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Effectiveness of behavioural interventions to reduce urinary tract infections and *Escherichia coli* bacteraemia for older adults across all care settings: a systematic review

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SUMMARY

Background: *Escherichia coli* bacteraemia rates in the UK have risen; rates are highest among older adults. Previous urinary tract infections (UTIs) and catheterization are risk factors.
Aim: To examine effectiveness of behavioural interventions to reduce *E. coli* bacteraemia and/or symptomatic UTIs for older adults.
Methods: Sixteen databases, grey literature, and reference lists were searched. Titles and/or abstracts were scanned and selected papers were read fully to confirm suitability. Quality was assessed using Critical Appraisal Skills Programme guidelines and Scottish Intercollegiate Guidelines Network grading.
Findings: Twenty-one 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 supplied statements of significance. One study reported decreasing catheter-associated UTI (CAUTI) by 88% (F (1,20) = 7.25). Another study reported reductions in CAUTI from 11.17 to 10.53 during Phase I and by 0.39 during Phase II (χ^2 = 254). A third study reported fewer UTIs per patient week (risk ratio = 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.
Conclusion: The heterogeneity of studies means that one effective intervention cannot be recommended. We suggest that feedback should be considered because it facilitated reductions in UTI when used alone or in multi-faceted 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.

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Introduction

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

In recognition of this threat, NHS England has an ambition to halve Gram-negative bloodstream infections (BSIs) 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 hospitalized patients of all ages can effectively reduce hospital catheter-associated urinary tract infection (CAUTI) rates; however, the review only included one randomized controlled trial (RCT) and the remaining studies were of a lower quality [9]. A systematic review of interventions to reduce urinary catheter insertion in hospitalized adults included eight low-quality studies and was unable to make any intervention recommendations [10]. There have been no systematic reviews assessing interventions for older adults to reduce CAUTI, catheterization 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 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; to assess the effectiveness of these interventions at reducing rates of *E. coli* bacteraemias and reducing symptomatic UTIs; and to 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 home: 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 are considered as 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 CAUTI in older adults in all care settings, are included. All care settings are included in this study because estimates show that ~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 were included if 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

Studies were excluded if 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 if 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 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 minimize 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 (D.H.) 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.

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 database 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. Informa Healthcare	Default search
10. Internurse	Default search
11. TRIP (Turning Research Into Practice)	Default search

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 five-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 randomized 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 UTI in adult guidelines in order to grade each study as low, moderate, or high quality [24].

Results

In all, 1595 studies were identified from 16 databases and 165 from grey literature searches. A total of 360 studies were removed as duplicates; 1400 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 summarizes 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

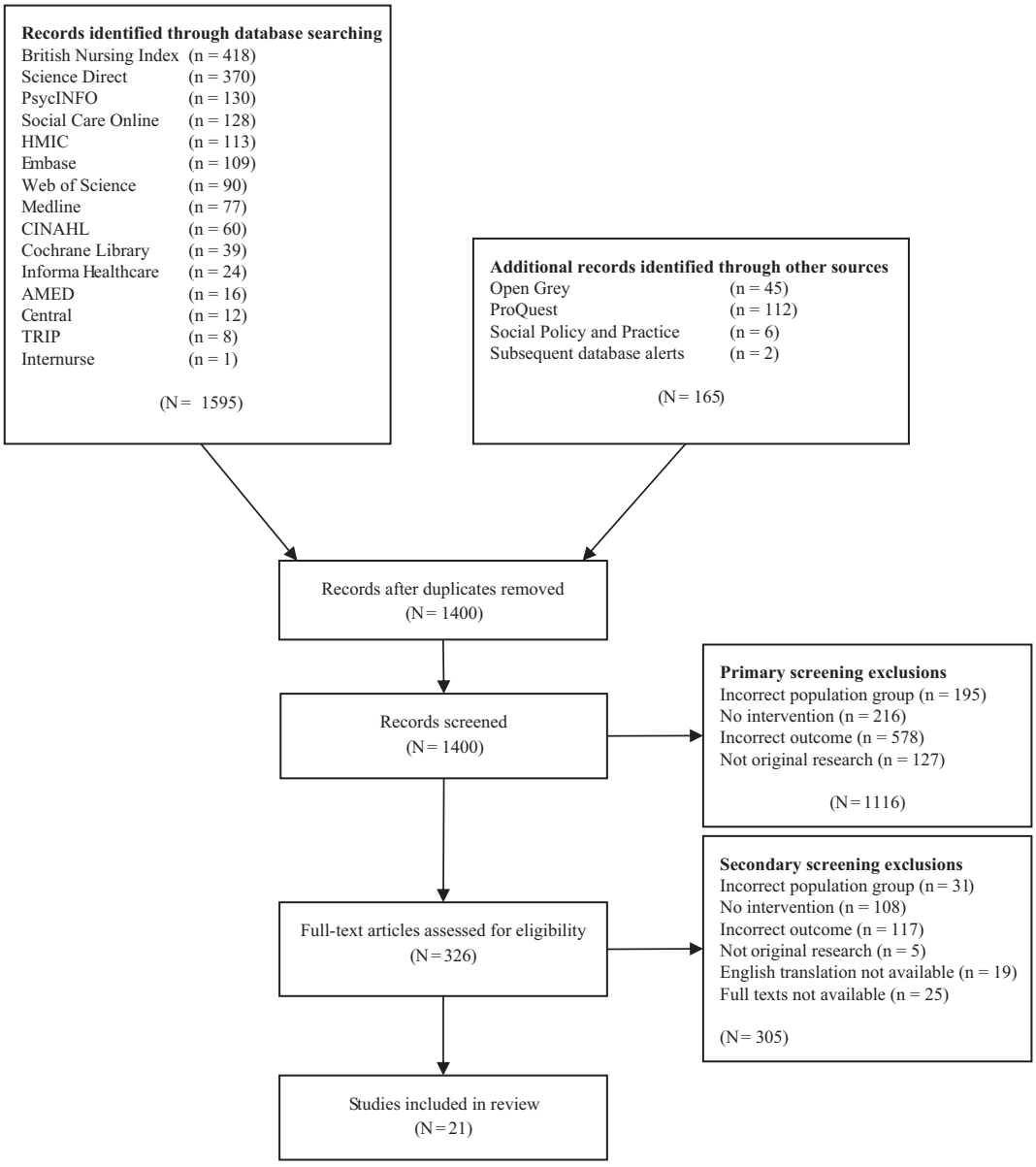

Figure 1. Literature search flow diagram of included and excluded studies (conforming with Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Medicine* 2009; 6 (7)).

Table III

Studies of interventions to reduce urinary tract infection (UTI) or *E. coli* bacteraemia in older adults in care settings

Intervention type	Study and country	Study design	Intervention population	No. 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	McMullen *et al.* [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 quality assurance 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 one cranberry 425 mg capsule • Use of silver-covered catheters		Apr 2002 to Dec 2004	Up to Sep 2006	• The UTI prevalence in May 2005 was zero • The UTI prevalence rate of <1% continued through 2006. • The monthly incidence of UTI was zero to one patient • There was an increase in UTI incidence in Aug and Sep 2006 of four and three patients, respectively • The care facility conducted staff education, and in Oct the UTI incidence returned to pre-Aug rates of <1% (0–1 patient) • Baseline rates not stated	Unclear	None	2– (high)
Multi-faceted intervention	van Gaal *et al.* [26] Netherlands	RCT	All nursing staff of 10 wards from 4 hospitals and 10 wards from 6 nursing homes	10	All adult patients admitted to the wards, and volunteering nursing home patients	Pre-intervention usual care average: 64 years (SD: 16.9) Pre-intervention experimental: 66 years (SD: 14.5) Post-intervention usual care: 67 years (SD: 16.1) Post-intervention intervention: 66 years (SD: 14.7)	SAFE or SORRY?: • education on adverse events • encouraging nurses to provide patients with an information leaflet for the prevention of pressure ulcers, urinary tract infection and falls • feedback through a computerized registration programme about patient's daily care and the presence or absence of an adverse event • implementation plan for every ward	Usual care	September 2006 to November 2008	9 months	• Rate ratio for hospital patients in the intervention group for developing adverse events (including 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	Yes	None	1– (high)

										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)			
Multi-faceted intervention	Dickson and Macomber [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 *et al.* [28] USA	Before-and-after study	Hospital staff	1	Two adjacent medical/surgical nursing units, 18 beds, averaging 18 patients. Approximately 150 patients/month with indwelling UCs on the general surgery unit and 125 patients/month on the pulmonary unit	• 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 mean 52.6 (SD: 15.2) phase 2 mean 55.3 (SD: 14.4) phase 3 mean 52.3 (SD: 14.8)	• Revision of hospital policy on insertion and care of indwelling 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 • 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	Phase 1 (pre-intervention): Jan–Mar 2009. Phase 2 (intervention): Feb–Mar Apr–Jun (second data collection period). Phase 3: Jul (focused intervention on the study units), Aug–Oct (the last data collection period)		• 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 (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 three 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	Reduction but missing statistical evidence	None	2+ (high)

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Table III (*continued*)

Intervention type	Study and country	Study design	Intervention population	No. 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
							• Replacement of silver alloy-coated catheters with usual latex and non-latex catheters • Standardization of catheter securement devices and stocking location, and provision of metered drainage bags in the standard insertion kit in all patient care areas							
Multi-faceted intervention	Theobald *et al.* [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 • Multi-disciplinary educational campaign • Structured catheter order set with clinical decision support • Automated catheter discontinuation orders • Protocol for post-catheter removal care		Dec 2012—Feb 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 one CAUTI on the study ward, with an interval of 412 days between infections • Baseline rates not stated	Reduction but missing statistical evidence	None	2+ (high)
Multi-faceted intervention	Jaggi *et al.* [30] India	Before-and-after study	Hospital staff	1	Inpatients with UCs	All ages (<5 to >65 years)	• Key areas requiring 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		Jan 2009—Dec 2009	6 months	• The baseline CAUTI rate in the first 6 months (pre-intervention) was 10.6, reducing to 5.6 (47.1% decrease) in the next 6 months (post intervention)	Reduction but missing statistical evidence	None	2− (high)
Multi-faceted intervention	Smith *et al.* [31] USA	Before-and-after study	24 registered nurses and 18 patient care technicians	1	Patients on a 43-bed medical/surgical floor	Pre-intervention: 77 (SD: 5.16) Phase 1: 77 (SD: 18.1)	• Educational modalities for nursing staff		6 months		• The CAUTI rate per 1000 patient-days was 11.17 pre-intervention,	Yes	None	2+ (high)

					in a 321-bed hospital	Phase 2: 79.5 (SD: 1.581)	• A dwell-time notification system to alert physicians • An audit and feedback system related to catheter care, handwashing, and perineal care • Annual competency assessment for catheter care, handwashing and perineal care			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 ($\chi^2 = 254.237$)			
Training and education	Singh *et al.* [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)	• Two modules appropriate for all healthcare personnel were planned as two 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 *et al.* [33] France	Before-and-after study	Hospital staff	6	Patients from six geriatric units or hospitals	• Mean age of pre-intervention group: 85.2 years (SD: 0.4) • 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 Feb 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 *et al.* [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 four 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 education	Gordon [35] USA	Before-and-after study	Nursing staff	1	Patients from a 40-bed medical and surgical unit within an acute care Level I trauma hospital	Mean age ranged between 19 and 85 years	• Staff education on CDC's best practice guidelines for indwelling UC insertion, CAUTI bundle care, indications for usage and maintenance, and alternatives	3 months	2 months	A statistically significant difference was found in the pre- and post-CAUTI rate ($\chi^2 = 55.00$, df = 1). CAUTI rates were 10.40 and post-intervention CAUTI rates were 0.00	Yes	The Iowa Model of Evidence-Based Practice to Promote Quality Care	2+ (high)

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Table III (*continued*)

Intervention type	Study and country	Study design	Intervention population	No. 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 quick reference pocket guide to use as a resource for CDC indications of usage • The slideshow was converted into an e-learning module							
Staffing method/type	Twigg [36] Australia	Before-and-after study	All nursing staff of three adult tertiary teaching hospitals	3	All patients of three adult tertiary teaching hospitals (1449 beds)	Average age: 60.6 years (range: 18–106)	In March 2002 the Australian Industrial Relations Commission ordered the introduction of nursing hours per patient-day		Jul 1st, 2000 to Jun 30th, 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 categorized 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)
Staffing method/type	Kwo-Chen *et al.* [37] Taiwan	RCT	61 family care givers (FCs) of patients	1	Patients from two surgical wards of a 500-bed teaching hospital	Average age: 64.45 years (±15.2)	Nurse family partnership: • FCs watched a 10 min educational film containing CAUTI prevention guidelines • 1 h individual training session • The experimental nurse and FCs discussed common goals to preventing the incidence of CAUTI • Guidelines emphasizing 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 • A checklist of CAUTI prevention guidelines	Routine nursing care	5 days	5 days	• Six 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 stated	No	None	1– (high)

Staffing method/type	Westra *et al.* [38] USA	Cross-sectional design	888,243 patients admitted for non-maternal health conditions of 785 home healthcare agencies	NA	888,243 patients admitted for non-maternal health conditions of 785 home healthcare agencies	>18	Wound, ostomy and continence nurses (WOC)		Oct 1st, 2008 to Dec 31st, 2009		• Patients with a WOC nurse significantly improved (OR: 1.4; CI: 1.38–1.43) or stabilized in UTIs by discharge (OR: 1.2; CI: 1.16–1.27) • Patients without a WOC nurse (had a home health nurse) significantly improved or stabilized 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)
Catheter removal protocol	Adams *et al.* [39] UK	Before-and-after study	All clinical staff from three 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-catheterized 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 stated	Reduction but missing statistical evidence	None	2– (high)
Catheter removal protocol	Loeb *et al.* [40] Canada	RCT	Nurses and physicians of tertiary care hospitals	3	692 hospitalized patients admitted to hospital with indwelling UCs inserted for ≤48 h	Average age of intervention group: 78.6 years, range 24–100; control group: 79.0 years, range 40–101	• Prewritten orders in patient charts • Six 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	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: 0.66–1.33) • At 7 days post-catheterization, 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: 0.75–2.14)	No	None	1– (high)

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Table III (*continued*)

Intervention type	Study and country	Study design	Intervention population	No. 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
							• 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				• 7 (2.1%) participants in each study arm developed symptomatic UTIs • Baseline rate not provided			
Catheter removal protocol	Bruminhent *et al.* [41] USA	Before-and-after study	Hospital staff	1	• Patients with urethral catheters from medical wards, surgical wards, cancer unit, cardiovascular units, and ICUs	• Mean age pre-intervention: 71.3 ± 17 years • Mean age post-intervention: 70 ± 17 years	A sticker placed on the medical record binder to remind physicians to remove unnecessary UCs		Patients admitted in Sep 2008, Dec 2008, and Mar 2009	6 months	• A significant reduction in the rate of CAUTI occurred in December 2008 (7.02 vs 2.08) and March 2009 (7.02 vs 2.72)	Yes	None	2+ (high)
Hydration	Taylor [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: Jun–Aug 2014. Post-intervention: Sep–Nov 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)
Catheter self-management	Wilde *et al.* [43] USA	RCT	Community dwelling catheter users	NA	Average age: 61 years, range 19–96		Three home visits and one 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 (30 mL/kg body weight), and identifying the individual's catheter-related problems	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 hospitalizations 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	Yes	Self-efficacy theory	1– (high)

							• An educational booklet					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			
Feedback	Goetz *et al.* [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: Jan–Mar 1995 • Post-intervention: up to Sep 1996	18 months	• The pre-intervention rate of UTI was 32/1000 CPD • UTI rate decreased by >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 *et al.* [45] USA	Non-randomized trial	• 10 residents in a long-term care facility with UCs • They had at least one prior symptomatic UTI, and pre-existing bladder colonization	1	• 10 residents in a long-term care facility with UCs • They had at least one prior symptomatic UTI, and pre-existing bladder colonization	Average age: 70.9 years (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 two consecutive cultures	• Rates of UTI did not differ before, during, and after bladder colonization in all 10 subjects	No	None	2– (high)

UTI, urinary tract infection; RCT, randomized controlled trial; UC, urinary catheter; CI, confidence interval; CAUTI, catheter-associated UTI; SD, standard deviation; CDC, Centers for Disease Control and Prevention; BSI, bloodstream infection; ICU, intensive care unit; CPD, catheter-patient-days; OR, odds ratio.

[25,26,33,36,38,40,42,44,45], and one study reported *E. coli* in blood or urine [39].

Five studies used an 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 were lack of allocation concealment and lack of blinding of participants/patients and healthcare 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 are shown in Table III. The main results are summarized 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 an 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, standardizing 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 h 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 an LTCF, but its 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 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 CAUTI rate ($\chi^2 = 254.237$) 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, customized for each job role and care setting, to teach catheter insertion and care [34]. Similarly, Gordon used the Centers 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, sterilization and disinfection, isolation precautions, etc., using didactic sessions, video shows, quizzes, role plays, and tests; 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 during a post intervention period of 15

months ($r = -0.45$), and Gordon found that CAUTI rates decreased in one hospital ward during a period of three months ($\chi^2 = 55.00$, 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), category B (6.0), category C (5.75), category D (5.0). There was a reduction in UTI rates on category B medical wards (risk ratio: 0.78; 95% confidence interval (CI): 0.62, 0.98), and category D all wards and medical wards, respectively (0.75; 0.59–0.95; and 0.68; 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 healthcare 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 assessments of significance were not supplied [39]. A US 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 were 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 catheterization 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: 0.64–2.05) 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 result from only recruiting 63% of nursing staff, the short follow-up period of only three 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 30 mL/kg body weight. Additionally, they were asked to identify any catheter-related problems, e.g. dislodgement, 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 during the first six months, and during 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 per 1000 to 17.4 per 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 saving 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-colonizing bacteria (three febrile UTI and two urosepsis/bacteraemia) and therefore 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 is shown in Table IV.

Discussion

The heterogeneity of interventions and results, and their low quality, mean that it is not possible to recommend one effective simple or complex intervention. However, we suggest that 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 catheterized 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 that 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.

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. Researchers might 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 because of this review. The Scottish Antimicrobial Prescribing Group (SAPG) recommends remaining well hydrated in order to help prevent UTIs [46] and a recent RCT has shown that optimal hydration can reduce recurrent cystitis for some women [47]. Other ways of reinforcing hydration should be examined with robust methodologies beyond the methods used in this study, and these were 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 aged $\geq$65 years, and that 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].

This is the first systematic review to summarize 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 they are often implemented with a before-and-after design rather than with 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 generalizability of the studies is also limited as >71% of the studies were conducted in only one health facility. Most studies of this nature are categorized as low quality.

More than 66% of the studies were conducted in hospitals and used behavioural interventions aimed at staff. Through Internet searches, the study group has identified different patient-facing resources currently being used in hospitals and care homes in developed countries which have not been evaluated in older adult groups, or at all.

This systematic review only investigated behavioural interventions. Interventions such as prophylaxis, cranberry products and catheter-associated interventions, e.g. intermittent catheterization vs indwelling catheterization, 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.

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,

Table IV
Effectiveness of the interventions

Intervention type	Study (intervention(s))	Quality	Effectiveness		Design	Setting
			Significant	Non-significant		
Multi-faceted interventions	McMullen *et al.* [25] (cranberry capsules, education[b], guidelines/protocol, silver catheters)	Low	Reduction but missing statistical evidence		Before-and-after	Long-term facility
	Van Gaal *et al.* [26] (education[b], feedback[b], implementation plans[a], patient involvement)	Low	Yes		RCT	Hospitals and nursing homes
	Dickson and Macomber [27] (auditing[b], education[b], feedback[b])	Low	Yes		Before-and-after	Hospital
	Oman *et al.* [28] (education[b], catheter product evaluations and standardizations[a], latex and non-latex catheters[a])	Low	Reduction but missing statistical evidence		Before-and-after	Hospital
	Theobald *et al.* [29] (education[b], guidelines/protocol[a], reminders[b])	Low	Reduction but missing statistical evidence		Before-and-after	Hospital
	Jaggi *et al.* [30] (auditing[b], checklists[a], education[b])	Low	Reduction but missing statistical evidence		Before-and-after	Hospital
	Smith *et al.* [31] (auditing[b], annual competency assessment[a], education[b], feedback[b], reminders[b])	Low	Yes		Before-and-after	Hospital
Training and education (topic and method)	Singh *et al.* [32] (general infection[a], face to face[a])	Low		Yes	Before-and-after	Hospital
	Girard *et al.* [33] (catheter management, face to face[a])	Low		Yes	Before-and-after	Hospital
	Justus *et al.* [34] (catheter insertion and care[a], online[a], simulations[a])	Low	Yes		Before-and-after	Hospital
	Gordon [35] (catheter insertion and care[a], online[a], face to face[a])	Low	Yes		Before-and-after	Hospital
Staffing methods/types	Twigg [36] (nursing hours per patient day[a])	Low	Yes		Before-and-after	Hospital
	Kwo-Chen *et al.* [37] (nurse—family partnership)	Low		Yes	RCT	Community
	Westra *et al.* [38] (wound, ostomy and continence nurses[a])	Low	Yes		Cross-sectional	Community
Catheter removal protocols	Adams *et al.* [39] (removal criteria[a])	Low	Reduction but missing statistical evidence		Before-and-after	Hospital
	Loeb *et al.* [40] (pre-written orders, removal criteria[a])	Low		Yes	RCT	Hospital
	Bruminhent *et al.* [41] (reminder stickers[a])	Low	Yes		Before-and-after	Hospital
Hydration toolkit	Taylor [42]	Low		Yes	Before-and-after	Long-term facility
Catheter self-management training[a]	Wilde *et al.* [43]	Low	Yes		RCT	Community
CAUTI rate feedback to staff[a]	Goetz *et al.* [44]	Low	Yes		Before-and-after	Hospital
Bacterial interference	Horwitz *et al.* [45]	Low		Yes	Non-randomized trial	Long-term facility

RTC, randomized controlled trial; CAUTI, catheter-associated urinary tract infection.
[a] Significant or reduction, one study.
[b] Significant or reduction, multiple studies.

with auditing, feedback and reminders might be considered as options to be used across care settings. Considerable research is required with robust methodologies in order to evaluate these interventions further. Whereas it is not always possible to conduct full RCTs with behavioural interventions, the use of control groups and appropriate randomization procedures should be considered where possible, as well as sufficiently powered samples. Future studies may want to consider using the McNulty—Zelen design which allows for randomization and blinded conditions by seeking proxy consent or a stepped-wedge design [55,56]. This allows for a strong methodological evaluation of an intervention used in routine healthcare.

Eighteen of the 21 studies reviewed here did not indicate 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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Conflict of interest statement

L. Jones and C. McNulty work for Public Health England's Primary Care Unit and are involved in the development and evaluation of the TARGET Antibiotics Toolkit (http://www.rcgp.org.uk/clinical-and-research/toolkits/target-antibiotic-toolkit.aspx).

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