols [9], and the strong linear relationship between catheter utilization rates and CAUTI rates ($r^2 = 0.79$) [77].

Explaining Heterogeneity in Coating Effectiveness

The variable efficacy of catheter coatings across studies can be explained by population and context differences. The BIP Foley catheter showed a 69% CAUTI reduction in Indian hospitals [40], while silver alloy catheters showed no benefit in SCI patients [25]. Several factors likely

contribute: (1) baseline CAUTI rates were much higher in the Indian study setting (20.8 per 1000 catheter-days in controls) [40] compared to SCI specialty centers, creating more room for improvement; (2) SCI patients have fundamentally altered urinary tract physiology including neurogenic detrusor overactivity and impaired immune function [43], which may overwhelm the antimicrobial capacity of coatings; and (3) the open-label design of the BIP Foley trial [40] and 3:1 randomization ratio may have introduced bias. For intermittent catheters, hydrophilic coatings demonstrate more consistent benefit (OR 0.36 [10] to RR 0.78 [70]), likely because the coating's primary mechanism — reduced urethral friction and trauma — addresses a catheter-specific risk factor rather than competing against systemic susceptibility.

Antibiotic Prophylaxis: Efficacy vs Resistance Trade-off

Antibiotic prophylaxis consistently reduces UTI incidence (IRR 0.52 for continuous low-dose [12]; ~81% reduction for WOCA [26]), but the emergence of resistance remains a critical concern. The AnTIC trial demonstrated significantly elevated resistance rates for nitrofurantoin (24% vs 9%), trimethoprim (67% vs 33%), and co-trimoxazole (53% vs 24%) after 12 months of prophylaxis [13]. The WOCA regimen appeared to avoid this problem over 2 years [18, 26], possibly because the weekly cycling of two antibiotics reduces selection pressure on any single resistance pathway. However, the WOCA evidence comes from smaller studies with shorter follow-up.

The differential efficacy across neurologic conditions (SCI: IRR 0.23; spina bifida: IRR 0.85) [58] suggests that the UTI pathophysiology differs between conditions. SCI patients may have more bacteriuria driven by reversible, catheter-dependent mechanisms amenable to prophylaxis, whereas spina bifida patients may have more structural contributors to UTI risk.

Institutional Interventions: Sustainability and Setting Effects

The most impressive CAUTI reductions come from sustained, multicomponent institutional programs. The 12-year program by Meneguetti et al. (2019) reduced CAUTI density from 14.9 to 1.1 per 1000 catheter-days [14], and the neuro ICU bundle achieved a 70% reduction [77]. However, the LTACH study by Chandramohan et al. (2018) demonstrated that CAUTI rates rebounded after the intervention period ended [78], underscoring that continuous vigilance is

required. In nursing home settings, the systematic review by Meddings et al. (2017) found that most studies were underpowered, with none achieving statistically significant UTI reduction [48], likely reflecting the challenges of implementing standardized protocols in long-term care where staffing and resources are more constrained [76].

The finding that a simple intervention — distracting combative nursing home residents during perineal care — reduced CAUTI by 73% ($p = 0.02$) [61] highlights that practical, context-specific barriers may be more important than the type of protocol implemented. This is consistent with the observation that female external wicking devices significantly reduced CAUTI only when accompanied by implementation protocols (IRR 0.46, $p < 0.001$) but not without them (IRR 0.68, $p = 0.17$) [57].

Key Conclusions by Context

For patients requiring short-term catheterization (<7 days), the primary strategy should be minimizing catheterization duration through reminder systems and stop orders [8, 9]. For patients requiring catheterization of 7–30 days, coated catheters (particularly noble metal alloy) may provide additional benefit [11, 40], and institutional care bundles are effective [72, 77]. For patients requiring long-term or permanent catheterization (>30 days), the evidence supports antibiotic prophylaxis for those with recurrent symptomatic UTIs (particularly those with SCI) [12, 58], optimal irrigation frequency (twice weekly) [34, 39], and hydrophilic catheters for intermittent catheterization users [10, 70]. The choice between indwelling and intermittent catheterization should be guided by patient functional status and preference rather than infection risk alone [6, 7].

DISCUSSION

This systematic review of 80 studies provides several key findings regarding the relationship between long-term urinary catheter use and recurrent UTIs. The results are organized around major themes: the duration–risk relationship, comparison of catheter types, effectiveness of catheter coatings, antibiotic prophylaxis trade-offs, institutional interventions, and non-antibiotic strategies.

Dose-Dependent Relationship Between Catheter Duration and UTI Risk

The evidence consistently demonstrates a strong, dose-dependent association between catheterization duration and UTI risk. Meta-analytic data from renal transplant recipients showed that each increment in catheter duration increases UTI odds (OR 1.52, 95% CI 1.03–2.03) (2), and long-term indwelling catheters were associated with a threefold higher risk (OR 3.03, 95% CI 1.59–6.59) (3). The systematic review by Darmawan et al. (2026) identified critical thresholds at 7, 14, and 30 days, with early removal (≤ 3 weeks) yielding ORs of 0.41–0.53 (4). Gad et al. (2021) estimated an approximate daily risk increase of 5%, reaching near-certain bacteriuria by 30 days (1). Among SCI patients followed for one year post-discharge, cumulative UTI incidence reached 71%, with indwelling catheter users experiencing significantly more UTIs (57%) than intermittent catheter users (37%) or spontaneous voiders (22%) (5).

Mechanistic interpretation: The progressive biofilm formation on catheter surfaces explains this dose-response relationship. Biofilm provides a protected niche for bacterial colonization and ascension, and even antimicrobial coatings only delay—not prevent—this process (23). This explains why coated catheters show benefit specifically in long-term (>14 day) use (11), as the protective window becomes clinically meaningful only when catheterization extends beyond the initial high-risk period.

Indwelling Versus Intermittent Catheterization: Resolving the Controversy

One of the most persistent controversies is whether indwelling catheters cause more UTIs than intermittent catheterization. The systematic review by Davis et al. (2023) found that only 3 of 24 studies reported significantly higher UTI risk with indwelling catheters, and all three had critical risk of bias (6). Similarly, the cross-sectional study by Neumeier et al. (2023) found no relevant difference in UTI frequency between indwelling and intermittent catheter groups (8% prevalence in both), though the indwelling group was older and had higher comorbidity (7).

These findings challenge conventional recommendations that favor intermittent catheterization based on infection risk alone. The apparent equivalence may be explained by **confounding by indication**: patients prescribed indwelling catheters tend to be older, have more severe neurological impairment, and higher comorbidity indices (5,7). The significant difference reported by Stillman et al. (2018)—57% vs 37%—likely reflects these population differences rather

than a pure catheter-type effect (5). The finding by Corona et al. (2020) that clean intermittent catheterization was associated with 7-fold higher UTI odds in multiple sclerosis patients is similarly influenced by more severe bladder dysfunction requiring catheterization (56). Therefore, catheter type per se appears less important than functional status, quality of care, and patient preference.

Catheter Coatings and Materials: Efficacy Depends on Context

The meta-analysis by Gauhar et al. (2022) found that coated catheters provided benefit only for long-term use (>14 days; RR 0.82, $p=0.04$) and not for short-term use (11). Antimicrobial-coated catheters collectively demonstrated a modest benefit (OR 0.80, 95% CI 0.74–0.88) (50), but this aggregate masks considerable variation.

The **noble metal alloy-coated BIP Foley catheter** showed a striking 69% reduction in CAUTI in a large Indian multicenter trial (IRR 0.31, 95% CI 0.21–0.46, $p<0.001$) (40). In contrast, silver alloy-coated catheters showed no benefit in SCI patients (OR 0.96, 95% CI 0.49–1.87) (25). Several factors explain this heterogeneity. First, baseline CAUTI rates were much higher in the Indian study (20.8 per 1000 catheter-days in controls) (40) compared to SCI specialty centers, creating more room for improvement. Second, SCI patients have fundamentally altered urinary tract physiology—including neurogenic detrusor overactivity and impaired immune function—which may overwhelm the antimicrobial capacity of coatings (43). Third, the open-label design of the BIP Foley trial and its 3:1 randomization ratio may have introduced bias (40).

For **intermittent catheterization**, hydrophilic coatings demonstrated more consistent benefit across multiple meta-analyses: OR 0.36 (95% CI 0.24–0.54) (10) and RR 0.78 (95% CI 0.62–0.97) (70). The mechanism likely involves reduced urethral friction and trauma, addressing a catheter-specific risk factor rather than competing against systemic susceptibility. However, cost-effectiveness remains a concern: Bermingham et al. (2013) found that gel reservoir catheters cost $>£54,350$ per QALY gained, and the difference in mean monthly UTI rates between hydrophilic and sterile non-coated catheters was not significant ($p=0.84$) (24). Single-use versus multiple reuse of intermittent catheters showed no significant difference in UTI rates (32).

Antibiotic Prophylaxis: Efficacy Versus Antimicrobial Resistance

The AnTIC trial, the largest RCT in this area (n=404), demonstrated that continuous low-dose antibiotic prophylaxis reduced symptomatic UTI by 48% (IRR 0.52, 95% CI 0.44–0.61, $p<0.0001$) in clean intermittent self-catheterization users (12,13). However, increased antimicrobial resistance was a major concern: resistance to nitrofurantoin (24% vs 9%), trimethoprim (67% vs 33%), and co-trimoxazole (53% vs 24%) was significantly higher in the prophylaxis group after 12 months (13,16).

The **weekly oral cyclic antibiotic (WOCA)** regimen showed substantial benefit in SCI patients, with an observational study reporting an 81% reduction in UTIs over 2 years and no emergence of multidrug-resistant bacteria (26), and an RCT confirming a reduction in symptomatic UTIs (median 1.0 vs 2.5, $p=0.024$) and elimination of febrile UTIs (18). The apparent avoidance of resistance may be explained by weekly cycling of two antibiotics, which reduces selection pressure on any single resistance pathway, though follow-up was shorter than in the AnTIC trial.

A critical secondary analysis of the AnTIC trial revealed that prophylaxis efficacy varied markedly by neurologic diagnosis: greatest benefit in SCI (IRR 0.23) and no significant benefit in spina bifida (IRR 0.85) (58). This suggests that UTI pathophysiology differs between conditions: SCI patients may have more bacteriuria driven by reversible, catheter-dependent mechanisms, whereas spina bifida patients may have more structural contributors (e.g., anatomical abnormalities, bowel dysfunction) that are less responsive to antibiotics.

Importantly, screening and treating asymptomatic bacteriuria in post-renal transplant patients was **counterproductive**, with higher UTI and pyelonephritis incidence in the intervention group (25% vs 10% UTI, $p=0.07$; 14% vs 2% pyelonephritis, $p=0.04$) (46). This supports current guidelines that recommend against treating asymptomatic bacteriuria except in specific high-risk populations (e.g., pregnant women, urologic surgery patients).

Institutional Interventions: Care Bundles and Protocols

Care bundles and institutional protocols represented the most consistently effective category of interventions. Reminder systems and stop orders reduced CAUTI rates by 52% (8), and nurse-driven protocols achieved a 55.91% risk reduction (9). The most dramatic sustained reductions came from long-term, multi-component programs: Meneguetti et al. (2019) documented a decline

from 14.9 to 1.1 CAUTIs per 1000 catheter-days over a 12-year period combining education and daily checklists (14). The neuro ICU bundle reduced rates from 13.3 to 4.0 per 1000 catheter-days with a strong linear relationship to catheter utilization ($r^2=0.79$) (77). Multimodal interventions in rural tertiary care reduced the standardized infection ratio by 60.2% (72).

However, sustainability and setting effects are critical. The LTACH study by Chandramohan et al. (2018) demonstrated that CAUTI rates paradoxically increased during intervention (4.36 vs 2.49 per 1000 catheter-days), though this may reflect denominator effects from rapid catheter day reduction (78). In nursing home settings, the systematic review by Meddings et al. (2017) found that most studies were underpowered, with only 1 of 5 studies showing significant CAUTI reduction (48), reflecting challenges in implementing standardized protocols in long-term care where staffing and resources are more constrained (76).

Notably, a simple intervention—distracting combative nursing home residents during perineal care—reduced CAUTI by 73% ($p=0.02$) (61). This highlights that practical, context-specific barriers may be more important than the type of protocol implemented. Similarly, female external wicking devices significantly reduced CAUTI only when accompanied by implementation protocols (IRR 0.46, $p<0.001$) but not without them (IRR 0.68, $p=0.17$) (57).

Bladder Irrigation: A Non-Linear Dose-Response

Bladder irrigation showed a non-linear relationship with UTI risk. Twice-weekly irrigation was superior to both more frequent (daily or twice daily) and no irrigation (34,39). Strikingly, Sun et al. (2011) found that twice-daily irrigation actually increased UTI rates to 56.67%, compared to 13.33% with no irrigation at all (59), suggesting that overly frequent irrigation disrupts protective mucosal mechanisms or introduces infection. Weekly saline washouts showed the most favorable profile, with significant symptomatic CAUTI reduction (IRR 0.40, 97.5% CI 0.20–0.80, $p=0.003$) (17).

Other Preventive Strategies

Among non-antibiotic strategies, **probiotics** did not demonstrate significant benefit in a well-designed double-blind RCT in SCI patients (HR 0.67, $p=0.17$ for RC14-GR1) (75). **D-Mannose** showed promise across multiple clinical studies, reducing recurrent UTIs and improving

quality of life in both catheter and non-catheter users (53). **Bowel management** in spina bifida patients reduced mean UTIs from 1.1 to 0.3 per year ($p<0.001$) (74), highlighting the role of cross-system interactions (e.g., constipation leading to bacterial translocation or voiding dysfunction). **Detrusor botulinum toxin A injection** significantly reduced UTI in SCI patients with neurogenic detrusor overactivity ($p=0.023$), with the effect linked to decreased detrusor pressure (42). The question of whether to replace catheters during CAUTI treatment remains unresolved, with two RCTs yielding opposing results (67).

CONCLUSION AND RECOMMENDATIONS

Conclusion

Summary of Key Findings: Long-term urinary catheter use (≥ 30 days) is associated with a dose-dependent increase in recurrent UTI risk, with identifiable thresholds at 7, 14, and 30 days. Early catheter removal remains the single most effective preventive strategy. The choice between indwelling and intermittent catheterization should be guided by patient functional status and preference rather than infection risk alone, as higher-quality evidence shows no consistent difference when confounders are accounted for. Coated catheters provide benefit specifically for long-term use (>14 days), with noble metal alloy coatings showing the largest effect in high-baseline-risk settings and hydrophilic coatings consistently reducing UTI risk in intermittent catheter users. Antibiotic prophylaxis effectively reduces symptomatic UTIs (48% reduction) but increases antimicrobial resistance; the weekly oral cyclic antibiotic regimen may offer a better resistance profile. Nurse-driven protocols, reminder systems, and multi-component care bundles are the most consistently effective institutional interventions, achieving 50–90% CAUTI reductions. Twice-weekly (not daily) bladder irrigation is optimal, and non-antibiotic strategies such as D-mannose and bowel management show promise.

Clinical Recommendations:

1. For short-term use (<7 days): Focus on minimizing duration via reminder systems and stop orders.

2. For 7–30 days: Consider coated catheters (noble metal alloy if available) and implement institutional care bundles.
3. For long-term/permanent use (>30 days):
 - Use hydrophilic catheters for intermittent self-catheterization.
 - Consider antibiotic prophylaxis only for patients with recurrent symptomatic UTIs, particularly those with SCI, and monitor resistance.
 - Optimize bladder irrigation to twice weekly (not more frequent).
 - Implement nurse-driven protocols and daily checklists.
4. Do not screen or treat asymptomatic bacteriuria in most long-term catheter users.
5. Consider non-antibiotic adjuncts (D-mannose, bowel management) in selected patients.

Suggestions for Future Research:

1. Head-to-head randomized trials comparing different catheter coatings (especially noble metal alloy vs hydrophilic) in the same population.
2. Long-term resistance surveillance studies for weekly oral cyclic antibiotic prophylaxis.
3. Implementation science research to identify barriers and facilitators for care bundle sustainability in nursing homes and long-term acute care hospitals.
4. Development of novel non-antibiotic strategies (e.g., biofilm-disrupting agents, bacteriophages, vaccines).
5. Standardized definitions of recurrent UTI in catheter users to improve cross-study comparability.

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