Interventions and strategies to prevent catheter-associated urinary tract infections with short-term indwelling urinary catheters in hospitalized patients: An integrative review

Shuhui Yu RN¹ | Andrea P. Marshall RN, PhD, Professor² | Jing Li RN³ | Frances Lin RN, PhD, Senior Lecturer⁴

1Urology Department, Peking University First Hospital, Beijing, China

2Menzies Health Institute Queensland, School of Nursing and Midwifery, Griffith University, Gold Coast Hospital and Health Service, Southport, Queensland, Australia

3General Surgery Department, Peking University First Hospital, Beijing, China

4School of Nursing and Midwifery, and Menzies Health Institute Queensland, Griffith University, Gold Coast Campus, Southport, Queensland, Australia

Correspondence

Shuhui Yu, Urology Department, Peking University First Hospital, Beijing 100034, China. Email: yushuhuiable@126.com

Abstract

Aim: To explore interventions and strategies to prevent catheter-associated urinary tract infections in hospitalized patients with a short-term indwelling urinary catheter.

Background: Interventions and strategies to prevent catheter-associated urinary tract infections are reported in the literature, but it is not clear which may be relevant when the indwelling urinary catheter is in place for a short period of time.

Design: An integrative review was performed.

Data sources: A search was undertaken in databases using the following search terms: “urinary catheter, bladder catheter OR urethral catheter*” and “bundl* OR care OR manag* OR intervent*”.

Review methods: Electronic databases were searched up until June 2019. Manual searching of reference lists of included studies was undertaken. Twelve studies reported in 15 articles were identified and analysed by two independent reviewers.

Results: Multifaceted interventions were informed by evidence-based protocols or guidelines. Implementation strategies included local adaption of guidelines or protocols; use of an opinion leader; audit and feedback; multi-disciplinary team involvement; reminders and stop orders; education and training.

Conclusion: Multifaceted, evidence-based interventions to prevent catheter-associated urinary tract infections are effective in preventing infections in patients with short-term urinary catheters. However, there is little evidence to inform which combined strategies are more likely to be effective.

KEYWORDS

Catheter-associated urinary tract infections, short-term catheterization, hospitalized patients, clinical practice guidelines; integrative review

SUMMARY STATEMENT

What is already known about this topic?

- Available research suggests that multiple interventions and strategies may be helpful in preventing catheter-associated urinary tract infections, particularly for long-term catheterization.

What this paper adds?

- In the context of short-term urinary catheterization, there are evidence-based strategies which may assist in reducing catheter-associated urinary tract infections. A variety of strategies may be effective in implementing guidelines, including local adaptation of guidelines, use of opinion leaders, audit and feedback, and using reminders, however these are poorly described in the current literature.

The implications of this paper:

- Multifaceted interventions can be effective in preventing catheter-associated urinary tract infections in patients with short-term urinary catheters across variable settings. Strategies to best implement these interventions requires further investigation but should be tailored to the local context.

1 INTRODUCTION

Short-term indwelling urinary catheters (UCs) are often needed in patients who undergo major surgical procedures. Due to the invasive nature of the catheter insertion, urinary tract infections (UTIs) are common, and account for up to 40% of all healthcare-acquired infections (Krein, Fowler, Ratz, Meddings, & Saint, 2015). Nearly 80% of all UTIs occur in patients who require short-term urinary catheterization (Ramanathan & Duane, 2014). Catheter-associated urinary tract infection (CAUTI) increases morbidity, mortality and health care costs (Ramanathan & Duane, 2014; Saint, 2000). It was estimated to cost \$896 US dollars for each CAUTI case in the United States (Zimlichman et al., 2013).

Evidence-based clinical practice guidelines (CPGs) have been developed to standardize practice related to catheter insertion, maintenance and removal in an effort to prevent CAUTI (Evelyn, Lindsay, Susan, & Carolyn 2014; Gould et al., 2010; Hooton et al., 2010). Data from

the International Nosocomial Infection Control Consortium (INICC) demonstrated that current CPGs decreased CAUTI rate from 8.2 to 6.9 infections per 1000 device days (Rosenthal et al., 2012). Using multidimensional implementation strategies including multidisciplinary teams, bundle interventions, process and outcome surveillance, and performance feedback. Implementation of a CPG to prevent CAUTI resulted in a 25% reduction in CAUTI rates (Saint et al., 2013). However, uptake of CAUTI prevention CPGs remains low (Krein et al., 2015) and adherence to CAUTI prevention CPGs has been reported to be lower than what has been reported for CPGs to prevent other healthcare associated infections (Krein, Kowalski, Hofer, & Saint, 2011).

Reported barriers to the uptake and implementation of CAUTI CPGs include difficulty with nurse and physician engagement in CAUTI prevention, patient and family request for indwelling catheters, and poor catheter insertion practices (Krein, Kowalski, Harrod, Forman, & Saint, 2013). It is also possible that low uptake may be the consequence of ineffective implementation. Furthermore, strategies for implementing CAUTI prevention CPGs are likely to be context-driven (Krein et al., 2011) which means that local barriers need to be identified and targeted strategies developed and tailored to the local context. Factors including external environment (financial incentives or administrative support), organisational structure, process and resources may also influence the effectiveness of the intervention and implementation strategies (Kringos et al, 2015). To our knowledge, the gap in applying CPGs into practice to prevent CAUTI still exists (Krein et al., 2011). More specifically, most current CPGs recommend what should be implemented but provide limited information on how implementation should occur. Given the context-specific nature of CPGs implementation, investigating not only the efficacy of the interventions but also the effectiveness of the implementation strategies is warranted (Evelyn, Lindsay, Susan, & Carolyn 2014).

2 REVIEW METHODS

2.1 Aim

The aim of this integrative review was to address two specific research questions: (a) In adult hospitalized patients what evidence-based interventions are used to prevent UTIs associated with short-term indwelling catheters; (b) What strategies were used to implement the interventions and to what degree have these been successful in implementing the interventions?

2.2 Design

This integrative review follows the method and process described by Whitmore and Knafl (2005). An integrative review strategy was selected by Whitmore and Knafl (2005), as it can include studies using diverse methodologies using an established process of specifying the review purpose, searching for literature, synthesizing data, and presenting results.

2.3 Search methods

Five electronic databases were searched including MEDLINE, the Cumulative Index of Nursing and Allied Health Literature (CINAHL), PubMed, EMBASE and the Cochrane database. Search terms included “urinary catheter, bladder catheter OR urethral catheter*” and “bundl* OR care OR manag* OR intervent*”. Although short-term urinary catheterisation has been defined by others (Griffiths & Fernandez, 2007; Kidd, Stewart, Kassis, Hom, & Omar, 2015) as catheterisation up to 14 day, we have used the definition proposed by Carithers (n.d.) of urinary catheter placement of less than 30 days.

2.4 Inclusion and exclusion criteria

Studies were included if they: (a) were conducted in an adult inpatient setting, (b) included patients with short-term catheterization, (c) were peer-reviewed, (d) used at least two implementation strategies, and (e) were published in English before June 2019 with no restriction to start year. We excluded studies that included patients with suprapubic urinary catheter; condom catheter; and intermittent catheterization.

2.5 Search outcome

We retrieved 2195 titles in the initial search. Two authors conducted the literature search and screening. After removing duplicates and screening title and abstracts, 157 full-text articles were assessed against the inclusion and exclusion criteria. A total of 13 articles met the eligibility criteria and were included in the review. The reference lists of these 13 articles were searched with two additional studies identified. A total of 15 articles from 12 studies were included in this review (see Figure 1).

(Insert Figure 1 about here)

2.6 Quality appraisal

Data were extracted into a summary table by two authors (see Table 1). In table 1, data was summarized into categories of study design, details of the intervention, implementation strategies, implementation process evaluation and patient outcome measures, and level of evidence, were provided. We used the 2011 Oxford Centre for Evidence-Based Medicine (OCEBM) Levels of Evidence (OCEBM Levels of Evidence Working Group, 2011). Deductive content analysis was carried out using categories commonly used in the studies (Elo & Kyngäs, 2008). Interventions and implementation strategies used by all studies were summarised in Table 2.

(Insert Table 1 and 2 near here)

Quality assessment of the included papers was completed by two authors (initials to be inserted after peer review) using the Mixed Methods Appraisal Tool (MMAT; Pluye et al., 2011). If there was a lack of agreement, a meeting between the two reviewers was held and assessment scores were discussed. If disagreement remain unresolved, a third reviewer (initials to be inserted after peer review) undertook an independent review and participated in discussion until consensus was achieved. We used the screening questions and the MMAT section of quantitative non-randomized which included four items with quality score ranged from 25% to 100%. The score for the 12 studies ranged from 50% to 100% (see Table 3).

(Insert Table 3 about here)

2.7 Data analysis

We conducted content analysis using interventions, and implementation strategies as initial codes to categorise the data into broad categories. The implementation strategies were further categorised using the names of commonly used strategies as labels.

3 RESULTS

3.1 Study Characteristics

Of the 12 included studies, nine studies were from developed countries, including six from the United States (Andreessen, Wilde, & Herendeen, 2012; Clarke et al., 2013; Davies et al., 2018; Oman et al., 2012; Theobald, Resnick, Spain, Dittus, & Roumie, 2017; Wald & Kramer, 2011), two from Switzerland (Sax et al., 2016; Ste'phan et al., 2006) and one from Canada (Norman, Ramsden, Ginty, & Sinha, 2017). The remaining three studies (6 articles) were conducted in developing countries, including Turkey (Leblebicioglu et al., 2013), Lebanon (Kanj et al., 2013), Philippines (Navoa-Ng et al., 2013), Brazil (Andrioli, Furtado, & Medeiros, 2016), Kenya (Tillekeratne et al., 2014), and a multi-national study conducted in 15 developing countries (Rosenthal et al., 2012). Three studies (5 articles) were conducted in intensive care units (ICU), nine studies in general hospital wards. All studies used a quasi-experimental intervention design (see Table 1). Eleven studies were single centre research and another one study (4 articles) reported aspects of the same multi-centre study which were conducted in 15 developing countries (Kanj et al., 2013; Leblebicioglu et al., 2013; Navoa-Ng et al., 2013; Rosenthal et al., 2012).

3.2 Interventions to decrease CAUTI rates

The number of interventions used in each study ranged from 2-15, with daily assessment of UC need being the most common intervention (see Table 1). Evidence-based clinical practice guidelines published by the Healthcare Infection Control Practices Advisory Committee

(HICPAC) of USA (Clarke et al., 2013), the Society for Healthcare Epidemiology of America (SHEA) (Kanj et al., 2013; Leblebicioglu et al., 2013; Navoa-Ng et al., 2013; Oman et al., 2012; Rosenthal et al., 2012), the Infectious Disease Society of America (IDSA) (Kanj et al., 2013; Leblebicioglu et al., 2013; Navoa-Ng et al., 2013; Oman et al., 2012; Rosenthal et al., 2012) and Centres for Disease Control and Prevention (CDC) of USA (Andreessen et al., 2012; Norman et al., 2017; Theobald et al., 2017) were commonly used to inform the development of study interventions (Andreessen et al., 2012; Clarke et al., 2013; Kanj et al., 2013; Leblebicioglu et al., 2013; Navoa-Ng et al., 2013; Oman et al., 2012; Rosenthal et al., 2012). Another six studies used interventions that were based on expert opinions and local protocols which were found to be effective in CAUTI prevention (Andrioli et al., 2016; Davies et al., 2018; Sax et al., 2016; Ste'phan et al., 2006; Tillekeratne et al., 2014; Wald & Kramer, 2011).

Key patient outcomes measured included reduction of CAUTI rates and median UC duration. A significant reduction in CAUTI rates was reported in 5 studies. The highest reported reduction in CAUTI rates was from 30.4 to 0 per 1000 UC-days (Tillekeratne et al., 2014). The study by Rosenthal et al. (2012) reported CAUTI reduction was more modest (7.86 to 4.95 per 1000 UC-days). Significant reduction of median UC duration was reported in seven studies with the shortest UC duration being 1.4 days (Wald & Kramer, 2011) and the longest 6.5 days (Norman et al., 2017).

3.3 Strategies to implement the interventions

Multifaceted strategies used to implement the interventions included: (a) local adaption of guidelines or protocols, (b) opinion leader, (c) audit, (d) feedback, (e) multi-disciplinary team involvement, (f) reminder or stop orders, (g) education, and (h) training.

3.3.1 Local adaption of guidelines or protocols

The use of a practice guideline for the prevention of CAUTI had a positive impact on CAUTI rates and decreased the duration of urinary catheter placement without increasing use of other

resources (Rosenthal et al., 2012). Most studies identified the need for local adaption of guidelines or protocols. However, the components of the CAUTI guideline or protocol varied across different studies. In one study conducted in America (Oman et al., 2012), the authors integrated the adapted urinary management policy into routine practice in hospital in phase 1 and drafted unit-specific policy in phase 2, which made it effective to change health professionals' behaviour. Moreover, in the multi-center international study, components of the CPGs were adapted in local practice in each country and consequently differed between sites (Kanj et al., 2013; Leblebicioglu et al., 2013; Navoa-Ng et al., 2013; Rosenthal et al., 2012). In the sub-study conducted in Lebanon and Turkey, 13 interventions recommended by current CPGs were implemented (Kanj et al., 2013; Leblebicioglu et al., 2013), whilst in the Philippines, only five interventions from current CPGs were implemented because of resource constraints (Navoa-Ng et al., 2013).

3.3.2 Using opinion leaders in the change process

Strong leadership, built on individual's technical competence, social accessibility, and conformity to the institution's norms (Flodgren et al., 2011), were evident in most of the studies included in this review (Sax et al., 2016; Ste'phan et al., 2006). All authors identified the involvement and commitment of opinion leaders. However, the composition of opinion leaders varied across studies which included physicians, nurses, nurse managers, epidemiologists, and infection control professionals. Furthermore, different multidisciplinary health care professionals played specific roles in different stages of the studies. Opinion leaders were used to locally adapt the guideline or protocol, promote effective communication, determine key issues to be addressed, and improve implementation compliance. Specially, continuous leadership was identified as a strategy to help with intervention sustainability (Sax et al., 2016).

3.3.3 Audit and feedback

Auditing health professionals' practice was used as an implementation strategy in 9 studies (12 articles). However, some papers did not report process outcomes, such as compliance rates of the interventions (Clarke et al., 2013; Oman et al., 2012; Wald & Kramer, 2011), which made it difficult to judge the effects of the audits conducted in these studies. In the multi-center international study, hand hygiene compliance, IUC insertion, management, and removal compliance were audited (Rosenthal et al., 2012). Significant improvements in hand hygiene protocol compliance (55.3% to 66.6%, $p=0.0001$), fixing UC on thigh (from 88% to 97%, $p=0.0001$), and UCs with a collecting bag (from 90% to 97% $p=0.0001$), were reported (Rosenthal et al., 2012).

While nine studies (12 articles) included audit as a strategy, only four studies (7 articles) reported using feedback as a strategy (Andrioli et al., 2016; Kanj et al., 2013; Leblebicioglu et al., 2013; Navoa-Ng et al., 2013; Rosenthal et al., 2012; Ste'phan et al., 2006; Wald & Kramer, 2011). Authors of these studies reported that using feedback had a positive effect in improving compliance with recommended practice. The frequency of feedback varied across studies, with some carried out monthly (Kanj et al., 2013; Leblebicioglu et al., 2013; Rosenthal et al., 2012) and some only conducted once at the completion of the intervention (Ste'phan et al., 2006). The feedback format used in different studies also varied which included using a poster, holding meetings, or sending feedback letters to relevant personnel. One study used poster as way of feedback, however they did not report who provided feedback at what time (Andrioli et al., 2016). The four papers from the multi-center international study (Kanj et al., 2013; Leblebicioglu et al., 2013; Navoa-Ng et al., 2013; Rosenthal et al., 2012) clearly described monthly reporting of patient and process outcomes by displaying results in prominent locations within the hospitals.

3.3.4 Multi-disciplinary team involvement

Five studies (8 articles) included in this review used a multi-disciplinary team approach for implementation (Andreessen et al., 2012; Kanj et al., 2013; Leblebicioglu et al., 2013; Navoa-Ng et al., 2013; Oman et al., 2012; Rosenthal et al., 2012; Ste'phan et al., 2006; Theobald et al., 2017). A wide range of health care professionals were included in the teams including nurses, physicians, therapists, infection control staff, central supply and clinical informatics representatives (Oman et al., 2012) and infection-control physician, a senior hospital epidemiologist (Ste'phan et al., 2006).

3.3.5 Reminder or stop orders

UC reminder or stop orders were used as a strategy in four studies, of which written reminder was applied in two studies (Theobald et al., 2017; Tillekeratne et al., 2014) and computer-based reminder or stop orders in three studies (Andreessen et al., 2012 Norman et al., 2017; Theobald et al., 2017).

3.3.6 Education and training to improve end-users' knowledge and skill

Nine studies (12 articles) used education as a strategy (Andreessen et al., 2012; Clarke et al., 2013; Davies et al., 2018; Kanj et al., 2013; Leblebicioglu et al., 2013; Navoa-Ng et al., 2013; Norman et al., 2017; Oman et al., 2012; Rosenthal et al., 2012; Ste'phan et al., 2006; Tillekeratne et al., 2014; Wald & Kramer, 2011). A variety of education strategies were used to implement the interventions across studies with the education provided based on recommended guidelines or protocols. The education strategies used included face to face education sessions (Andrioli et al., 2016), on-line study (Oman et al., 2012), along with printed educational material (Oman et al., 2012). In one study a quiz was used to assess the participants' knowledge before and after education session (Andrioli et al., 2016). Training was used as an implementation strategy in six studies (Andrioli et al., 2016; Kanj et al., 2013; Leblebicioglu et al., 2013; Navoa-Ng et al., 2013; Oman et al., 2012; Rosenthal et al., 2012). One study (Oman et al., 2012) used competency-based training, including UC insertion training and bladder

scanner training. Another study (Rosenthal et al., 2012) used self-directed learning materials to train researchers.

4 DISCUSSION

We explored the evidence-base for multifaceted interventions and implementation strategies to prevent CAUTI in this review. The implementation of interventions contained in current evidence-based CPGs are found to be effective in preventing CAUTI. The rates of CAUTI fell significantly in five out of 12 studies. Median UC duration dropped significantly in seven out of 12 studies. Results from all included papers showed a reduction of CAUTI rates, which is supported by other CPG implementation literature (Yazici, & Bulut, 2018).

In keeping with recommendations that CPGs be tailored to the local context, the interventions implemented differed across studies. However, interventions used were described more comprehensively in some studies than others. The most commonly used intervention was daily assessment of UC need (Evelyn, Lindsay, Susan, & Carolyn 2014; quality of evidence: III).

Intervention effectiveness depends on effective implementation (Toman, Harrison, & Logan, 2001). In recent years, there has been an increased interest in identifying effective strategies to promote the use of research evidence in clinical practice (Prior et al., 2008). One such strategy is the implementation of evidence-based CPGs. All the studies included in this review implemented a CPG, either in whole or in part. The modification of CPGs was in response to different clinical contexts and resource availability. This approach is in line with the recommendations of Craig et al. (2013b) who suggest that multifaceted interventions may have better effect when tailored to the local context rather than adopted as a standardised intervention. The challenges of introducing and sustaining change in clinical practice is a complex process and can be influenced by the expertise and skills, available resources and local clinical culture. Thus, guideline adaptation becomes an important strategy to ensure successful implementation (Toman, et al., 2001; Grimshaw, et al., 2006).

Similar to the interventions themselves, there are also a number of implementation strategies which can be used to implement the CPGs into clinical practice. Implementation strategies are also context dependent and their selections should be based on an assessment of what is likely to be most feasible and useful in a clinical context. (Grimshaw et al., 2006). A strategic approach to implementing change to clinical practice was not evident in many of the studies included in this review. While all studies adopted recommendations from CAUTI CPGs, the process of the implementation was poorly reported (Clarke et al., 2013; Oman et al., 2012; Tillekeratne et al., 2014) and it is unclear whether the choice of implementation strategies was guided by theory or research. Reporting both process and patient outcomes is necessary in evaluating complex interventions, particularly when a change in practice does not result as this can be due to either the intervention ineffectiveness or poor implementation. (Craig et al., 2013b).

Common strategies used to implement the CPGs included opinion leaders, audit and feedback, multidisciplinary team involvement, reminders, and education/training. The role of opinion leaders may have been useful to support practitioners to overcome the barriers and unify them as a team, although the extent to the use of opinion leaders influencing implementation was not clear. In one study where there was an 8-year follow-up to track the effects on clinical outcomes (Sax et al., 2016), the authors highlighted the local opinion leader as crucial for the sustained effectiveness of the intervention. This is consistent with the results of a Cochrane systematic review of effects of local opinion leaders which also concluded that opinion leaders alone or as part of uptake strategies may be effective to improve the implementation of best practice in health care, with a 12% absolute increase in compliance rates in the intervention group (Flodgren et al., 2011).

Ten of the 12 studies included in this review reported both process and patient outcomes. Audit and feedback of process and outcome evaluation have been found to be an effective

strategy to change clinician behaviour (Ivers et al., 2012; Navoa-Ng et al., 2013). While patient outcomes are the common indicators of studies, process evaluation is also an essential element in designing and evaluating multifaceted interventions (Moore et al., 2015). Compliance rates of the intervention and effectiveness of the implementation strategies are important to monitor performance (Reelick, Faes, Esselink, Kessels, & Rikkert, 2011). In addition, process evaluation can be used to assess fidelity and quality of the implementation, reflect causal relationships, and identify contextual factors associated with variation in outcomes of interventions (Oakley et al., 2006). To avoid Hawthorn effect (McCambridge, Witton, & Elbourne, 2014), it is preferable that staff are not aware of the audit being conducted. Hence, future research is needed to inform who, what and how to audit in more details. Moreover, a number of methods were used to give feedback including posters, meetings, or letters to relevant personnel. However, it was unclear which, if any, was more effective.

Multidisciplinary team involvement was mentioned in five studies. The composition of the multidisciplinary team varied in the studies included in this review. There is still little known about how the use of multidisciplinary teams contributes to practice changes in health care (Zwarenstein, Goldman, & Reeves, 2009). It has been suggested that a mixed-method approach could be used to evaluate the effectiveness of multidisciplinary team involvement in relation to patient outcomes, and process outcomes (Wooten et al., 2014). At a minimum, the key relevant staff to be included in the multidisciplinary team should be investigated.

Reminder strategies include verbal or written reminders, electronic reminders system or stop orders in previous research (Meddings et al., 2014; Shuman & Chenoweth, 2018). Although the number of reminder strategies were limited in our review, it was the very important method to decrease the inappropriate UC utilization. One study published in 2013 (Chen et al., 2013) displayed use of a written reminder reduced the CAUTI rate in intensive care units (ICU). A randomized stepped-wedge trial in 2019 (Mitchell et al., 2019) also showed electronic reminder

system in hospitalized patients significantly reduced the mean duration of UC catheterization for 23% in non-ICU units. Except electronic reminder, the verbal or written reminders were effective to reduce the duration of inappropriate indwelling UC (Felix et al., 2016). We hope this result will encourage more units or hospital to use reminder or stop orders to decrease the duration of UC.

Education and training are common strategies used to implement recommended CPGs (Grimshaw et al., 2005). They can be used to timely and rapidly improve end-users' knowledge and skills. Education and training were found to be only slightly effective in one of the included papers (Andrioli et al., 2016). This finding is supported by the results of a Cochrane review (Grimshaw et al., 2005), which found that the effectiveness of education and training in implementation is minimal. Education is frequently considered to be important to implement without first determining whether a knowledge deficit exists. The minimal impact of education on practice change suggests that knowledge deficits may not necessarily, but always be contributing factors and should be determined before education is selected as a key implementation component.

Although we used an established process in undertaking this review, there are some inherent limitations to be recognised. All the articles in this review were quasi-experimental studies, and consequently lacked the rigour of more robust trial designs such as the randomised controlled trial. Stronger study designs are required to more comprehensively evaluate both the CAUTI interventions and the implementation strategies used. While only papers published in English were included in this review, we recognise the potential for language bias.

5 CONCLUSION

Implementation of evidence-based practice guidelines to prevent CAUTI can be effective in reducing rates of infection. While there are a number of interventions recommended within guidelines, there is less known on which strategies are most effective for ensuring

implementation of guidelines and recommendations. Assessment of clinical context is important for determining the most effective strategies for implementing CPGs, including those specific to reducing CAUTI. Future research should include reporting of intervention effectiveness and process outcomes specific to implementation strategies to assist clinicians in determining which interventions and implementation strategies are likely to work best in their clinical context.

REFERENCES

- Andreessen, L., Wilde, M. H., & Herendeen, P. (2012). Preventing catheter-associated urinary tract infections in acute care: the bundle approach. *Journal of Nursing Care Quality*, 27(3), 209-217. doi: 10.1097/NCQ.0b013e318248b0b1.
- Andrioli, E. R., Furtado, G. H. , & Medeiros, E. A. (2016). Catheter-associated urinary tract infection after cardiovascular surgery: Impact of a multifaceted intervention. *American Journal of Infection Control*, 44(3), 289-293. doi: 10.1016/j.ajic.2015.09.030. Epub 2015 Nov 14.
- Cahill, N. E., & Heyland, D.K. (2010). Bridging the guideline-practice gap in critical care nutrition: a review of guideline implementation studies. *JPEN J Parenter Enteral Nutr*, 34(6), 653-659. doi: 10.1177/0148607110361907.
- Carithers, G. B., (n.d.). Indwelling catheters definition. Retrieved September 7, 2017, From www.urotoday.com/urinary-catheters-home/indwelling-catheters/.../definitions.html.
- Chen, Y. Y., Chi, M. M., Chen, Y. C., Chan, Y. J., Chou, S. S., & Wang, F. D. (2013). Using a criteria-based reminder to reduce use of indwelling urinary catheters and decrease urinary tract infections. *American Journal of Critical Care*, 22(2), 105-114. doi:10.4037/ajcc2013464
- Clarke, K., Tong, D., Pan, Y., Easley, K. A., Norrick, B., Ko, C., Stein, J. (2013). Reduction in catheter-associated urinary tract infections by bundling interventions. *International Journal For Quality In Health Care: Journal Of The International Society For Quality In Health Care / Isqua*, 25(1), 43-49. doi: 10.1093/intqhc/mzs077
- Craig, P., Dieppe, P., Macintyre, S., Michie, S., Nazareth, I., & Petticrew, M. (2013b). Developing and evaluating complex interventions: the new Medical Research Council guidance. *Int J Nurs Stud*, 50(5), 587-592. doi: 10.1016/j.ijnurstu.2012.09.010
- Davies, P. E., Daley, M. J., Hecht, J., Hobbs, A., Burger, C., Watkins, L., Brown, C. V. R. (2018). Effectiveness of a bundled approach to reduce urinary catheters and infection rates in trauma patients. *American Journal of Infection Control*, 46(7), 758-763. doi:10.1016/j.ajic.2017.11.032
- Elo, S., & Kyngäs, H. (2008). The qualitative content analysis process. *Journal of Advanced Nursing*, 62(1), 107-115. doi: 10.1111/j.1365-2648.2007.04569.x
- Evelyn, L., Lindsay, E, N., Susan, E, C., & Carolyn , G. (2014). Strategies to Prevent Catheter-Associated Urinary Tract Infections in Acute Care Hospitals: 2014 Update. *Infection Control and Hospital Epidemiology*, 35(5), 464-479. doi: 10.1086/675718

- Felix, L., Smith, B. A., Santos, E., Gabasan, A., Dzenkevych, O., Kourouni, I., & Klein, R. S. (2016). Physician-initiated daily verbal reminders decrease the duration of indwelling urinary catheter use compared with nurse-initiated reminders. *American Journal of Infection Control*, 44(3), 346-348. doi:10.1016/j.ajic.2015.10.019
- Flodgren, G., Parmelli, E., Doumit, G., Gattellari, M., O'Brien, M. A., Grimshaw, J., & Eccles, M. P. (2011). Local opinion leaders: effects on professional practice and health care outcomes. *Cochrane Database Syst Rev*, 10(8), CD000125. doi: 10.1002/14651858.CD000125.pub4
- Gould, C. V., Umscheid, C. A., Agarwal, R. K., Kuntz, G., Pegues, D. A., & Healthcare Infection Control Practices Advisory Committee (2010). Guideline for prevention of catheter-associated urinary tract infections 2009. *Infection Control and Hospital Epidemiology*, 31(4), 319-326. doi: 10.1086/651091
- Grimshaw, J. M., Thomas, R. E., MacLennan, G., Fraser, C., Ramsay, C. R., Vale, L., Donaldson, C. (2005). Effectiveness and efficiency of guideline dissemination and implementation strategies. *International Journal of Technology Assessment in Health Care*, 21(1), 149-149.
- Grimshaw, J., Eccles, M., Thomas, R., MacLennan, G., Ramsay, C., Fraser, C., & Vale, L. (2006). Toward evidence-based quality improvement. Evidence (and its limitations) of the effectiveness of guideline dissemination and implementation strategies 1966-1998. *Journal of General Internal Medicine*, 21 Suppl 2, S14-20. doi: 10.1111/j.1525-1497.2006.00357.x
- Griffiths, R., & Fernandez, R. (2007). Strategies for the removal of short-term indwelling urethral catheters in adults. *Cochrane Database Syst Rev*(2), CD004011. doi: 10.1002/14651858.CD004011.pub3
- Hooton, T. M., Bradley, S. F., Cardenas, D. D., Colgan, R., Geerlings, S. E., Rice, J. C., .Nicolle, L. E. (2010). Diagnosis, Prevention, and Treatment of Catheter-Associated Urinary Tract Infection in Adults: 2009 International Clinical Practice Guidelines from the Infectious Diseases Society of America. *Clinical Infectious Diseases*, 50(5), 625-663. doi: 10.1086/650482
- Ivers, N., Jamtvedt, G., Flottorp, S., Young, J. M., Odgaard-Jensen, J., French, S. D., . Oxman, A. D. (2012). Audit and feedback: effects on professional practice and healthcare outcomes. *Cochrane Database Syst Rev*(6), CD000259. doi: 10.1002/14651858.CD000259.pub3
- Joanna Briggs Institute (2010). Management of short-term indwelling urethral catheters to prevent urinary tract infections. Best Practice: evidence-based information sheets for health professionals, 14(12), 1-4.
- Kanj, S. S., Zahreddine, N., Rosenthal, V. D., Alamuddin, L., Kanafani, Z., & Molaeb, B. (2013). Impact of a multidimensional infection control approach on catheter-associated urinary tract infection rates in an adult intensive care unit in Lebanon: International Nosocomial Infection Control Consortium (INICC) findings. *International Journal Of Infectious Diseases: IJID: Official Publication Of The International Society For Infectious Diseases*, 17(9), e686-e690. doi: 10.1016/j.ijid.2013.01.020
- Kidd, E. A., Stewart, F., Kassis, N. C., Hom, E., & Omar, M. I. (2015). Urethral (indwelling or intermittent) or suprapubic routes for short-term catheterisation in hospitalised adults. *Cochrane Database Syst Rev*(12), CD004203. doi: 10.1002/14651858.CD004203.pub3
- Krein, S. L., Kowalski, C. P., Hofer, T. P., & Saint, S. (2011). Preventing Hospital-Acquired Infections: A National Survey of Practices Reported by U.S. Hospitals in 2005 and 2009. *Journal of general internal medicine*, 27(7), 773-779. doi: 10.1007/s11606-011-1935-y

- Krein, S. L., Kowalski, C. P., Harrod, M., Forman, J., & Saint, S. (2013). Barriers to Reducing Urinary Catheter Use : A Qualitative Assessment of a Statewide Initiative. *JAMA Internal Medicine*, 173(10), 881-886. doi: 10.1001/jamainternmed.2013.105
- Krein, S. L., Fowler, K. E., Ratz, D., Meddings, J., & Saint, S. (2015). Preventing device-associated infections in US hospitals: national surveys from 2005 to 2013. *BMJ Quality & Safety*, 24(6), 385-392. doi: 10.1136/bmjqs-2014-003870
- Kringos, D. S., Sunol, R., Wagner, C., Mannion, R., Michel, P., Klazinga, N. S., on behalf of the DUQuE Consortium. (2015). The influence of context on the effectiveness of hospital quality improvement strategies: a review of systematic reviews. *BMC Health Serv Res*, 15, 277. doi: 10.1186/s12913-015-0906-0
- Leblebicioglu, H., Ersoz, G., Rosenthal, V. D., Nevzat-Yalcin, A., Akan, Ö. A., Sirmatel, F., . Bacakoglu, F. (2013). Impact of a multidimensional infection control approach on catheter-associated urinary tract infection rates in adult intensive care units in 10 cities of Turkey: International Nosocomial Infection Control Consortium findings (INICC). *American Journal of Infection Control*, 41(10), 885-891. doi: 10.1016/j.ajic.2013.01.028
- McCambridge, J., Witton, J., & Elbourne, D. R. (2014). Systematic review of the Hawthorne effect: new concepts are needed to study research participation effects. *Journal of Clinical Epidemiology*, 67(3), 267-277. doi: 10.1016/j.jclinepi.2013.08.015
- Meddings, J., Rogers, M. A., Krein, S. L., Fakih, M. G., Olmsted, R. N., & Saint, S. (2014). Reducing unnecessary urinary catheter use and other strategies to prevent catheter-associated urinary tract infection: an integrative review. *BMJ Quality & Safety*, 23(4), 277-289. doi:10.1136/bmjqs-2012-001774
- Mitchell, B. G., Northcote, M., Cheng, A. C., Fasugba, O., Russo, P. L., & Rosebrock, H. (2019). Reducing urinary catheter use using an electronic reminder system in hospitalized patients: A randomized stepped-wedge trial. *Infection Control and Hospital Epidemiology*, 40(4), 427-431. doi:10.1017/ice.2019.31
- Moore, G. F., Audrey, S., Barker, M., Bond, L., Bonell, C., Hardeman, W., Baird, J. (2015). Process evaluation of complex interventions: Medical Research Council guidance. *British Medical Journal*, 19,350:h1258. doi: ARTN h125810.1136/bmj.h1258
- Navoa-Ng, J. A., Berba, R., Rosenthal, V. D., Villanueva, V. D., Tolentino, M. C., Genuino, G. A., Mantaring, J. B., 3rd. (2013). Impact of an International Nosocomial Infection Control Consortium multidimensional approach on catheter-associated urinary tract infections in adult intensive care units in the Philippines: International Nosocomial Infection Control Consortium (INICC) findings. *J Infect Public Health*, 6(5), 389-399. doi: 10.1016/j.jiph.2013.03.002
- Norman, R. E., Ramsden, R., Ginty, L., & Sinha, S. K. (2017). Effect of a Multimodal Educational Intervention on Use of Urinary Catheters in Hospitalized Individuals. *Journal of the American Geriatrics Society*, 65(12), 2679-2684. doi:10.1111/jgs.15074
- Oakley, A., Strange, V., Bonell, C., Allen, E., Stephenson, J., & Team, R. S. (2006). Process evaluation in randomised controlled trials of complex interventions. *British Medical Journal*, 332(7538), 413-416. doi: DOI 10.1136/bmj.332.7538.413
- OCEBM Levels of Evidence Working Group*. "The Oxford Levels of Evidence 2". Oxford Centre for Evidence-Based Medicine. <http://www.cebm.net/index.aspx?o=5653>. * OCEBM Levels of Evidence Working Group = Jeremy Howick, Iain Chalmers (James Lind Library), Paul Glasziou, Trish Greenhalgh, Carl Heneghan, Alessandro Liberati, Ivan Moschetti, Bob Phillips, Hazel Thornton, Olive Goddard and Mary Hodgkinson

- Oman, K. S., Makic, M. B., Fink, R., Schraeder, N., Hulett, T., Keech, T., & Wald, H. (2012). Nurse-directed interventions to reduce catheter-associated urinary tract infections. *American Journal of Infection Control*, 40(6), 548-553. doi: 10.1016/j.ajic.2011.07.018
- Prior, M., Guerin, M., & Grimmer-Somers, K. (2008). The effectiveness of clinical guideline implementation strategies-a synthesis of systematic review findings. *Journal of Evaluation in Clinical Practice*, 14(5), 888-897. doi: 10.1111/j.1365-2753.2008.01014.x
- Pluye, P., Robert, E., Cargo, M., Bartlett, G., O'Cathain, A., Griffiths, F., Boardman, F., Gagnon, M.P., & Rousseau, M.C. (2011). Proposal: A mixed methods appraisal tool for systematic mixed studies reviews. Retrieved on [date] from <http://mixedmethodsappraisaltoolpublic.pbworks.com>. Archived by WebCite® at <http://www.webcitation.org/5tTRTc9yJ>
- Ramanathan, R., & Duane, T. M. (2014). Urinary tract infections in surgical patients. *Surgical Clinics of North America*, 94(6), 1351-1368. doi: 10.1016/j.suc.2014.08.007
- Reelick, M. F., Faes, M. C., Esselink, R. A., Kessels, R. P., & Olde, R. M.G. (2011). How to Perform a Preplanned Process Evaluation for Complex Interventions in Geriatric Medicine: Exemplified With the Process Evaluation of a Complex Falls-Prevention Program for Community-Dwelling Frail Older Fallers. *Journal of the American Medical Directors Association*, 12(5), 331-336. doi: 10.1016/j.jamda.2011.01.006
- Rosenthal, V. D. (2008). Device-associated nosocomial infections in limited-resources countries: findings of the International Nosocomial Infection Control Consortium (INICC). *American Journal of Infection Control*, 36(10), S171 e177-112. doi: 10.1016/j.ajic.2008.10.009
- Rosenthal, V. D., Todi, S. K., Alvarez-Moreno, C., Pawar, M., Karlekar, A., Zeggwagh, A. A., Ulusoy, S. (2012). Impact of a multidimensional infection control strategy on catheter-associated urinary tract infection rates in the adult intensive care units of 15 developing countries: findings of the International Nosocomial Infection Control Consortium (INICC). *Infection*, 40(5), 517-526. doi: 10.1007/s15010-012-0278-x
- Saint, S. (2000). Clinical and economic consequences of nosocomial catheter-related bacteriuria. *American Journal of Infection Control*, 28(1), 68-75.
- Saint, S., Greene, M. T., Kowalski, C. P., Watson, S. R., Hofer, T. P., & Krein, S. L. (2013). Preventing catheter-associated urinary tract infection in the United States: a national comparative study. *JAMA Internal Medicine*, 173(10), 874-879. doi: 10.1001/jamainternmed.2013.101
- Saint, S., Greene, M. T., Krein, S. L., Rogers, M. A., Ratz, D., Fowler, K. E., Fakih, M. G. (2016). A Program to Prevent Catheter-Associated Urinary Tract Infection in Acute Care. *N Engl J Med*, 374(22), 2111-2119. doi: 10.1056/NEJMoa1504906
- Sax, H., Kuster, S. P., Tehrany, Y. A., Ren, R., Uckay, I., Agostinho, A., Pittet, D. (2016). Eight-year sustainability of a successful intervention to prevent urinary tract infection: A mixed-methods study. *American Journal of Infection Control*, 44(7), 820-824 doi: 10.1016/j.ajic.2016.01.013.
- Shuman, E. K., & Chenoweth, C. E. (2018). Urinary Catheter-Associated Infections. *Infectious Disease Clinics of North America*, 32(4), 885-897. doi:10.1016/j.idc.2018.07.002
- Ste'phan, F., Sax, H., Wachsmuth, M., Hoffmeyer, P., Clergue, F., & Pittet, D. (2006). Reduction of Urinary Tract Infection and Antibiotic Use after surgery : A Controlled , Prospective, Before-After Intervention Study. *Clinical Infectious Disease*, 42(11), 1544-1551.

- Theobald, C. N., Resnick, M. J., Spain, T., Dittus, R. S., & Roumie, C. L. (2017). A multifaceted quality improvement strategy reduces the risk of catheter-associated urinary tract infection. *International Journal for Quality in Health Care*, 29(4), 564-570. doi:10.1093/intqhc/mzx073
- Tillekeratne, L. G., Linkin, D. R., Obino, M., Omar, A., Wanjiku, M., Holtzman, D., & Cohn, J. (2014). A multifaceted intervention to reduce rates of catheter-associated urinary tract infections in a resource-limited setting. *American Journal of Infection Control*, 42(1), 12-16. doi: 10.1016/j.ajic.2013.07.007
- Toman, C., Harrison, MB., & Logan, J. (2001). Clinical practice guidelines necessary but not sufficient for evidence-based patient education and counseling. *Patient Education and Counseling*, 42(3), 279-287.
- Wald, H. L., & Kramer, A. M. (2011). Feasibility of audit and feedback to reduce postoperative urinary catheter duration. *Journal Of Hospital Medicine*, 6(4), 183-189. doi: 10.1002/jhm.846
- Whittemore, R., & Knafl, K. (2005). The integrative review: updated methodology. *Journal of Advanced Nursing*, 52(5), 546-553. doi: 10.1111/j.1365-2648.2005.03621.x
- Wooten, K. C., Rose, R. M., Ostir, G. V., Calhoun, W. J., Ameredes, B. T., & Brasier, A. R. (2014). Assessing and evaluating multidisciplinary translational teams: a mixed methods approach. *Evaluation & the Health Professions*, 37(1), 33-49. doi: 10.1177/0163278713504433
- Yazici, G., & Bulut, H. (2018). Efficacy of a care bundle to prevent multiple infections in the intensive care unit: A quasi-experimental pretest-posttest design study. [Journal Article]. *Applied Nursing Research*, 39, 4-10. doi: 10.1016/j.apnr.2017.10.009
- Zimlichman, E., Henderson, D., Tamir, O., Franz, C., Song, P., Yamin, C. K., Bates, D. W. (2013). Health care-associated infections: a meta-analysis of costs and financial impact on the US health care system. *JAMA Internal Medicine*, 173(22), 2039-2046. doi: 10.1001/jamainternmed.2013.9763
- Zwarenstein, M., Goldman, J., & Reeves, S. (2009). Interprofessional collaboration: effects of practice-based interventions on professional practice and healthcare outcomes. *The Cochrane Database of Systematic Reviews*, 3, CD000072. doi: 10.1002/14651858.CD000072.pub2

TABLE 1 Summary of Included Studies with Process and Patient Outcome Measures

First Author / Country	Design and sample	Interventions	Implementation strategies	Evaluation: Process Outcomes	Evaluation: Patient Outcomes	Level of Evidence
Andrioli, (2016), Brazil	Prospective Cohort, before- and-after N=330 (pre- n=110, Intervention n=102 Post- n=115) Duration was 17 months. In 1 cardiac ICU	1. Catheterise when necessary 2. UC insertion with aseptic technique. 3. Manage UC based on guidelines 4. Remove UC promptly	1. Audit protocols 2. Conduct 40 min face to face training 3. Evaluate knowledge level 4. Feedback using letter and poster	1. Adherence to pre- and post-insertion hand hygiene both improved significantly separately from 9.1% to 100% and from 36.4% to 100% 2. Adherence to connecting the bag to UC before insertion was from 9.1% to 30% between pre- and post-intervention (p=0.476) 3. Adherence to use sterile gloves and lubricant was 100% 4. Adherence to the remaining recommendations increased from >80% and >90% in pre- and intervention 5. Adherence to UC maintenance care overall improved significantly 6. Professional knowledge improved significantly from 18.2% to 61.1%	1. CAUTI rates fell from 11.42 to 4.4 per 1000 catheter-days (p=0.216) 2. Median UC duration dropped from 3 to 2.5 days (p=0.365)	Level 3
Tillekeratne, (2014), Kenya	A pre-test/post-test study N=125 (pre 82, post 43) Duration was 4 months. In 4 medical wards of 1 limited-resource hospital	1. UC placement: highlight the use of hand hygiene 2. UC management (1) keep a closed drainage system (2) empty the urine bag regularly (3) leave UC below the bladder (4) daily assessment UC need	1. Active surveillance symptomatic CAUTI rate 5 days per week 2. Co-produce multifaceted interventions based on expert opinions and a literature review	1. Placement UC to gravity significantly increased from 80.5% to 97.7% 2. The use of a closed urinary collection system increased from 92.7% to 97.7% (p=0.21)	1. CAUTI rate decreased significantly from 30.4 to 0 per 1000 catheter-days. 2. CAUTI rate decreased significantly from 4.6 to 0 per 1000 patient-days.	Level 3

			(1) education on the placement and management of UC (2) reminder signs (3) weekly infection prevention rounds		3. No significant difference on UC duration from 6.9 to 5.6 days. 4. UC utilization ratio decreased significantly from 0.14 to 0.09. 5. CAUTI rate decreased significantly from 5.2 to 1.5 per 1000 catheter days	
Clarke,(2013), USA	Prospective, before-and-after study N=2228 Duration was 9 months In a community hospital	1.The exclusive use of silver alloy catheters 2. Prevent UC movement 3.Keep UC position correctly 4. Removal UC on postoperative Day 1	1.Introduce guideline 2.Educate nursing staff 3.Audit compliances with interventions	None		Level 3
Oman ,(2012), USA	Pre-post intervention N=695 (phase 1 n=219, phase 2 n=238, phases 3 n=238) Intervention for 6 months Hospitalized patients in 1 pulmonary unit and 1 surgery unit	Hospital-wide nursing intervention incorporating the following strategies (1) hospital policy changes on UC a. clean patients' genitalia area with sterile before insertion UC b. use sterile gloves for UC insertion c. secure the UC without movement d. keep UC below the bladder e. empty the drainage bag regularly f. daily remainder of UC removal g. indication for UC use h. use a bladder scanner i. offer a bedside commode (2) product improvement, (3) multi-professionals provide education	1. Conduct a multidisciplinary team 2. Examine the evidence 3. Hospital-wide nursing catheter insertion training 4. Unit-specific nursing practice (1) education for 60 minutes a. journal club discussions b. competency-based training on bladder scanner training (2) Post fliers of catheter care (3) Charge catheter care daily (4) Partnered with patients and families	1. 96% of the assigned staff completed the online educational program 2. 100% of the operating room nurses completed insertion training 3. 95% of nurses and assistive staff in the intervention unit completed journal club discussions and bladder scanner 3. Bladder scanner used by 50 times for 2-month period	1. CAUTI rate not achieve significant reduction. 2. UC duration decreased significantly on the surgery unit from 3.01 to 2.2 3. Product cost savings were estimated to be \$52,000/year	Level 3

Andreessen, (2012),USA	<p>Pre-post intervention</p> <p>N=141 (pre n= 90, post n= 51)</p> <p>The intervention period lasted over 2 months.</p> <p>Patients with acute placement of indwelling UC on 3 medical/surgical units</p>	<p>1.A care bundle consisted of:</p> <p>(1) insertion</p> <p>a. obtain order</p> <p>b. consider smaller size UC</p> <p>c. strict hand hygiene</p> <p>d. secure catheter</p> <p>e. document insertion date and UC size.</p> <p>(2) maintenance</p> <p>a. asses daily UC need</p> <p>b. consider UC alternatives</p> <p>c. document daily clinical need</p> <p>d. perform peri-care daily</p> <p>e. keep catheter below bladder</p> <p>f. confirm presence every shift</p> <p>g. keep drainage tubing unobstructed</p> <p>h. cleanse urine sampling</p> <p>2. Update supplies</p> <p>3. Advocate alternative bladder drainage</p>	<p>1. Create a multi-disciplinary team</p> <p>2. Create a UC care bundle</p> <p>3. Develop a computer-based documentation template and 24-hour order system for continual daily assessment of UC</p> <p>4. Educate all the staff</p> <p>5. Assess the compliance</p>	<p>1. Catheter use documentation was increased from 2% to 98%.</p> <p>2. A new insertion/removal computerized documentation template saved to 60% of the time</p> <p>3. A new 24-hour order template saved to 65% of original time</p> <p>4. Catheter sizes documentation increased from 40% to 100%, and 90% patients used 14-16 Fr.</p> <p>5. 45% of the charts had a documented indication</p>	<p>1. Overall UC days statistically significantly reduced by 71%</p> <p>2. Overall UC use reduced by 56%</p>	Level 3
<p>Rosenthal , (2012), International Nosocomial Infection Control Consortium (INICC)</p>	<p>Multi-center prospective before–after cohort study</p> <p>N=56,429 (baseline 6,212 and intervention 50,217)</p> <p>Average intervention was 22.9±20.85 months in 57 adult ICU in 43 hospitals in 15 developing countries</p>	<p>1. Insertion of UC only needed and removal not necessary</p> <p>2. Use UC based on indications</p> <p>3. Consider alternative UC methods</p> <p>4. Hand hygiene</p> <p>5. Use smaller UC</p> <p>6. Use sterile products</p> <p>7. Use aseptic technique</p>	<p>1.Develop a multi-disciplinary team</p> <p>2.Find evidence-based guidelines on care bundles</p> <p>3.Train investigators</p> <p>4. Process surveillance</p> <p>(1) audit hand hygiene compliance three times a week</p>	<p>1. Significant improvement on hand hygiene compliance from 55.3% to 66.6% (p=0.0001)</p> <p>2. Significant improvement of UCs on thigh from 88% to 97% (p=0.0001)</p> <p>3. Significant improvement on UCs hanging below bladder level from 90% to 97% (p=0.0001)</p>	<p>1. Significant reduction of CAUTI rate from 7.86 to 4.95 per 1000 UC-days</p> <p>2. Significant reduction on UC average duration from 4.89±9.16 to 4.44±9.02</p>	Level 2

15 developing countries	from April 1999 to February 2011	8. Appropriate management UC 9. Maintain unobstructed urine flow 10. Keep UC below bladder 11. Empty the bag regularly 12. Cleaning the meatal area 13. Surveillance of CAUTI	(2) monitor UC care once a day, 5. Outcome surveillance monthly 6. Performance feedback/ monthly			
Navoa-Ng*,(2013), Philippines	Prospective before–after cohort study N=3183 (baseline n=283, intervention n=2,898) Average intervention period was 27.9±18.2 months; 4 AICUs in 2 hospitals from 2 cities	1. Perform hand hygiene 2. Maintain unobstructed urine flow 3. Keep UC below bladder 4. Empty the bag regularly 5. Monitor CAUTI	It was a sub-study of Rosenthal’s work in the implementation column and the implementation strategies were the same. In this study interventions were limited to 5 key interventions because of resource constraints. Implementation strategies were the same	1. Significant improvement on hand hygiene from 57.23% to 78.21% and the correct positioning of the urinary catheter from 41.56% to 88.84%, combined with urine bag hanging from 41.56% to 92.88%. 2. UC duration with no significant changes	1. Significant reduction of CAUTI rates from 11.0 to 2.66 per 1000 UC-days	Level 2
Leblebicioglu *,(2013), Turkey	Prospective before–after cohort study N=4,231 (baseline 627, intervention 3,604) Average intervention period was 22.4±17.2 months 13 adult ICUs of 10 hospitals in 10 cities	It was a sub-study of Rosenthal’s work in the implementation column and interventions were the same	It was a sub-study of Rosenthal’s work in the implementation column and the implementation strategies were the same	1. Significant improvement on rate of hand hygiene compliance from 33% to 58%. 2. Significant increase on compliance with UC on thigh (from 92% to 99%). 3. Collecting bag hanging remained high (from 98% to 99%)	1. Significant reduction of CAUTI rates from 10.63 to 5.65 per 1000 UC-days	Level 2
Kanj *,(2013), Lebanon	Prospective before–after cohort study N=1506 (baseline n=35, intervention n=1,417)	It was a sub-study of Rosenthal’s work in the implementation column and interventions were the same	It was a sub-study of Rosenthal’s work in the implementation column and the implementation strategies were the same	1. Mean duration of urinary catheter was similar in both phases. 2. Rate of hand hygiene compliance remained high in two phases.	1. Significant reduction of CAUTI rates from 13.07 to 2.21 per 1000 UC-days	Level 2

	The intervention period amounted to 50 months 1 adult ICU from November 2007 to March 2012			3. Rate of compliance with correct position of the urinary catheter and collection bag hanging were 100% in both phases.		
Wald,(2011), USA	Pre-post study N=846 (baseline n=373, follow-up n=473) Adults patients in orthopedic and general surgery units in 1 hospital	1. The definition and epidemiology of CAUTI 2. Harm associated with CAUTI 3. Risk factors for CAUTI 4. Indications for indwelling catheters 5. Alternatives to catheters 6. Define the UC performance measure	1. Educate nurses 2. Audit UC duration 3. Feedback performance	1. 2/3 of registered nurse received educational intervention and feedback on each unit 2. A total of 79% of nurses agreed or strongly agreed with the intervention and 42% would change their practice	1. CAUTI rate did not significantly drop from 8.9 to 0 per 1000 device-days on orthopaedic surgery 2. Mean UC duration decreased significantly (1.7-1.4 days on orthopedic surgery, and 2.6 -2.2 days on general surgery) 3. Catheter duration of less than 3 days increased significantly on orthopedic surgery from 86% to 92%	Level 3
Sax,(2016), Switzerland	Pre-post study N=336 (pre n=280, post n=259, 2-year follow-up n=300, 8-year follow-up n=336); Adult patients in 1 orthopaedic department	1. Insert UC with aseptic technique 2. Insert UC with aseptic equipment 3. Connect to a closed drainage system	1. Perform the surveillance twice a week 2. Conduct a semi-structured individual interview	1. Rates of UC placement sustained in 17.6%-20.0% 2. Poor recall of the intervention and knowledge of guidelines except in the OR	1. CAUTI rate sustained in 2.4-2.6 per 1000 patient-days 2. UC Duration sustained in 3-5 days	Level 3
Ste'phan , (2006), Switzerland	Controlled, prospective before-after study	1. Insert UC with aseptic technique 2. Insert UC with aseptic equipment 3. Connect to a closed drainage system	1. Conduct surveillance until hospital discharge (1) perform 6 days per week	1. Adherence to guidelines was 82.2% and 80.8% 2-year follow up	1. Significant reduction of CAUTI rates from 45.8 to 18.6 per 1000 patient days	Level 3

	N=1,328 (pre-, n=529, post, n=499, 2-year follow-up n=300) Intervention lasted in 1 month Adult patients in orthopedic or abdominal surgery departments		(2) validate all surveillance records (3) record non-infectious complications 2. Develop locally guidelines 3. Include multi-professions 4. Perform educational presentation 5. Display posters 6. Feedback on practice and results		2. UC length of significant reduction from 5 to 3.9 days	
Norman, (2017), Canada	Quasi-experimental interrupted time series For 41 months In medical and surgical units	1. Indications for indwelling catheters 2. Management techniques (e.g., insertion and maintenance) from the Centers for Disease Control	1. Display educational posters 2. Conduct small-group teaching sessions 3. Change electronic health records and nursing documentation systems	No	1. Significant reduction of mean catheter days by 5.6 days on medical wards and 6.5 days on surgical wards 2. Significant reduction of Monthly catheterization incidence by 3% on medical wards and 6.4% on surgical wards	Level 3
Theobald, (2017), USA	Pre-post study For 24 months (N=99) In a medical unit	1. Indications for catheterization 2. Remove UC sooner	1. Set a bedside catheter reminder 2. Conduct a multidisciplinary educational campaign 3. Develop a structured catheter order set 4. Develop automated catheter discontinuation orders	1. Significant increase of documentation of catheterization indications from 80% to 88.6% 2. Significant increase use of structured UC orders from 30.8% to 66.7% 3. Mean duration of UC remaining 3-4 days	1. Significant reduction of catheter utilization ratio from 12% to 7.8%. 2. Significant reduction of CAUTI rate from 3.53 to 0.7 per 1000 catheter days	Level 3

Davies, (2018) USA	The retrospective cohort study for 2 years in a trauma center (Pre, n=5003; Post, n=1233)	1.Reinforce UC indications 2.Proper maintenance techniques 3.Early discontinuation of UC	5. Conduct a protocol for post-catheter removal care 1.Audits UC indications 4 times per week for 3 months by nurses 2.A diagnosis algorithm to provide education and bedside rounds	No	3. Rates of falls or catheter reinsertions 1. UC duration remained unchanged 2. Significant reduction of catheter utilization ratio from 25% to 26% 3. CAUTI rate reduced over one third	Level 3
-----------------------	---	--	--	----	---	---------

*It is the sub-study from the same multi-center study

TABLE 2 Interventions and implementation strategies and outcome measures related to research questions

Questions	Content	Citation	
		References	Total studies
Questions1- what evidence-based interventions are used to prevent UTIs associated with short-term indwelling catheters	1. Insertion UC needed and removal not necessary	Andrioli, (2016); Clarke,(2013); Rosenthal ,(2012); Leblebicioglu,(2013); Kanj ,(2013); Theobald, (2017); Davies,(2018)	7
	2. Use UC based on indications	Andrioli, (2016); Rosenthal ,(2012); Leblebicioglu,(2013); Kanj ,(2013); Wald,(2011); Norman,(2017); Theobald, (2017); Davies,(2018)	8
	3. Consider alternative methods of UC	Clarke,(2013); Rosenthal ,(2012); Leblebicioglu,(2013); Kanj ,(2013); Wald,(2011),	5
	4. Hand hygiene	Tillekeratne,(2014); Andreessen,(2012); Rosenthal ,(2012); Navoa-Ng,(2013); Leblebicioglu,(2013); Kanj ,(2013)	6
	5. Use smaller UC	Andreessen,(2012); Rosenthal ,(2012); Leblebicioglu,(2013); Kanj ,(2013)	4
	6. Use sterile products for insertion	Oman ,(2012); Rosenthal ,(2012); Leblebicioglu,(2013); Kanj ,(2013); Ste'phan ,(2006); Sax (2016)	6
	7. Use aseptic technique for insertion	Andrioli, (2016); Oman ,(2012); Rosenthal ,(2012); Leblebicioglu,(2013); Kanj ,(2013); Ste'phan ,(2006); Sax (2016)	7

	8. Appropriate management UC	Andrioli, (2016); Tillekeratne,(2014); Clarke,(2013); Oman ,(2012); Andreessen,(2012); Rosenthal ,(2012); Leblebicioglu,(2013); Kanj ,(2013); Ste'phan ,(2006); Sax (2016); Davies,(2018)	11
	9. Maintain unobstructed urine flow	Andreessen,(2012); Navoa-Ng,(2013); Leblebicioglu,(2013); Kanj ,(2013)	4
	10. Keep the bag below the bladder	Tillekeratne,(2014); Clarke,(2013); Oman ,(2012); Andreessen,(2012); Rosenthal ,(2012); Navoa-Ng,(2013); Leblebicioglu,(2013); Kanj ,(2013)	8
	11. Empty the bag regularly	Tillekeratne,(2014); Oman ,(2012); Rosenthal ,(2012); Navoa-Ng,(2013); Leblebicioglu,(2013); Kanj ,(2013)	6
	12. Cleaning the meatal area	Andreessen,(2012); Rosenthal ,(2012); Navoa-Ng,(2013); Leblebicioglu,(2013); Kanj ,(2013)	5
	13.Surveillance CAUTI	Rosenthal ,(2012); Navoa-Ng,(2013); Leblebicioglu,(2013); Kanj ,(2013)	4
	14.Daily assessment UC need	Tillekeratne,(2014); Oman ,(2012); Andreessen,(2012); Rosenthal ,(2012); Leblebicioglu,(2013); Kanj ,(2013); Norman,(2017); Theobald, (2017)	8
	15. Use a bladder scanner	Oman ,(2012); Theobald, (2017)	2
Questions2- What strategies were used to implement the interventions	1.local adaption of guideline or protocol	Clarke,(2013); Oman ,(2012); Andreessen,(2012); Rosenthal ,(2012); Navoa-Ng,(2013); Leblebicioglu,(2013); Kanj ,(2013); Norman,(2017); Theobald, (2017)	9
	2. opinion leader	Sax (2016); Ste'phan, (2006); Davies,(2018)	3
	3. audit	Andrioli, (2016); Tillekeratne,(2014); Clarke,(2013); Andreessen,(2012); Rosenthal ,(2012); Navoa-Ng (2013); Leblebicioglu, (2013); Kanj ,(2013); Wald,(2011); Sax,(2016); Ste'phan ,(2006); Davies,(2018)	12
	4.feedback	Andrioli, (2016); Rosenthal ,(2012); Navoa-Ng (2013); Leblebicioglu,(2013); Kanj ,(2013); Wald,(2011); Ste'phan ,(2006)	7
	5.multi-disciplinary team involvement	Andreessen,(2012); Kanj, (2013); Leblebicioglu, (2013); Navoa-Ng, (2013); Oman ,(2012); Rosenthal, (2012); Ste'phan, (2006); Theobald, (2017)	8
	6.reminder and stop orders	Andreessen,(2012); Tillekeratne,(2014); Norman,(2017); Theobald, (2017)	4
	7.education	Andreessen,(2012); Clarke,(2013); Kanj ,(2013); Leblebicioglu ,(2013); Navoa-Ng ,(2013); Oman ,(2012); Rosenthal, (2012); Ste'phan, (2006); Tillekeratne, (2014); Wald,(2011); Norman,(2017); Davies,(2018)	12
	8.training.	Andrioli, (2016); Oman ,(2012); Rosenthal ,(2012); Navoa-Ng(2013); Leblebicioglu,(2013); Kanj ,(2013)	6
Questions2- what degree have these been successful in implementing the interventions	1. CAUTI rates significantly fell	Andrioli, (2016); Tillekeratne,(2014); Rosenthal ,(2012); Navoa-Ng,(2013); Leblebicioglu(2013); Kanj ,(2013); Ste'phan ,(2006); Theobald, (2017)	8
	2. Median UC duration dropped	Andrioli, (2016); Oman ,(2012); Andreessen,(2012); Rosenthal ,(2012); Wald,(2011); Ste'phan ,(2006);	7

significantly	Norman,(2017)	
3. UC utilization ratio decreased	Tillekeratne,(2014); Norman,(2017); Theobald, (2017)	3
significantly		

TABLE 3 Quality assessment of included quantitative studies by used the 2011 Oxford Centre for Evidence-Based Medicine (OCEBM)

Items	Rosenthal (2012)	Leblebicioglu (2012)	Kanj (2013)	Navoa-Ng (2013)	Andrioli (2016)	Ste'phan (2006)	Sax (2016)	Tillekeratne (2014)	Oman (2012)	Clarke (2013)	Andreessen (2012)	Wald (2011)	Norman (2017)	Theobald (2017)	Davies, (2018)
OCEBM 1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
OCEBM 2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
OCEBM 3	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	No	No	No
OCEBM 4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
OCEBM 5	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
OCEBM 6	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes	Yes	No	Yes
MMAT Score	100%	100%	100%	100%	75%	100%	100%	50%	50%	100%	50%	100%	75%	50%	75%

OCEBM 1=Are there clear qualitative and quantitative research questions (or objectives*), or a clear mixed methods question (or objective*)?

OCEBM 2=Do the collected data allow address the research question (objective)? E.g., consider whether the follow-up period is long enough for the outcome to occur (for longitudinal studies or study components).

OCEBM 3=Are participants (organizations) recruited in a way that minimizes selection bias?

OCEBM 4=Are measurements appropriate (clear origin, or validity known, or standard instrument; and absence of contamination between groups when appropriate) regarding the exposure/intervention and outcomes?

OCEBM 5=In the groups being compared (exposed vs. non-exposed; with intervention vs. without; cases vs. controls), are the participants

comparable, or do researchers take into account (control for) the difference between these groups?

OCEBM 6=Are there complete outcome data (80% or above), and, when applicable, an acceptable response rate (60% or above), or an acceptable follow-up rate for cohort studies (depending on the duration of follow-up)?

MMAT – mixed methods appraisal tool