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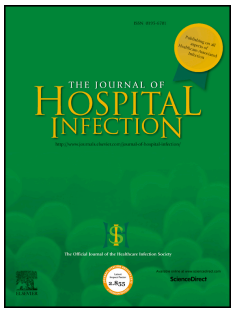

Effectiveness of Behavioural Interventions to Reduce Urinary Tract Infections and E. coli Bacteraemia for Older Adults Across all Care Settings: A Systematic Review

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Effectiveness of Behavioural Interventions to Reduce Urinary Tract Infections and E. coli Bacteraemia for Older Adults Across all Care Settings: A Systematic Review

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Abstract

Background

Escherichia coli bacteraemia rates in the UK have risen; rates are highest amongst older adults. Previous Urinary Tract Infections (UTIs) and catheterisation are risk factors. This review examines effectiveness of behavioural interventions to reduce E.coli bacteraemia and/or symptomatic UTIs for older adults.

Method

Sixteen databases, grey literature and reference lists were searched. Titles and/or abstracts were scanned and selected papers read fully to confirm suitability. Quality was assessed using Critical Appraisal Skills Programme guidelines and Scottish Intercollegiate Guidelines Network grading.

Results

21 studies were reviewed, and all lacked methodological quality. Six multi-faceted hospital interventions including education, with audit, and feedback or reminders reduced UTIs but only three provided statements of significance. Dickson et al reported decreasing catheter associated UTI (CAUTI) by 88% F(1,20)=7.25. Smith et al, reported reductions in CAUTI from 11.17 to 10.53 during Phase I and by 0.39 during Phase II (Chi-square=254). Van Gaal et al reported fewer UTIs per patient week (rr=0.39). Two hospital studies of online training and catheter insertion and care simulations decreased CAUTIs from 33 to 14 and from 10.40 to 0. Increasing nursing staff, community continence nurses, and catheter removal reminder stickers reduced infection. There were no studies examining prevention of *E. coli* bacteraemias.

Conclusions

The heterogeneity of studies means one effective intervention cannot be recommended. We suggest feedback should be considered because it facilitated reductions in UTI when used alone or in multifaceted interventions including education, audit or catheter removal protocols. Multi-faceted education is likely to be effective. Catheter removal protocols, increased staffing and patient education require further evaluation.

Introduction

E. coli bacteraemia rates have increased by 24.3% between 2012 and 2016,[1] with three quarters defined as community onset.[2] The age group with the highest rates of *E. coli* bacteraemia in England were older adults (>85 years) with 898.3 and 621.6 reports per 100,000 population for males and females respectively in 2016/17.[3] The 30-day all-cause case fatality rate was 14.7%[4] for the 40,580 cases of *Escherichia coli* (*E. coli*) bacteraemia cases reported in 2016/17. On-going mandatory surveillance of *E. coli* bacteraemia has identified 46.9% of cases were most likely due to urinary tract infections (UTIs),[3, 5] and one of the biggest risk factors for this is exposure to antibiotic therapy in the previous four weeks.[6]

In recognition of this threat, NHS England has an ambition to halve Gram negative bloodstream infections (BSI) by 2021 (*E. coli*, *Klebsiella spp* and *Pseudomonas aeruginosa*), with the initial focus on *E.coli* bacteraemias. [7] Clinical commissioning groups were charged with leading this by reducing all *E. coli* BSIs by 10% in Year 1, through a Quality Premium (from April 2017, for two years).[8]

There is a range of literature examining interventions aimed at reducing symptomatic UTI and *E. coli* bacteraemia rates in hospital settings.[9, 10] A systematic review found that catheter removal reminders and stop orders in hospitalised patients of all ages can effectively reduce hospital catheter associated urinary tract infection (CAUTI) rates; however the review only included one randomised controlled trial (RCT) and the remaining studies were of a lower quality.[9] A systematic review of interventions to reduce urinary catheter insertion in hospitalised adults, included eight low quality studies and was unable to make any intervention recommendations.[10] There are no systematic reviews that have assessed interventions for older adults to reduce catheter associated UTI, catheterisation rates across the full range of care settings such as community or care homes, and there are no systematic reviews of interventions to reduce E.coli bacteraemia. Interventions found to be successful for older adults in one care setting may not be applicable in other settings and will warrant further investigations.

The objectives of this review are to describe existing published behavioural intervention evaluations aimed at reducing rates of *E. coli* bacteraemia or reducing symptomatic UTIs for older adults across care settings; assess the effectiveness of these interventions at reducing rates of *E. coli* bacteraemias and reducing symptomatic UTIs; and recommend behavioural interventions for use in clinical practice.

Methods

Research question: How effective are interventions at reducing symptomatic urinary tract infections and *E. coli* bacteraemia in older adults across all care settings?

Population: Older adults in hospital or community care settings
Intervention: All behavioural interventions
Comparator: None specified
Outcome: Symptomatic UTI and *E. coli* bacteraemia

Definition of care settings, including care homes, secondary care, community care and long-term care settings: Care homes offer accommodation and personal care for people who may not be able to live independently. There are three main types of care homes: residential (with no nursing staff), nursing homes providing nursing care, and mixed with both categories of patients.[11, 12] Secondary care is sometimes referred to as hospital or acute care.[13] Individuals being cared for at home or at another's home is considered community care. Long-term care facilities is a collective term for nursing homes and assisted living facilities.[14]

Definition of a symptomatic UTI: The experience of urinary symptoms and a diagnosis of UTI resulting from a full clinical assessment.

Definition of *E. coli* bacteraemia: The confirmation of *E. coli* in the blood by microbiological analysis.

Systematic review registration: Details of the protocol for this systematic review were registered on PROSPERO (Registration number: CRD42017055588) and can be accessed at: http://www.crd.york.ac.uk/PROSPERO/display_record.asp?ID=CRD42017055588.

Inclusion criteria: All studies evaluating behavioural interventions to reduce or prevent symptomatic UTI or *E. coli* bacteraemia, including catheter associated UTI (CAUTI) in older adults in all care settings. All care settings are included in this study because estimates show that approximately 3% of care home residents are discharged from hospital into care homes or the community with a urinary catheter and are therefore at an increased risk of developing CAUTI.[15] International studies conducted from 1990 onwards where full texts were available in English. 1990 was chosen as the cut off year as a balance for capturing enough interventions relevant to modern healthcare.

Exclusion criteria: Interventions aimed at reducing asymptomatic bacteriuria as this is very common in the elderly and treatment with antibiotics does not reduce mortality or symptomatic episodes.[16-18] If patients' ages were not provided in the full text, or age was not implied e.g. conducted on a geriatric unit. Additionally, studies were excluded if they included specialist hospital units such as intensive care units (ICUs) or burns wards, as the populations in these particular settings are unlikely to provide transferable results to older adults with different comorbidities.

Studies were excluded if they used interventions such as diagnostic algorithms in order to improve accuracy in identifying UTI/CAUTI as these studies did not aim to reduce infection rates. Studies were also excluded if the interventions were antimicrobial/pharmaceutical (i.e. non-behavioural) as systematic reviews on the value of antimicrobials and pharmaceutical products for the prevention of UTIs already exist.[19]

Search strategy: Electronic bibliographic databases were searched in the summer of 2017 for published work, using a search strategy based on the population, intervention, comparator, outcome framework. Grey literature was searched for unpublished items, working documents, conference abstracts and theses, in order to minimise publication bias. Reference lists of included studies in the review were also searched. All studies were stored and managed in EndNoteX7.

Search terms: The search terms were defined and agreed upon with an external researcher (DH) and agreed internally by the research team (Table I).

Electronic databases: Databases were chosen for relevancy (Table II). Filters were adjusted to search full text, abstracts only, or titles only, to obtain a manageable number of studies.

Grey literature: OpenGrey, Social Policy and Practice and ProQuest were searched for further studies including thesis. Additionally, national guidelines, government policies and other relevant reports were searched e.g. The 5 year AMR strategy, NHS Quality Premium Guidelines, PHE Health Protection Report, as well as relevant websites e.g. government statistics websites, NHS Choices etc.[5, 20, 21]

Study selection

Primary screening: All studies from the database and grey literature searches were imported into EndNote X7, and titles and/or abstracts were scanned for relevance based on the inclusion and exclusion criteria, by the main author.

Secondary screening: The full texts of all studies selected from the primary screening stage were read against the inclusion and exclusion criteria. A second researcher checked 10% of studies at both stages, any disagreements were discussed and a consensus was reached. Excluded studies were saved and documented in EndNote X7 with their reason for exclusion.

Data extraction and critical appraisal: A table was developed to critically appraise and extract data for each study based on the Critical Appraisal Skills Programme (CASP) checklists for randomised controlled trials (RCTs) and cohort studies, and the Cochrane risk of bias checklist. [22, 23] A grading system was developed based on the SIGN Management of suspected bacterial urinary tract infection in adults guidelines [24] in order to grade each study as low, moderate or high quality.

Results

1,595 studies were identified from 16 databases and 165 from grey literature searches. 360 studies were removed as duplicates. 1,400 studies went forward for primary screening and a further 1116 were excluded. 326 went forward for secondary screening and 305 were excluded for not having the required population group or outcome measures. 21 studies were included in the final review (Figure 1). A narrative synthesis approach was chosen due to the heterogeneity of studies included in the review such as the intervention types, methodologies used and data collected.

Table III summarises the characteristics of the final 21 studies included in this review. Of the 21 studies included (14 hospital, three long-term care setting, one hospital and long-term care setting, three community), seven studies (six hospital) evaluated the effectiveness of multi-faceted complex interventions.[25-31] Four hospital studies evaluated a form of education or training,[32-35] three (one hospital) examined staffing types.[36-38] Three hospital studies evaluated urinary catheter removal protocols,[39-41] and one study in a long-term care facility (LTCF) used a hydration intervention.[42] One community study examined a catheter self-management intervention[43]; another hospital study used a CAUTI rate feedback intervention,[44] and one used a bacterial interference intervention in a LTCF.[45]

Eleven studies reported CAUTI rates as the primary outcome,[27-32, 34, 35, 37, 41] nine reported UTI rates[25, 26, 33, 36, 38, 40, 42, 44, 45] and one study reported *E. coli* in blood or urine.[39]

Five studies used a RCT based design[26, 37, 40, 43, 45], 15 studies used a before and after design[25, 27-36, 39, 41, 42, 44] and one study used a cross sectional design.[38] Nine studies used a time series method of analysis. [25, 26, 29, 30, 34, 36, 40, 43, 45]

Risk of bias in included studies

Seven of the 15 before and after studies met the Critical Appraisal Skills Programme (CASP) cohort guideline criteria;[27, 32, 34-36, 41, 44] three did not address all important confounding factors;[25, 33, 39] four had insufficient follow up period to determine the long term effects of the intervention and its implementation;[31, 37, 39, 42] and five did not report significance tests.[25, 28-30, 39]

All studies including the RCTs in this review were given a high risk of bias rating. The most common reasons for this was lack of allocation concealment and lack of blinding of participants/patients and health care staff. Due to the nature of the behavioural interventions being evaluated, all participants knew that an intervention was being implemented which may have resulted in a change in their practice. Lack of random allocation in the majority of studies indicated a high risk of selection bias. Many of the studies were conducted in real life settings such as hospitals and care homes, therefore contamination from other relevant interventions is a possibility.

Effect of the interventions

Full details of intervention effectiveness and study grading can be seen in Table III. The main results are summarised below grouped by intervention type, with study quality grades grouped into high, moderate and low, although no studies were deemed of high or moderate quality.

Multi-faceted interventions with statements of significance

Three of the seven multi-faceted intervention studies using education and feedback, demonstrated a significant reduction in UTI (one) or CAUTI (two) rates, all of which were low quality. One also audited intervention compliance and a second audited urinary catheter care. Two of the three were conducted in hospitals, and one in a hospital and a LTCF. [26, 27, 31] Despite showing a reduction in UTI the study by van Gaal in hospitals and LTCFs was not sufficiently powered to look at this outcome.[26]

Multi-faceted interventions without statements of significance

The other four multi-faceted intervention studies reported a reduction in CAUTI[28-30] or UTI[25] but did not report any measures of statistical significance.[25, 28-30] One study focused specifically on urinary catheter care by educating staff to replace silver coated catheters with latex and non-latex alternatives, standardising catheter devices and undertaking catheter care evaluations to reduce CAUTI rates.[28] One American study used hospital bedside catheter reminders, staff education, automated catheter discontinuation orders 48 hours after insertion, and hospital protocols for post-catheter removal care.[29] One study identified key areas for catheter care improvement in the hospital setting and implemented a bundle of CAUTI prevention measures using a urinary catheter insertion and care checklist, training on infection prevention guidelines and intervention compliance audits.[30] Another study used a combination of education, cranberry capsules, silver coated catheters and the provision of guidelines to staff in reducing incidence and prevalence of UTI in a LTCF but whose results were unclear without any statements of significance.[25] Alongside the elements listed above, each of these studies used an educational or a training approach within their intervention and all were given a low quality grading due to their before and after designs.

Summary of the Multi-faceted interventions

There is low quality evidence from five before and after studies, and one RCT for the effectiveness of multi-faceted interventions that use audits, feedback, education and/or reminder protocols to remove catheters, on CAUTI[27-31] and UTI rates,[26] three of which provided statements of significance.[26, 27, 31] Van Gaal *et al* found that that the rate ratio for UTIs in four hospitals using education, feedback, patient involvement and implementation plans was 0.39. Dickson *et al* found an 88% reduction in hospital CAUTI rates ($F(1,20) = 7.25$). Smith *et al* found a significant reduction in one hospital's CAUTIs (Chi square = 254.237) having used audits, education, feedback, reminders and annual competency assessments.

Education and/or training interventions

A total of four low quality studies used education/training interventions, of which two studies in a hospital setting demonstrated significant reductions in CAUTI rates. Justus *et al.* used a blended learning method of online videos followed by hands on simulations,

customised for each job role and care setting, to teach catheter insertion and care.[34] Similarly, Gordon *et al.* used the Centre for Disease Control and Prevention's best practice guidelines in catheter care, providing a pocket guide for catheter insertion and care, and further face to face education and online e-modules for staff to use at future meetings.[35] The mixed age population of these studies is a limitation; therefore further evaluation is needed to examine the effects of these interventions on older adults with CAUTI alone.

The other two educational studies by Singh *et al* and Girard *et al* delivered face to face training programmes across hospital staff on geriatric units but neither study found a significant reduction in CAUTI or UTI.[32, 33] Singh *et al* used a face to face training intervention in geriatric units at six locations, which covered general infection control, including hand hygiene, sterilisation and disinfection, isolation precautions etc. using didactic sessions, video shows, quizzes, role plays and tests, and despite not finding reductions in CAUTI they did find significant reductions in all other infection rates.[32]

The combination of face to face education and online education was evaluated in two American hospital studies.[34, 35] Justus *et al* found that CAUTIs in one 350 bed hospital decreased from 33 to 14 over 15 months post intervention (r = -0.45), and Gordon et al also found that CAUTI rates decreased in one hospital ward over 3 months (x2 = 55.00, df = 1).

Adaptation/changes to staffing methods/types

Two of the three studies examining changes in staffing found a significant reduction in UTI, although both were low quality. One was a cross sectional study set in the community and the other was a before and after design in a hospital setting. The first study examined UTI rates at two time points, one before and one after the introduction in March 2002 of increased nursing hours per patient day (NHPPD), to improve staffing levels in Australian hospitals. There was an increase of 313 full time equivalent nurses in wards across the state's public hospitals. Wards were grouped into categories based on their NHPPD; category A (7.5 NHPPD), category B (6.0 NHPPD), category C (5.75 NHPPD), category D (5.0 NHPPD). There was a reduction in UTI rates on category B medical wards (RR = 0.78; CI = 0.62, 0.98), and category D all wards and medical wards respectively (RR = 0.75; CI = 0.59, 0.95) (RR = 0.68; CI = 0.52, 0.90).[36]

The second study examined rates of UTI in all patients at home cared for by a wound, ostomy and continence (WOC) nurse compared to home health care nurse only, provided by 808 care agencies. Patient UTIs in both groups significantly improved by discharge from the nurse care, however, patients with a WOC nurse had fewer severe problems.[38]

The third before and after study also of low quality, did not report significant reductions in CAUTI. They implemented a nurse family partnership on two surgical wards of one hospital in Taiwan. This involved educating a family member to undertake CAUTI prevention and catheter care after discharge to the home setting. Family members reported no increase in their self-efficacy to catheter care, which may explain the lack of success of the intervention.[37]

Catheter removal protocols

Two of three low quality hospital studies demonstrated effectiveness of catheter removal protocols. Adams *et al*. evaluated implementation of HOUDINI within a before and after study at three medical wards at a small acute general hospital in the UK. HOUDINI is an intervention used to empower nurses to remove urinary catheters that are no longer clinically indicated. HOUDINI was introduced at hospital ward meetings for all staff and reinforced with posters on notice boards, drug trolleys and ward-round trolleys, and hand held cards given to staff. The use of HOUDINI reduced *E. coli* catheter associated positive urine samples by 70% compared to controls, although statements of significance were not provided.[39] A USA study using a before and after design, simply placed reminder stickers saying 'please evaluate need for urinary catheter. Thank you.' on patient bed charts in hospitals to remind physicians to remove catheters if they are unnecessary. They found a significant reduction in CAUTI in December 2008 (7.02 vs 2.08) and March 2009 (7.02 vs 2.72).[41]

A third study, also of low quality, investigating urinary catheter removal protocols, implemented pre-written orders on hospital patients' bed charts to check criteria for catheter necessity. The criteria warranting catheterisation included: urinary obstruction, neurogenic bladder and urinary retention, urological surgery, fluid challenge for acute renal failure, open sacral wound care for incontinent patients, and comfort care for urinary incontinence in terminal illness. There were no differences between the CAUTI rates for the intervention group and the control group, possibly because the overall reduction in duration of catheterization of 1.34 days (95% CI, 0.64 to 2.05), may not have been sufficient to significantly reduce bacteriuria.[40]

Hydration

The one study implementing a hydration intervention was a low quality before and after study in a 110 bed LTCF in the USA. The intervention included: face to face staff training, brochures, fact sheets, information about optimum fluid consumption, and urine and fluid charts, tailored using the Health Belief Model. UTI rates did not significantly differ from pre-intervention (0.14, SD = 0.06) to post-intervention (0.13, SD = 0.03), (t (2) = 0.10).[42] it is suggested that this may be as a result of only recruiting 63% of nursing staff, the short follow up period of only 3 months and low prevalence rates of UTI pre-intervention in a study involving 110 bedded LTCF.

Catheter self-management

In a single RCT type study in the USA, community catheter users (average age of 60.6 years in the intervention group and 62.2 years in the control group) were taught to conduct catheter self-monitoring and to review monitoring information of their long term indwelling urinary catheters (Both urethral and suprapubic). They were taught individually in their homes, to calculate the fluid intake and urine output averages and compare them to the optimal volume of 30ml/kg body weight. Additionally, they were asked to identify any catheter-related problems e.g. dislodgment, blockage etc, and given an educational booklet describing basic catheter self-management skills related to maintaining optimal and consistent fluid intake and preventing catheter dislodgement. The overall aim of the intervention was to increase user self-efficacy and was based on self-efficacy theory. CAUTI rates decreased over the first six months, and over 12 months from 4.89 to 4.12. The control

group received usual care, consisting of catheter-related care provided by home care nurses, clinics, or private providers; they also had a significant decrease in CAUTI during the second half of the study, suggesting that further high quality studies are needed.[43]

Feedback of CAUTI rates to staff

One before and after study in medical-surgical wards in a USA hospital, gave nursing staff their unit-specific CAUTI rates via a graphic quarterly report sent to the Associate Chief, Nursing Service, to forward to the nurse manager of each nursing ward, as a form of feedback each quarter for 18 months (patients in critical care units were not included). They found that UTI rates were halved from 32/1000 catheter-patient-days to 17.4/1000 catheter-patient-days (95% CI, 14.6 – 20.6), although the study was of low quality.[44] They calculated that 106 infections were prevented, representing an estimated cost savings of $403,000. This is the only study of feedback used as a single intervention that suggests the effectiveness of reporting CAUTI rates to hospital staff. Other studies successfully used feedback as part of multi-faceted interventions with significant reductions in UTI and CAUTI.[26, 27, 31]

Bacterial interference

One low quality study inserted Foley catheters coated with a non-pathogenic *E. coli* HU2117 into participants with the rationale that the *E. coli* HU2117 would competitively exclude bladder uropathogens and induce favourable clinical outcomes, but they found no significant difference in UTI rates as a result. Five of the 10 subjects suffered invasive disease from the co-colonising bacteria (3 febrile UTI and 2 urosepsis/bacteraemia) and as a result the study ended half way through following consultation with the safety monitoring board.[45] There are currently no high quality evidence studies to support the use of bacterial interference in preventing UTI.

A summary of the intervention effectiveness can be seen in Table IV.

Discussion

The heterogeneity of interventions and results, and their low quality mean it is not possible to definitely recommend one effective simple or complex intervention. However, we suggest feedback should always be included in any intervention as this facilitated significant reduction when used alone or as part of a multifaceted intervention including education, audit or catheter removal protocols. Education without an added component is unlikely to be effective. In catheterised populations catheter removal protocols increasing nursing staff and one to one patient education are worthy of further evaluation.

The six multi-faceted intervention studies showing reductions in CAUTI and UTI include a combination of feedback, education, auditing, and catheter removal protocols,[26-28, 30, 31] and all four of the studies using feedback (either within a multi-faceted intervention or separately) demonstrated significant reductions,[26, 27, 31, 44] suggesting that feedback should always be included in any interventions. However, further high quality studies are needed to confirm this evidence.

There was low quality evidence that face to face educational interventions covering general infection and catheter management were ineffective but a combination of online training and simulations on catheter insertion and care were effective. Further research is needed to confirm the effectiveness of educational methods using simulations that could be used.

There was some low quality evidence that catheter removal protocols, increasing nursing staff and patient training on catheter self-management could be effective interventions, but with the few low quality studies found, firm conclusions cannot be made as to their effectiveness despite the significant results. Research should consider investigating these interventions further using robust methodologies.

There was no evidence of effect from one hydration toolkit in one low quality study. However the role of hydration in UTI prevention should not be negated as a result of this review. The Scottish Antimicrobial Prescribing Group (SAPG) recommend remaining well hydrated in order to help prevent UTIs [46] and the Natural Hydration Council report that adequate hydration in older adults can help prevent UTI.[47] Other ways of reinforcing hydration should be examined with robust methodologies beyond the methods used in this study, and considered with other UTI prevention strategies.

No studies were identified that examined prevention of E. coli bacteraemias as a primary outcome, as all studies examined UTIs or CAUTIs as their outcome measure. This is probably because measurement of E. coli bacteraemia requires a very large sample size and blood cultures are rarely taken. However, interventions reducing UTIs and CAUTIs are still important to consider as tools to prevent *E. coli* bacteraemia as a 2014 Public Health England *E. coli* bacteraemia report showed that 50% of *E. coli* cases related to the urogenital tract and 72% occurred in patients 65 years and over, and 64% of patients had reported at least one UTI in the previous 12 months.[48] UTIs are more likely to recur within 12 months of the first infection [49] with antibiotic resistance at its greatest one month following antibiotic treatment.[50]

Strengths and limitations

This is the first systematic review to summarise the evidence of behavioural interventions to reduce UTI and *E. coli* bacteraemia in older adults across care settings. The broad inclusion criteria of examining behavioural interventions across all care settings can help identify where interventions may warrant transfer from one care setting to another.

A limitation of this review is that, despite the broad remit, the final number of studies is relatively low. It is possible that more studies with negative or non-significant effects were not published.

All of the studies reviewed here evaluated behavioural interventions, in which it is very difficult to blind participants and are often implemented with a before and after design rather than a concurrent control group. There is also a high risk of performance bias as participants may have been motivated to successfully implement interventions if they know they are being evaluated, especially for personnel who may have had a stake in the success of a study. The generalisability of the studies is also limited as over 71% of the studies were conducted in only one health facility. Most studies of this nature are categorised as low quality.

Over 66% of the studies were conducted in hospitals and used behavioural interventions aimed at staff. The study group has identified a number of different patient facing resources through web searches, currently being used in hospital and care homes in developed countries which have not been evaluated in older adult groups, or at all. 71

This systematic review only investigated behavioural interventions. Interventions such as prophylaxis, cranberry products and catheter associated interventions e.g. intermittent catheterisation vs indwelling catheterisation, trial without catheter, and male external catheters, are well documented in other reviews and discussed comprehensively in guidelines; therefore they were not included in this study.[19, 51-54] The word ‘bundle’ was not included as a search term in this review, therefore other future reviews may want to consider including this as an intervention term in order to capture other multi-faceted interventions.

Implications for research and practice

This is the first systematic review examining behavioural interventions to reduce UTI and *E. coli* bacteraemia for older adults across care settings. There were no single or multi-faceted interventions that provided conclusively positive results. However, increased staffing, catheter removal protocols, feedback and multi-faceted interventions using education, with auditing, feedback and reminders could be considered as potential options that could be used across care settings. Considerable research is required with robust methodologies in order to evaluate these interventions further. While it is not always possible to conduct full RCTs with behavioural interventions, research should consider the use of control groups and appropriate randomisation procedures where possible, as well as sufficiently powered samples. Future studies may want to consider using the McNulty-Zelen design[55, 56] which allows for randomisation and blinded conditions by seeking proxy consent or a stepped wedge design. This allows for a strong methodological evaluation of an intervention used in routine healthcare.

Eighteen of the 21 studies reviewed here did not state any use of behavioural theory to guide the research. Researchers may want to consider use of behavioural theories such as the COM-B and Theoretical Domains Framework (TDF) in order to design and evaluate interventions.[57, 58] The COM-B and TDF are designed to account for all potential influences on behaviour and provide a framework for intervention development and evaluation. The model postulates that an intervention which successfully addresses all or many of the behavioural domains is more likely to succeed, which may explain why many of the multi-faceted interventions saw reductions in UTI or CAUTI. The successful interventions identified here may benefit from being used as a bundle of interventions as a collection of resources can address multiple behavioural domains whereas singular interventions are unlikely to address many more than a few domains.

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Table I: Search terms for bibliographic database searches based on the PICO framework

Population	(caregiver OR carer OR careworker OR "health care assistant" OR "health personnel" OR nurs* OR personnel OR staff OR "support worker" OR "care home" OR "home for the aged" OR "long term care" OR "nursing home" OR "residen* aged care" OR "residen* facility" OR "residen* home" OR "residen* care" OR elderly OR "older adults" OR "over 65s" OR hospital* OR "secondary care" OR ward OR unit OR clinic OR hospice OR community OR home)
Intervention	(intervention* OR implement* OR "quality improv*" OR "practice change" OR "practise change" OR "behavio*r change" OR dissemination OR train* OR outreach OR educat* OR "organisation* change" OR "organization* change" OR champion OR resource* OR leaflet* OR information* OR adopt* OR "profession* development" OR supervision OR leadership OR strateg*)
Comparator	None specified
Outcome	("urinary tract infection*" OR uti OR cauti OR "catheter associated urinary tract infection*" OR "E. coli bacteraemia" OR "E. coli bacteremia" OR E. coli OR bacteraemia OR bacteremia OR "Escherichia coli" OR "symptomatic urinary tract infection*" OR "symptomatic uti" OR "Escherichia coli bacteremia" OR "Escherichia coli bacteraemia")

Table II: Bibliographic databases searches with corresponding search filters

Database	Filter
1. EBSCO	
a. Cumulative Index for Nursing and Allied Health Literature (CINAHL)	Searched Title
b. MEDLINE	Searched Title
c. PsycINFO	Searched Abstract
d. AMED	Searched All text
e. PsycARTICLES	Searched Abstract
2. British Nursing Index (BNI)	Searched Abstract
3. The Cochrane Library (Cochrane Database of Systematic Reviews)	Searched Abstract
4. OVID	
a. EMBASE	Searched Title
b. Health Management Information Consortium (HMIC)	Searched Abstract
5. Cochrane Central Register of Controlled Trials (CENTRAL)	Default search
6. Social Care Online	Searched Title
7. Web of Science	Searched Title
8. ScienceDirect	Searched All fields
9. Informahealthcare	Default search
10. Internurse	Default search
11. TRIP (Turning Research Into Practice)	Default search

Table III: Studies of interventions to reduce UTI or E. coli bacteraemia in older adults in care settings

Intervention type	Study and country	Study design	Intervention population	Number of facilities in study	Outcome population	Age of outcome population	Intervention	Control condition	Study duration	Follow up	Results	Significant reductions in UTI or *E. coli*	Behaviour change models	Design and bias grade
Catheter removal protocol	Loeb (2008) [40] - Canada	RCT	Nurses and physicians of tertiary care hospitals	3	692 hospitalised patients admitted to hospital with indwelling UCs inserted for ≤48 h	Average age of intervention group = 78.6, range 24 to 100 Control group = 79.0, range 40 to 101	• Prewritten orders in patient charts • 6 criteria for acceptable UC: urinary obstruction, neurogenic bladder and urinary retention, urological surgery, fluid challenge for acute renal failure, open sacral wound care for incontinent patients, and comfort care for urinary incontinence in terminal illness • Nurses reviewed medical history and test results, then removed catheters if necessary • Regular follow-ups with nursing staff to ensure that the automatic stop orders were followed	Usual care		Indefinite	• At UC removal, 51 participants (19%) in the stop-order group developed UTIs compared with 51 (20%) in the usual care group, relative risk 0.94, (95% CI, 0.66 to 1.33), • At 7 days post-catheterisation, 28 of those tested (21.1%) in the stop-order group compared to 19 (16.7%) in the usual care group had UTIs, relative risk 1.26 (95% CI, 0.75 to 2.14), • 7 (2.1%) participants in each study arm developed symptomatic UTIs, • Baseline rate not provided	No	None	1-(High)
Catheter self-management	Wilde (2015) [43] - USA	RCT	Community dwelling catheter users	NA	Average age = 61 ranging from 19–96		Three home visits and 1 telephone call by a trained registered nurse to deliver the intervention: • participants were taught to conduct self-monitoring using a 3 day urinary diary • reviewing the information from the urinary diary, calculating the intake and output averages and comparing these to an optimal volume (30ml/kg body weight), and identifying the individual's catheter-related problems • An educational booklet	Usual care	12 months		• The experimental group continued to report significantly higher CAUTI severity scores and CAUTI-related emergency room visits and frequencies of events, as well as more hospitalisations for CAUTI • Compared with baseline rate estimates, the experimental group had significant decreases in CAUTI rates during the first half of the study, and for the overall full study time period of 12 months. The control group had a significant decrease in CAUTI during the second half of the study • Baseline rate not provided	Yes	Self-efficacy theory	1-(High)
Multi-faceted intervention	van Gaal (2011) [26] – The Netherlands	RCT	All nursing staff of 10 wards from 4 hospitals and	10	All adult patients admitted to the wards,	Pre-intervention usual care average = 64	SAFE or SORRY?: • education on adverse events • encouraging nurses to provide patients with An	Usual care	September 2006 to November 2008	9 months	• Rate ratio for hospital patients in the intervention group for developing adverse events (including	Yes	None	1-(High)

Intervention type	Study and country	Study design	Intervention population	Number of facilities in study	Outcome population	Age of outcome population	Intervention	Control condition	Study duration	Follow up	Results	Significant reductions in UTI or *E. coli*	Behaviour change models	Design and bias grade
			10 wards from 6 nursing homes		and volunteering nursing home patients	(SD = 16.9) Pre-intervention experimental = 66 (SD = 14.5) Post-intervention usual care = 67 (SD = 16.1) Post-intervention intervention = 66 (SD = 14.7)	information leaflet for the prevention of pressure ulcers, urinary tract infection and falls • feedback through a computerised registration programme about patient's daily care and the presence or absence of an adverse event • implementation plan for every ward				UTIs, falls and pressure ulcers) was 0.57 (95% CI: 0.34–0.95), compared to usual care. Intervention group baseline rate: 46(0.09) • In nursing homes, the rate ratio for patients in the intervention group was 0.67 (95% CI: 0.48–0.99), compared to usual care. Intervention group baseline rate: 79 (0.09) • In hospitals, this difference was especially accounted for by fewer UTIs per patient week (rate ratio = 0.39; intervention group baseline = 22, 0.05) and falls per patient week (rate ratio = 0.67) • In nursing homes, this difference was mainly accounted for by fewer pressure ulcers per patient week (rate ratio = 0.34) and falls per patient week (rate ratio = 0.63)			
Staffing method/type	Kwo-Chen (2015) [37] - Taiwan	RCT	61 Family care (FC) givers of patients	1	Patients from 2 surgical wards of a 500 bed teaching hospital	Average age = 64.45 (± 15.2 years)	Nurse family partnership: • FCs watched a 10 min educational film containing CAUTI prevention guidelines • 1 hour individual training session • The experimental nurse and FCs discussed common goals to preventing the incidence of CAUTI • Guidelines emphasising maintaining a closed drainage system, keeping the drainage bag below the level of the patient's bladder, practising strict hand hygiene and performing routine perianal care • Instructional handbooks	Routine nursing care	5 days	5 days	• 6 patients (20%) in the experimental group and 12 patients in the control group (38.8%) had a CAUTI, but the difference was not significant ($\chi 2 = 2.85$) • No significant difference emerged for reported Caregiver Self-Efficacy Scores between the two groups. • Baseline rate not provided	No	None	1-(High)

Intervention type	Study and country	Study design	Intervention population	Number of facilities in study	Outcome population	Age of outcome population	Intervention	Control condition	Study duration	Follow up	Results	Significant reductions in UTI or *E. coli*	Behaviour change models	Design and bias grade
							• A checklist of CAUTI prevention guidelines							
Multi-faceted intervention	McMullen (2007) [25] - USA	Before and after study	Long term care facility staff	1	All residents with a diagnosis of chronic bacteriuria and recurrent UTI and all residents with a current diagnosis of UTI		• A letter by the administrator, director of nursing, medical director, and QA nurse and a copy of the American Medical Directors Association (AMDA) guidelines sent to all attending physicians • An in-service training with case studies and a quiz was prepared for all licensed nurses • The quiz data led to an action plan for unit nurses to review all residents treated for UTIs to ensure they met AMDA guidelines • Residents received 1 cranberry 425 mg capsule • Use of silver-covered catheters		April 2002 to December 2004	Up to September 2006	• The UTI prevalence in May 2005 was zero • The UTI prevalence rate of less than 1% continued through 2006. • The monthly incidence of UTI was zero to 1 patient • There was an increase in UTI incidence in August and September 2006 of 4 and 3 patients, respectively • The care facility conducted staff education, and in October the UTI incidence returned to pre-August rates of less than 1% (0-1 patient) • Baseline rates not provided	Unclear	None	2- (High)
Multi-faceted intervention	Dickson (2016) [27] - USA	Before and after study	Hospital staff	1	Hospital patients with a Foley catheter	Unknown	• Peri-care on insertion - Foley kits included a ziplock package with peri-care wipes, hand hygiene, and a bright yellow reminder for peri-care prior to insertion • Peri-care twice a day - Visual reminders were placed on computer screens • Mandatory skills-lab • Monthly bundle audit		• pre-intervention - 2014 • post intervention - 10 months in 2015	10 months	• Pre-intervention CAUTI rate = 2.05 per 1000 device days, Post-intervention CAUTI rate = 0.24, an 88% reduction. F(1,20) = 7.25,	Yes	None	2+ (High)
Multi-faceted intervention	Oman (2012) [28] - USA	Before and after study	Hospital staff	1	2 adjacent medical/surgical nursing units, 18 beds, averaging 18 patients. Approximately 150 patients/mo	• Pulmonary unit = phase 1 mean 58.2 (SD = 14.0) phase 2 mean 58.1 (SD = 14.6) phase 3 mean = 57.2 (SD = 14.9) • Surgery unit = phase 1	• Revision of hospital policy on insertion and care of indwelling urinary catheters (UCs) • competency-based catheter insertion training • evaluation of the hospital's indwelling UC products • Mandatory factoid presentation of policy changes available via the hospital's learning management system		Phase 1(pre-intervention) = January to March 2009 Phase 2 (intervention) = February - March April		• The baseline CAUTI rates were 0.0 and 1.9 on the pulmonary and surgical units, respectively. The pulmonary unit continued to have 0.0 incidence of CAUTI in the post-intervention data collection periods. The surgical unit rate increased in the second data collection period (3.4) and decreased	Reduction but missing statistical evidence	None	2+ (High)

Intervention type	Study and country	Study design	Intervention population	Number of facilities in study	Outcome population	Age of outcome population	Intervention	Control condition	Study duration	Follow up	Results	Significant reductions in UTI or *E. coli*	Behaviour change models	Design and bias grade
					nth with indwelling urinary catheters (UCs) on the general surgery unit and 125 patients/month on the pulmonary unit.	mean 52.6 (SD = 15.2) phase 2 mean 55.3 (SD = 14.4) phase 3 mean 52.3 (SD = 14.8)	• Product evaluation • Education on routine and frequent emptying and placement of UC bag below the bladder prior to therapy, radiologic examination, and transport, for rehabilitation therapists, radiology staff, and transport staff • replacement of silver alloy-coated catheters with usual latex and non-latex catheters • standardisation of catheter securement devices and stocking location, and provision of metered drainage bags in the standard insertion kit in all patient care areas		- June (second data collection period) Phase 3 = July (focused intervention on the study units), August to October (the last data collection period)		(2.2) in the third period • The mean length of stay on the surgical unit was 6.91, 8.03, and 6.55 days for the 3 data collection phases, respectively. On the pulmonary unit, there was a progressive decrease in length of stay from 7.39, 7.21, and 6.72 days, respectively			
Multi-faceted intervention	Theobald (2017) [29] - USA	Before and after study	Hospital staff	1	All patients with an indwelling UC admitted to the 40-bed general acute medical unit		• Bedside catheter reminder • Multidisciplinary educational campaign; • Structured catheter order set with clinical decision support • Automated catheter discontinuation orders • Protocol for post-catheter removal care		December 2012 - February 2015	27 week transition/intervention period 70 week full implementation/sustainability	• CAUTI on the study ward was 3.53 per 1000 UC days. Following full implementation the CAUTI rate fell to 0.70 per 1000 catheter days • The average number of days between CAUTI was 101. Since full implementation, there has only been 1 CAUTI on the study ward, with an interval of 412 days between infections • Baseline rates not provided	Reduction but missing statistical evidence	None	2+ (High)
Multi-faceted intervention	Jaggi (2012) [30] - India	Before and after study	Hospital staff	1	Inpatients with UCs	All ages (<5 years - >65 years)	• Key areas required improvement were identified • Bundle of prevention measures was implemented by a UC checklist • Training on the standard definitions and the guidelines • Auditing by the infection control department to determine the compliance to the UC checklist and the hand hygiene practices		January 2009 - December 2009	6 months	• The baseline CAUTI rate in the first 6 months (pre-intervention) was 10.6 and it reduced to 5.6 (47.1% decrease) in the next 6 months (post intervention)	Reduction but missing statistical evidence	None	2- (High)

Intervention type	Study and country	Study design	Intervention population	Number of facilities in study	Outcome population	Age of outcome population	Intervention	Control condition	Study duration	Follow up	Results	Significant reductions in UTI or *E. coli*	Behaviour change models	Design and bias grade
Multi-faceted intervention	Smith (2009) [31] - USA	Before and after study	24 registered nurses and 18 patient care technicians	1	Patients on a 43-bed medical/surgical floor in a 321 bed hospital	Pre-intervention = 77 (SD = 5.16) Phase 1 = 77 (SD = 18.1) Phase 2 = 79.5 (SD = 1.581)	• Educational modalities for nursing staff • A dwell time notification system to alert physicians • An audit and feedback system related to catheter care, hand washing, and perineal care • Annual competency assessment for catheter care, hand washing and perineal care		6 months		• The CAUTI rate per 1000 patient days was 11.17 pre-intervention, 10.53 during Phase I and 0.392 during Phase II. • There were significant differences in infection rates before and after the educational intervention in CAUTI (Chi square= 254.237)	Yes	None	2+ (High)
Training and education	Singh (2012) [32] - India	Before and after study	184 Hospital staff	1	All adult patients (2838) undergoing cardiovascular surgical procedures during the study period	Pre-intervention = 57.1 (SD = 10.1) Post-intervention = 58.1 (SD = 10.1)	2 modules appropriate for all health-care personnel were planned as 2 half-day training programs with all faculty and staff. The training sessions were in the form of didactic sessions, video shows, quizzes, role plays and tests		January 2009 – December 2010	1 year	• CAUTI infection rate /1000 catheter days, annual growth rate of -0.56 pre-intervention, to -93 post intervention. • No significant difference between CAUTI rates pre and post	No	None	2+ (High)
Training and education	Girard (2015) [33] - France	Before and after study	Hospital staff	6	Patients from 6 geriatric units or hospitals	• mean age of pre-intervention group = 85.2 years (SD = .4) • mean age of post-intervention group = 85.5 years (SD = 7.0)	multi-modal training programme to: • improve understanding of micturition • measurement of bladder volume and indications for catheter drainage • limit available medical devices • improve prescription and traceability procedures		Training was conducted between February and May 2011	1 year	• Cumulative incidence of CAUTI between 2009 and 2012 was a small change and not significant • Baseline rates not provided	No	None	2+ (High)
Training and education	Justus (2016) [34] - USA	Before and after study	680 nurses, nursing assistants, and transporters from a 350-bed acute care hospital	1	Hospital patients with catheters		Theoretical material of current best practices of catheter care and 4 best practices of CAUTI prevention, including: • Preventing unnecessary UC insertions • Proper insertion of UCs • Early removal of UCs • Accurate documentation		30 months	15 months	CAUTIs decreased from 33 to 14. there was a significant inverse relationship between whether education was administered and the monthly number of CAUTIs, with a point-biserial correlation of r = –0.45,	Yes	None	2+ (High)
Training and	Gordon (2016) [35] -	Before and after	Nursing staff	1	Patients from a 40-	mean age ranged	• Staff education on CDC's best practice guidelines for		3 months	2 months	A statistically significant difference was found in the	Yes	The Iowa Model of	2+ (High)

Intervention type	Study and country	Study design	Intervention population	Number of facilities in study	Outcome population	Age of outcome population	Intervention	Control condition	Study duration	Follow up	Results	Significant reductions in UTI or *E. coli*	Behaviour change models	Design and bias grade
education	USA	study			bed medical and surgical unit within an acute care Level I trauma hospital	between 19–85 years	indwelling UC insertion, CAUTI bundle care, indications for usage and maintenance, and alternatives • A quick reference pocket guide to use as a resource for CDC indications of usage • The slideshow was converted into an e-learning module				pre and post CAUTI rate (X^2=55.00, df =1). CAUTI rates were 10.40 and post-intervention CAUTI rates were 0.00		Evidence-Based Practice to Promote Quality Care	
Staffing method/type	Twigg (2011) [36] - Australia	Before and after study	All nursing staff of 3 adult tertiary teaching hospitals	3	All patients of 3 adult tertiary teaching hospitals (1449 beds)	Average age = 60.6 ranging from 18 - 106	In March 2002 the Australian Industrial Relations Commission ordered the introduction of nursing hours per patient day		1st July 2000 - 30 June 2004	28 months	• No significant difference of UTI results for combined or separate hospitals for all, medical or surgical patients • No significant difference of UTI results for wards categorised A or C for all, medical or surgical patients • A significant reduction of UTI was found on category B wards for medical patients • A significant reduction of UTI was found on category D wards for all patients and medical patients • Baseline rates not provided	Yes, depending on ward type and patient type	None	2+ (High)
Catheter removal protocol	Adams (2012) [39] - UK	Before and after study	All clinical staff from 3 medical wards at a small acute general hospital: Ward A – elderly care Ward B – medical gastroenterology Ward C – respiratory medicine	1	Ward patients		HOUDINI is an acronym: • Haematuria • Obstruction • Urology surgery • Decubitus ulcer • Input and output measurement • Nursing end of life care • Immobility Where none of these indications exist the catheter should be removed. HOUDINI was introduced at ward meetings. Posters were displayed on notice boards, drug trolleys and ward-round trolleys. Small hand-held cards with HOUDINI on were made available to staff.	Non-catheterised patients	pre-intervention = 2 months post-intervention = 2 months	2 months	• Non-duplicated *E. coli* laboratory confirmed catheter sampled urine decreased by 70% compared with the control group in which non-duplicated *E. coli* laboratory confirmed mid-stream specimen of urine increased by 25% • Non-duplicated *E. coli* BSI from patients with UCs remained unchanged at 0%. • Baseline rates not provided	Reduction but missing statistical evidence	None	2- (High)
Catheter removal	Bruminhent (2010) [49] -	Before and after	Hospital staff	1	• Patients with	• Mean age pre-	A sticker placed on the medical record binder to remind		Patients admitted in	6 months	• A significant reduction in the rate of CAUTI occurred in	Yes	None	2+ (High)

Intervention type	Study and country	Study design	Intervention population	Number of facilities in study	Outcome population	Age of outcome population	Intervention	Control condition	Study duration	Follow up	Results	Significant reductions in UTI or *E. coli*	Behaviour change models	Design and bias grade
protocol	USA	study			urethral catheters from medical wards, surgical wards, cancer unit, cardiovascular units, and ICUs	intervention = 71.3 ± 17 • Mean age post-intervention = 70 ± 17	physicians to remove unnecessary UCs		September 2008, December 2008, and March 2009		December 2008 (7.02 vs 2.08) and March 2009 (7.02 vs 2.72)			
Hydration	Taylor (2015) [42] - USA	Before and after study	Staff of a long term care facility	1	Residents of a 110 bed long term care facility	>65	• Training on hydration (role-play, lecture, demonstration, visual aids) • Fluid intake brochure • Fluid and older persons fact sheet • Preventing UTIs in older persons fact sheet • Practical tips for encouraging water consumption fact sheet • Daily fluid intake chart • Urine colour chart		Pre-intervention = June - August 2014 Post-intervention = September - November 2014	3 months	• Pre-intervention UTI prevalence rates ranged from 0.07 to 0.19 and averaged 0.14 (SD = 0.06). Post-intervention UTI prevalence rates ranged from 0.11 to 0.17 and averaged 0.13 (SD =0.03).(t(2) = 0.10)	No	The Health Belief Model	2- (High)
Feedback	Goetz (1999) [44] - USA	Before and after study	Nursing staff	1	• Patients with indwelling urethral, suprapubic, and ureteral catheters on a medical-surgical ward		Providing nursing staff with unit-specific CAUTI rates via a graphic quarterly report		• Pre-intervention = January - March 1995 • Post-intervention = up to September 1996	18 months	• The preintervention rate of UTI was 32/1000 CPD • UTI rate decreased by more than 50% to 14.8/1000 CPD • In the post-intervention the average infection rate was 17.4/1000 CPD (95% CI, 14.6-20.6, compared with the pre-intervention rate)	yes	None	2+ (High)
Bacterial interference	Horwitz (2015) [45] - USA	Non-randomised trial	1• 10 Residents in a long-term care facility with UCs • They had at least 1 prior symptomatic UTI, and	1	• 10 Residents in a long-term care facility with UCs • They had at least 1 prior symptomatic UTI, and pre-existing bladder	Average age = 70.9 (range 57-88)	Insertion of a Foley catheter coated with *E. coli* HU2117	No controls	28 days	Monthly urine samples collected after study catheter removal until HU2117 did not grow from	• Rates of UTI did not differ before, during, and after bladder colonisation in all 10 subjects	No	None	2- (High)

Intervention type	Study and country	Study design	Intervention population	Number of facilities in study	Outcome population	Age of outcome population	Intervention	Control condition	Study duration	Follow up	Results	Significant reductions in UTI or *E. coli*	Behaviour change models	Design and bias grade
			pre-existing bladder colonisation		colonisation					2 consecutive cultures				
Staffing method/type	Westra (2013) [38] - USA	Cross-sectional design	888,243 patients admitted for nonmaternal health conditions of 785 home health care agencies	NA	888,243 patients admitted for nonmaternal health conditions of 785 home health care agencies	>18	Wound, ostomy and continence nurses (WOC)		October 1, 2008, - December 31, 2009		• Patients with a WOC nurse significantly improved (OR = 1.4; CI = 1.38-1.43) or stabilized in UTI's by discharge (OR = 1.2; CI = 1.16-1.27) • Patients without a WOC nurse (had a home health nurse) significantly improved or stabilised in UTIs by discharge • Prevalence of UTI for those with WOC nurse = 8.2%, compared to 10.4% without WOC nurse • Incidence of UTI for those with a WOC nurse = 1.2%, compared to 1.7% without WOC nurse	Yes	None	2-(High)

UC, Urinary catheter
UTI, Urinary tract infection
CAUTI, Catheter-associated UTI
CPD,
SD,
CDC,
RCT,

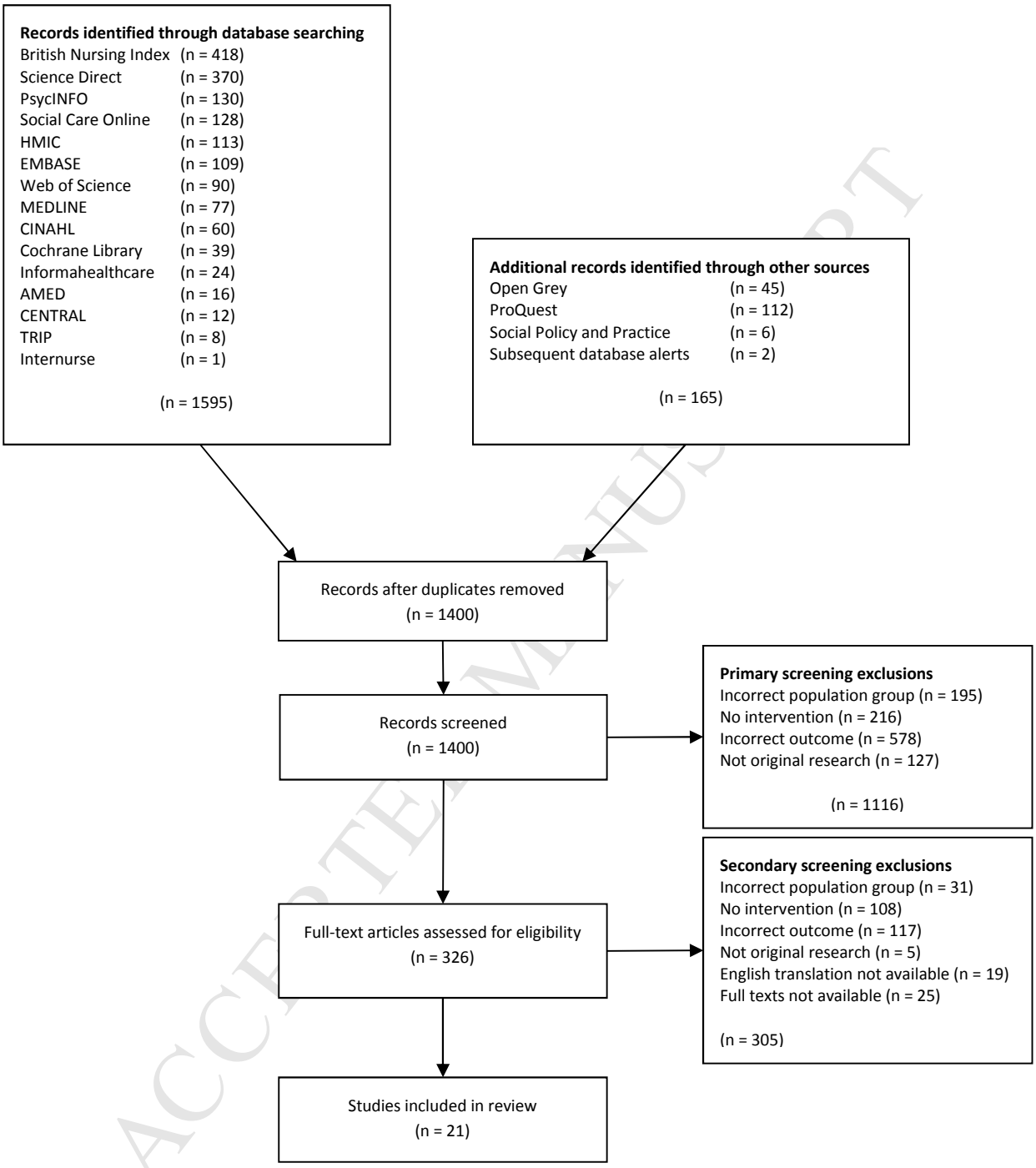
Table IV: A summary of the effectiveness of the interventions

Intervention type	Study	Quality	Effectiveness		Design	Setting
			Significant	Non-significant		
***Catheter self-management training**	Wilde (2015	Low	**X**		RCT	Community
Catheter removal protocols *Removal criteria (rc) Pre-written orders (pwo) *Reminder stickers (rs)	Loeb (2008) (pwo, rc)	Low		**X**	RCT	Hospital
	Adams (2012) (rc)	Low	Reduction but missing statistical evidence		Before and after	Hospital
	Bruminhent (2010) (rs)	Low	**X**		Before and after	Hospital
Multi-faceted interventions: **Education (e) Cranberry capsules (c) Silver catheters (sc) *Guidelines/protocol (gp) *Latex and non-latex catheters (lc) **Feedback (f) **Reminders (r) *Checklists (ch) Posters (p) **Auditing (a) Personal protective equipment (ppe) Urethral meatus cleansing (umc) Catheter assessments (ca) *Catheter product evaluations and standardisations (es) *Patient involvement (pi) *Implementation plans (ip) *Annual competency assessment (aca)	vanGaal (2011) (e, f, ip, pi,)	Low	**X**		RCT	Hospitals and nursing homes
	McMullen (2007) (c, e, gp, sc)	Low	Reduction but missing statistical evidence		Before and after	Long term facility
	Dickson (2016) (a, e, f)	Low	**X**		Before and after	Hospital
	Oman (2012) (e, es, lc)	Low	Reduction but missing statistical evidence		Before and after	Hospital
	Theobald (2017) (e, gp, r)	Low	Reduction but missing statistical evidence		Before and after	Hospital
	Jaggi (2012) (a, ch, e)	Low	Reduction but missing statistical evidence		Before and after	Hospital
	Smith (2009) (a, aca, e, f, r)	Low	**X**		Before and after	Hospital
Staffing methods/types: *Nursing hours per patient day (nhpd) Nurse family partnership (nfp) *Wound, ostomy and continence nurses (woc)	Kwo-Chen (2015) (nfp)	Low		**X**	RCT	Community
	Twigg (2011) (nhpd)	Low	**X**		Before and after	Hospital
	Westra (2013) (woc)	Low	**X**		Cross sectional	Community
Training and education (topic and method): *General infection (gi) *Catheter insertion and care (cic) Catheter management (cm) *Face to face (ff) *Online (o) *Simulations (s)	Singh (2012) (gi, ff)	Low		**X**	Before and after	Hospital
	Girard (2015) (cm, ff)	Low		**X**	Before and after	Hospital
	Justus (2016) (cic, o, s)	Low	**X**		Before and after	Hospital
	Gordon (2016) (cic, o, ff)	Low	**X**		Before and after	Hospital
Hydration toolkit	Taylor (2015)	Low		**X**	Before and after	Long term facility
***CAUTI rate feedback to staff**	Goetz (1999)	Low	**X**		Before and after	Hospital
Bacterial interference	Horwitz (2015)	Low		**X**	Non-randomised trial	Long term facility

*Significant or reduction, one study

** Significant or reduction, multiple studies

Figure 1: Literature search flow diagram of included and excluded studies[1]



1. Moher D, Liberati A, Tetzlaff J, Altman DG, Group TP. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLoS Medicine.* 2009;6(7).