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Reducing unnecessary urinary catheter use and other strategies to prevent catheter-associated urinary tract infection: an integrative review

Jennifer Meddings,[1] Mary A M Rogers,[1] Sarah L Krein,[1,2] Mohamad G Fakih,[3] Russell N Olmsted,[4] Sanjay Saint[2,1]

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[1]Department of Internal Medicine, University of Michigan Medical School, Ann Arbor, Michigan, USA
[2]VA Ann Arbor Healthcare System, Ann Arbor, Michigan, USA
[3]Department of Internal Medicine, St. John Hospital and Medical Center, Detroit, Michigan, USA
[4]St. Joseph Mercy Health System, Ann Arbor, Michigan, USA

Correspondence to
Dr Jennifer Meddings, Department of Internal Medicine, University of Michigan Medical School, 2800 Plymouth Road, Building 16, Room 427W, Ann Arbor, MI 48109, USA; Meddings@umich.edu

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ABSTRACT

Background Catheter-associated urinary tract infections (CAUTI) are costly, common and often preventable by reducing unnecessary urinary catheter (UC) use.

Methods To summarise interventions to reduce UC use and CAUTIs, we updated a prior systematic review (through October 2012), and a meta-analysis regarding interventions prompting UC removal by reminders or stop orders. A narrative review summarises other CAUTI prevention strategies including aseptic insertion, catheter maintenance, antimicrobial UCs, and bladder bundle implementation.

Results 30 studies were identified and summarised with interventions to prompt removal of UCs, with potential for inclusion in the meta-analyses. By meta-analysis (11 studies), the rate of CAUTI (episodes per 1000 catheter-days) was reduced by 53% (rate ratio 0.47; 95% CI 0.30 to 0.64, p<0.001) using a reminder or stop order, with five studies also including interventions to decrease initial UC placement. The pooled (nine studies) standardised mean difference (SMD) in catheterisation duration (days) was −1.06 overall (p=0.065) including a statistically significant decrease in stop-order studies (SMD −0.37; p<0.001) but not in reminder studies (SMD, −1.54; p=0.071). No significant harm from catheter removal strategies is supported. Limited research is available regarding the impact of UC insertion and maintenance technique. A recent randomised controlled trial indicates antimicrobial catheters provide no significant benefit in preventing symptomatic CAUTIs.

Conclusions UC reminders and stop orders appear to reduce CAUTI rates and should be used to improve patient safety. Several evidence-based guidelines have evaluated CAUTI preventive strategies as well as emerging evidence regarding intervention bundles. Implementation strategies are important because reducing UC use involves changing well-established habits.

THE PROBLEM

Urinary tract infection (UTI) has long been considered the most common healthcare-associated infection (HAI), with the vast majority of these infections occurring after placement of the convenient, uncomfortable,[1] often unnecessary[2–4] and easily forgotten urinary catheter.[5] With an estimated[6 7] 449 334 healthcare-associated catheter-associated urinary tract infections (CAUTIs) per year, associated with an additional cost (in 2007) of US$749–1007[7–9] per admission (or an estimated US$3744 when complicated by blood stream infections),[10] it is not surprising that CAUTIs were among the first hospital-acquired conditions selected for non-payment by Medicare as of October 2008,[11] and have been further targeted for complete elimination[12] as a 'never event,' with a national goal to reduce CAUTI by 25% by 2014.[13] These national initiatives renewed public and research interest in the prevention of CAUTI, prompting updates of several comprehensive guidelines[14–17] and reviews of strategies to prevent CAUTI released since the 2001 Making Health Care Safer report.[18]

WHAT STRATEGIES MAY PREVENT CATHETER-ASSOCIATED URINARY TRACT INFECTIONS?

Similar to other HAIs — such as central line-associated blood stream infection — many CAUTI prevention strategies have been 'bundled' into a composite of

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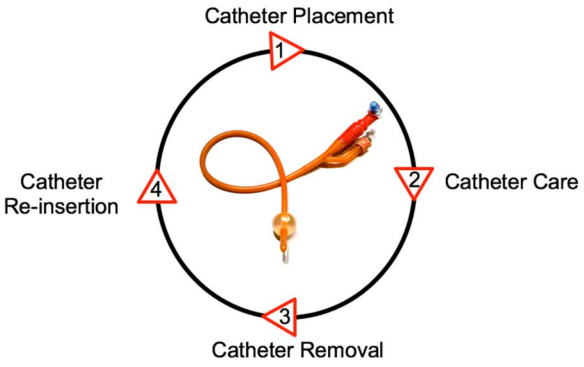

Figure 1 Lifecycle of the urinary catheter.[21] This conceptual model illustrates four stages of the urinary catheter lifecycle as targets for interventions to decrease catheter use and catheter-associated urinary tract infection.

multimodal sets of interventions known as 'bladder bundles.'[19] These bundles consist of educational interventions to improve appropriate use and clinical skill in catheter placement, behavioural interventions such as catheter restriction and removal protocols, and use of specific technologies such as the bladder ultrasound. Despite some early success in implementing a bladder bundle[19] to reduce urinary catheterisation rates,[20] CAUTI prevention has proven challenging for several important reasons. For example, monitoring urinary catheter use and CAUTI rates to inform and sustain urinary catheter-related interventions is very resource intensive. Perhaps more importantly, improving practice regarding urinary catheter placement and removal also requires interventions to change the expectations and habits of nurses, physicians and patients about the need for urinary catheters.

To help organise and prioritise the many potential interventions to prevent CAUTI, we use the conceptual model of the 'lifecycle of the urinary catheter'[21] to highlight that the highest yield interventions to prevent CAUTI will target at least one of the four 'stages' of the catheter's 'life.' As illustrated in figure 1, the 'lifecycle' of the catheter (1) begins with its initial placement, (2) continues when it remains in place, day after day, (3) ceases when it is removed and (4) may start over if another catheter is inserted after removal of the first one.

Because avoiding unnecessary urinary catheter use is the most important strategy in prevention of CAUTI, we review the evidence on two types of interventions that target unnecessary urinary catheter use: (1) protocols and interventions to decrease unnecessary *placement* of urinary catheters (catheter lifecycle stage 1), and (2) interventions that prompt *removal* of unnecessary urinary catheters (catheter lifecycle stage 3).

REVIEW PROCESS

The evidence summarised in this chapter was generated using a literature search conducted for a prior systematic review and meta-analysis[22] along with a focused update of the published peer-reviewed literature (from August 2008 to October 2012) through a MEDLINE search for intervention studies to reduce use of unnecessary urinary catheters in the acute care of adults. A CINAHL database search was also performed for interventions developed and implemented by nurses related to urinary catheter use. Studies were included if at least one outcome involving catheter use or CAUTI events (table 1) was reported as a result of the intervention, and with a comparison group (either preintervention vs postintervention, or a separate control group). Details of the systematic literature searches and methods employed for selection and reporting of the studies for this review are provided in the online supplementary appendix. The online supplementary appendix table summarises all the intervention studies described in this review, including study designs, patient populations and the interventions employed to avoid unnecessary catheter placement or to prompt catheter removal. This review was supported by the Agency for Healthcare Research and Quality (AHRQ), which had no role in the selection

Table 1 Description of outcomes evaluated (adapted from the prior meta-analysis[22])

Measures of Catheter-associated Urinary Tract Infection (CAUTI) development	**Number of CAUTI episodes per 1000 catheter-days** was recorded and a rate ratio was calculated to compare preintervention vs postintervention. When rates of both asymptomatic and symptomatic CAUTI were reported separately,[57] the rates of symptomatic CAUTI were used for the meta-analysis.[22] **Cumulative risk of CAUTI during hospitalisation** (ie, **the percentage of patients who developed CAUTI**) was also extracted for each study, and a risk ratio was calculated to compare risks before and after the intervention for the meta-analysis.[22]
Measures of urinary catheter use	**Mean number of days of urinary catheter use per patient** was recorded before and after the intervention, and a standardised mean difference was calculated to compare the two groups for the meta-analysis.[22] **Percentage of patient days in which the catheter was in place** (reported by the study directly, or calculated from ratio of catheter days/patient days if provided in the study), for the comparison group (before intervention or control group) and postintervention **Percentage of patients studied who had a urinary catheter placed during the study period,** for the comparison group (before intervention or control group) and postintervention
Need for catheter replacement	**Recatheterisation need** was extracted as the number and percent of patients who required replacement of a catheter after prior removal of an indwelling catheter.

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or review of the evidence or the decision to submit this manuscript for publication.

WHAT STRATEGIES MAY REDUCE UNNECESSARY CATHETER USE?

Strategies to avoid unnecessary placement of indwelling urinary catheters

Simply put, patients without urinary catheters do not develop CAUTI. Yet, multiple studies show that between 21% and 55.7%[2 4 20 23–25] of urinary catheters are placed in patients who do not have an appropriate indication and, therefore, may not even need a catheter. Over the past decade, several studies have employed interventions to decrease unnecessary catheter placement (described in the online supplementary appendix table). Although educational interventions are a common and important first step to decrease inappropriate catheter use, more effective and potentially more sustainable interventions go a step further by instituting restrictions on catheter placement. Protocols that restrict catheter placement can serve as a constant reminder for providers about the appropriate use of catheters, can suggest alternatives to indwelling catheter use (such as condom catheters or intermittent straight catheterisation), but perhaps most importantly, can generate accountability for placement of each individual urinary catheter. A fairly typical approach for developing a catheter restriction protocol is to begin with a basic list of appropriate catheter uses (such as the list provided in the Centers for Disease Control and Prevention's Healthcare Infection Control Practices Advisory Committee (HICPAC) guideline[14]); this list (see box 1) can then be tailored to include other indications based on local opinion and specialised patient populations.

The technology required to implement catheter placement restrictions ranges from low-technology strategies, such as a hospital or unit policy on appropriate catheter placement, or preprinted catheter orders with limited indications, to higher-technology strategies, such as computerised orders[24 26–28] for catheter placement. Catheter restriction protocols have been a common component of successful multimodal interventions to decrease catheter use and/or CAUTI rates, including hospital-wide[24] interventions and interventions tailored for specific environments, such as the emergency department,[23 29] inpatient units[20 28] (including general medical[26 30 31] surgical[32] wards and ICU[32–36]), and in the periprocedural[35] setting. Urinary retention protocols[27 31 32 35–37] are a type of catheter restriction protocols that often incorporate the use of a portable bladder ultrasound[27 28 31 35 37–41] to verify retention prior to catheterisation, and recommend use of intermittent catheterisation rather than indwelling catheters to manage a common and often temporary issue.

Box 1 Indications for indwelling urethral catheter use (from 2009 Centers for Disease Control and Prevention guideline[14])

A. Examples of appropriate indications for indwelling urethral catheter use

- Patient has acute urinary retention or bladder outlet obstruction
- Need for accurate measurements of urinary output in critically ill patients
- Perioperative use for selected surgical procedures:
  1. Patients undergoing urologic or other surgery on contiguous structures of genitourinary tract
  2. Anticipated prolonged surgery duration; catheters inserted for this reason should be removed in postanesthesia care unit
  3. Patients anticipated to receive large-volume infusions or diuretics during surgery
  4. Need for intraoperative monitoring of urinary output
- To assist in healing of open sacral or perineal wounds in incontinent patients
- Patient requires prolonged immobilisation (eg, potentially unstable thoracic or lumbar spine, multiple traumatic injuries such as pelvic fractures)
- To improve comfort for end-of-life care if needed

B. Examples of inappropriate uses of indwelling catheters

- As a substitute for nursing care of the patient or resident with incontinence
- As a means to obtain urine for culture or other diagnostic tests when patient can voluntarily void
- For prolonged postoperative duration without appropriate indications (eg, structural repair of urethra or contiguous structures, prolonged effect of epidural anesthesia, etc.)

Strategies to prompt removal of unnecessary urinary catheters

Urinary catheters are commonly left in place when no longer needed.[4 25] In most hospitals, four steps are required to remove a urinary catheter[21]: (1) a physician recognises the catheter is in place, (2) the physician recognises the catheter is no longer needed, (3) the physician writes the order to remove the catheter and (4) a nurse removes the catheter. Thus, by default, hours and sometimes days may pass before an unnecessary catheter is recognised and removed. Because every additional day of urinary catheter use increases the patient's risk of infectious[42] complications, and catheter use is also associated with non-infectious[43] catheter-related complications, interventions that facilitate prompt removal of unnecessary catheters can have a strong impact. We describe below the evidence regarding strategies that may accelerate

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or bypass some of these four steps to prompt catheter removal.

Perhaps the most important CAUTI prevention strategy after placement of the catheter is to maintain awareness of the catheter's existence (in lifecycle stage 2 of figure 1), as healthcare providers may be unaware the catheter is in place.[5] Thus, a key step in prompting removal of unnecessary catheters is frequently (by day or by shift) reminding nurses and physicians that the catheter remains in place. Catheter reminder interventions include a daily checklist[24 35 36 44–46] or verbal/written reminder[34 47–51] to assess continued catheter need, a sticker reminder on the patient's chart[38 52 53] or catheter bag,[54] or an electronic[24] reminder that a catheter is still in place. Reminder interventions can be generated by nurses, physicians or electronic order sets, and can be targeted to remind either nurses or physicians about the catheter. Some reminder interventions have employed nurses dedicated to detecting unnecessary catheters.[24 38] Reminder interventions can also serve to remind clinicians of appropriate catheter indications.

Unfortunately, reminder interventions can also be easy to ignore[52] and catheters may remain in place without action. The next type of intervention to prompt removal of unnecessary catheters which goes a step further, is a 'stop order' that requires action. Stop orders prompt the clinician (either nurse or physician) to remove the catheter by default after a certain time period has elapsed or condition has occurred, unless the catheter remains clinically appropriate. For example, catheter stop orders can be configured to 'expire' in the same fashion as restraint or antibiotic orders, unless action is taken by a clinician. Stop orders directed at physicians[24 26 28 31 33 51] require an order to be renewed or discontinued on the basis of review at specific intervals, such as every 24–48 h after admission or postprocedure. Stop orders directed at nurses either require the nurse to obtain a catheter removal order from physicians,[30 35 55] or can empower nurses to remove the catheter without requesting a physician order[31 33 37 46 56–61] on the basis of an appropriate indication list. Admittedly, implementing a nurse-empowered catheter removal protocol may be less effective than anticipated, as early qualitative research of nurse-empowered interventions indicate some nurses are uncomfortable with this autonomy[59] and might not remove catheters as expected.

BENEFITS AND HARMS

What is the impact of strategies to avoid unnecessary urinary catheter use?

Impact of interventions to avoid unnecessary catheter placement

Multiple before-and-after studies have found that interventions to decrease inappropriate catheter placement (such as catheter placement restrictions and urinary retention protocols) have resulted in a decrease in the use of urinary catheters,[23 24 27 28 31 32 34 36 46 62] a lower proportion of catheters in place without a physician order,[23 24 26 29] and a reduction in the proportion of catheters in place without an appropriate indication.[23 24 29 31]

Impact of reminder and stop-order interventions on catheter use and CAUTIs

As an update to our prior systematic review and meta-analysis of 14 studies[22] published prior to August 2008, this systematic review (through October 2012) identified a total of 30 studies employing reminders and/or stop orders to prompt removal of unnecessary urinary catheters that reported at least one CAUTI or urinary catheter use measure defined in table 1. Table 2 summarises each of these 30 studies, including the outcomes reported, and a brief summary of the interventions employed (with more details regarding the interventions provided in the online supplementary appendix table). The majority (28) of studies were prepost designs, including three[32 50 52] with concurrent controls; one study[57] was a randomised control trial (RCT) and one study was a non-randomised crossover trial.[26]

With very similar results to the prior[22] meta-analysis, the updated meta-analysis using 11 studies (figure 2, stratified by reminder vs stop order, and also see online supplementary appendix figure, stratified by study's focus on intensive care patients) indicated the rate of CAUTI (episodes per 1000 catheter-days) was reduced by 53% (rate ratio 0.47; 95% CI 0.30 to 0.64, $p<0.001$) with use of a reminder or stop order, with five of these studies also including interventions to restrict initial catheter placement. Based on this updated meta-analysis, reminders and stop orders could result in large numbers of avoided CAUTI episodes per 1000 catheter-days, particularly when baseline rates of CAUTI are high (table 3). Eight studies provided sufficient detail for pooling of the cumulative risk of CAUTI during the study period; the risk ratio for CAUTI was 0.72 (95% CI 0.52 to 0.99; $p=0.045$) for the intervention versus comparison groups (figure 3).

Using nine studies with sufficient detail for pooling (figure 4), the pooled standardised mean difference (SMD) in duration of catheterisation was −1.06 days overall ($p=0.065$) including a statistically significant decrease in studies that used a stop order (SMD −0.37; $p<0.001$) but not in those that used a reminder (SMD, −1.54; $p=0.071$). Many studies reported other outcomes for urinary catheter use (detailed in table 2), but none of the studies identified since the prior meta-analysis provided sufficient detail (eg, number of patients in intervention or control groups, and measures of variability such as SD) to update the prior meta-analyses for these other urinary catheter use outcomes.

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Table 2 Summary of CAUTI and urinary catheter (UC) outcomes reported for studies with reminder or stop-order interventions, evaluated as potential studies to include in meta-analyses

		CAUTI outcomes		Indwelling urinary catheter use outcomes		
1st author (year)	Interventions*	CAUTI per 1000 catheter days	% Patients who developed CAUTI	Mean days of UC use per patient	% Patient days with UC in use	% Patients with UC used
Adams (2010)[60]	S					25 → 7.6
Andreessen (2012)[28]	P, S, B			5.6 → 2.9†		All catheterised‡
Apisarnthanarak (2007)[47]	R	21.5 → 5.2†		11.0 → 3.0†		82 → 84
Bruminhent (2010)[53]	R	7.02 → 2.08†§				All catheterised‡
Cornia (2003)[26]	P, S, E		8.8 → 13.8	8.0 → 5.0†		All catheterised‡
Crouzet (2007)[48]	R	12.3 → 1.8†	10.6 → 1.1†	8.4 → 6.7		All catheterised‡
Dumigan (1998)[33]	P, S, E	14.3 → 9.2			74 → 76	
Elpern (2009)[34]	P, R	4.7 → 0†				All catheterised‡
Fakih (2008)[50]	R				20 → 16†	
Fuchs (2011)[35]	P, S	2.88 → 1.46				All catheterised‡
Gotelli (2008)[56]	S					24.0 → 17.0
Huang (2004)[49]	R	11.5 → 8.3†	3.8 → 2.4†	7.0 → 4.6†		74.5 → 76.2
Jain (2006)[44]	R, B, A	3.8 → 2.4				
Knoll (2011)[24]	P, R, S, B, O				Mean daily UC prevalence: 15.2 → 13.7§	
Loeb (2008)[57]	S		2.1 → 2.1	5.0 → 3.7†		All catheterised‡
Murphy (2007)[54]	R, E	Reduced UTI rates by 30%, no details				
Reilly (2008)[36]	P, R, E			4.7 → 3.0	96 → 86	All catheterised‡
Robinson (2007)[55]	S		40.0 → 13.3	8.6 → 4.5		
Roser (2012)[61]	P, S, O	CAUTI (details unclear): 45 → 28			UC 'Utilisation rates': ICU: 84 → 68 (not further defined) MedSurg: 16 → 11	
Rothfield (2010)[30]	P, S	3.2 → 2.4			33.3 → 18.5†	33.3 → 18.8
Saint (2005)[52]	R			0.6 → 0.4†	14 → 13	
Schultz (2011)[37]	P, S				90–95 → 76–84	
Sequin (2010)[51]	S	5.0 → 4.9	4.3 → 3.0	Median 5.0 → 4.0†		92.7 → 91.2
Stephan (2006)[32]	P, S, E	45.8 → 18.6†		5.0 → 3.9†		
Titsworth (2012)[46]	P, R, S, B, A, O	13.3 → 4.0†			UC Utilisation rates of ICU beds with UCs:100 → 73	
Topal (2005)[31]	P, S, E	36.0 → 19.0†	19.5 → 12.3		16 → 10†	
Van den Broek (2011)[38]	P, R, S, O		12.6 → 12.7	ICU/CCU: 25.6 → 16.2 Med: 14.9 → 12.5† Neuro: 15.8 → 15.7 Surg: 11.8 → 10.5†		ICU/CCU: 74 → 81 Med: 14 → 14 Neuro: 20 → 19 Surg: 21 → 19†
Voss (2009)[58]	S			4.9 → 3.9	26 → 10	33 → 15.3
Weitzel (2008)[45]	R		37 → 6.7	8.6 → 4.5		
Wenger (2010)[59]	S, E, A	2.26 → 1.02†				

A grey-shaded table cell indicates that the outcome was not reported in the study.
*Intervention key (note: interventions described in more detail in online supplementary appendix table).
†Difference of $p<0.05$ reported between comparison group (before intervention or control) → postintervention group.
‡Not applicable, as only catheterised patients were included for these studies (so 100% catheterised).
§Reporting first published postintervention result, for this study that reported serial postintervention results.
P=Intervention to avoid unnecessary catheter Placement (eg, restricted indications of use, bladder scanner protocols, etc).
R=Reminder intervention that UC is still present, could be directed at either physician or nurse.
S=Stop order intervention, prompting/requiring removal of the UC based on time or clinical criteria.
E=Education regarding UC placement or maintenance.
B=Bladder bundle of interventions (which included UC placement, maintenance care standardisation).
A=Antimicrobial UCs.
O=Other CAUTI or catheter-related interventions, detailed in online supplementary appendix table.
CAUTI, catheter-associated urinary tract infection; CCU, coronary care units; ICU, intensive care units; UTI, urinary tract infection.

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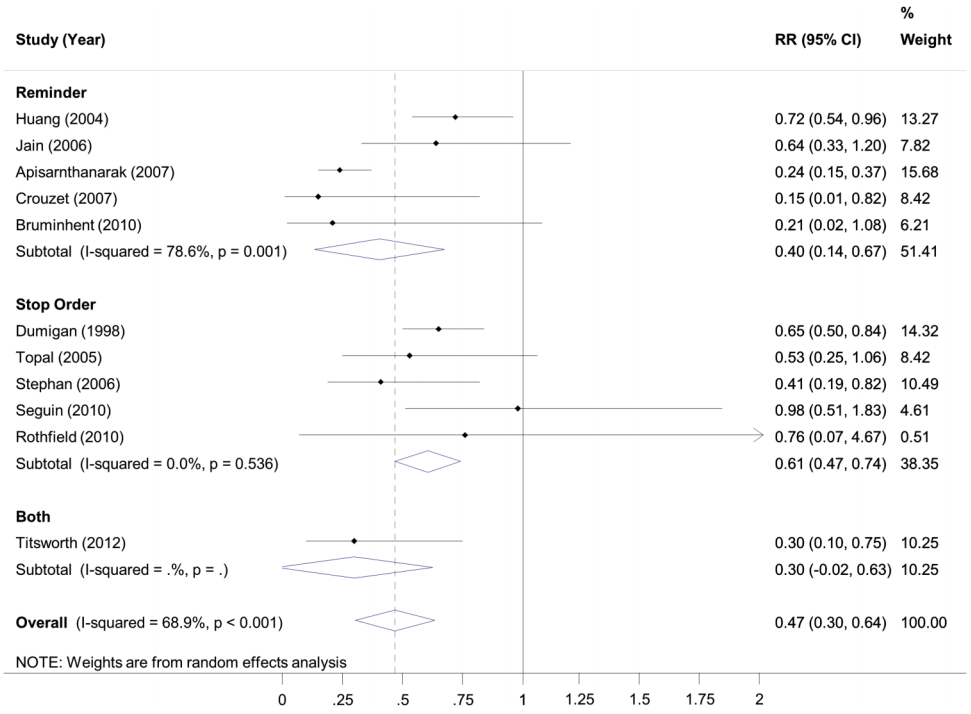

Figure 2 Meta-analysis of rate ratios for catheter-associated urinary tract infection episodes per 1000 catheter days, for intervention versus control groups, stratified by type of intervention to prompt catheter removal.

The one RCT[57] that used a urinary catheter stop order warrants further discussion. In this study focusing on catheterised general medicine patients, urinary catheter use decreased more in the 347 patients in the stop-order group compared to 345 patients receiving usual care by −1.34 days (95% CI −0.64 to −2.05 days, p<0.001). Unexpectedly, symptomatic CAUTI rates did not change, occurring in 2.1% of both stop-order and usual-care groups (p=0.99). Of note, Loeb *et al* did not report CAUTIs per 1000 catheter days, so these results could not be included in pooled rate ratios (figure 2), but were included in pooled risk ratios (figure 3). There are several potential reasons why a decrease in CAUTIs was not seen in this study, including high rates of antimicrobial use in both controls and stop-order groups (protective against CAUTI, and a variable not often reported in these comparative studies), and the possibility that a 1-day reduction in catheter use may not be sufficient to demonstrate an effect on the risk of UTI, although the effects on rates of UTI (by tracking catheter days) are not known.

Table 3 Number of avoided CAUTI episodes per 1000 catheter days

Baseline rate of CAUTI episodes per 1000 catheter days	Number of avoided CAUTI episodes per 1000 catheter days anticipated by the type of intervention to prompt catheter removal		
	Reminder	Stop order	Overall
5	3.0	2.0	2.7 (95% CI 1.8 to 3.5)
10	6.0	4.0	5.3 (95% CI 3.6 to 7.0)
20	11.9	7.9	10.6 (95% CI 7.3 to 13.9)

CAUTI, catheter-associated urinary tract infections.

Potential for unintended harm by catheter removal interventions

Interventions that facilitate removal of urinary catheters pose the risk of premature urinary catheter removal, with patients then requiring unnecessary recatheterisation; any catheterisation event is associated with procedure-related discomfort and other potential complications. Thus, monitoring the need for recatheterisation is important to avoid unintended patient harm. In the meta-analysis of reminder and stop-order studies, only four of the 14 studies reported rates of recatheterisation[26 48 52 57] with low recatheterisation rates noted in both intervention and control groups. None of the 16 more recent studies involving reminders or stop orders to prompt catheter removal reported data on potential patient harm, such as premature removal.

SUMMARY OF OTHER STRATEGIES TO PREVENT CAUTI

Several recent evidence-based guidelines[14–17] have focused on preventing CAUTI, and have assessed the evidence and provided recommendations for implementing prevention strategies. Key recommendations in the Centers for Disease Control and Prevention (CDC) guideline,[14] in addition to appropriate catheter use (box 1), include (1) aseptic insertion of urinary catheters by properly trained personnel, using aseptic

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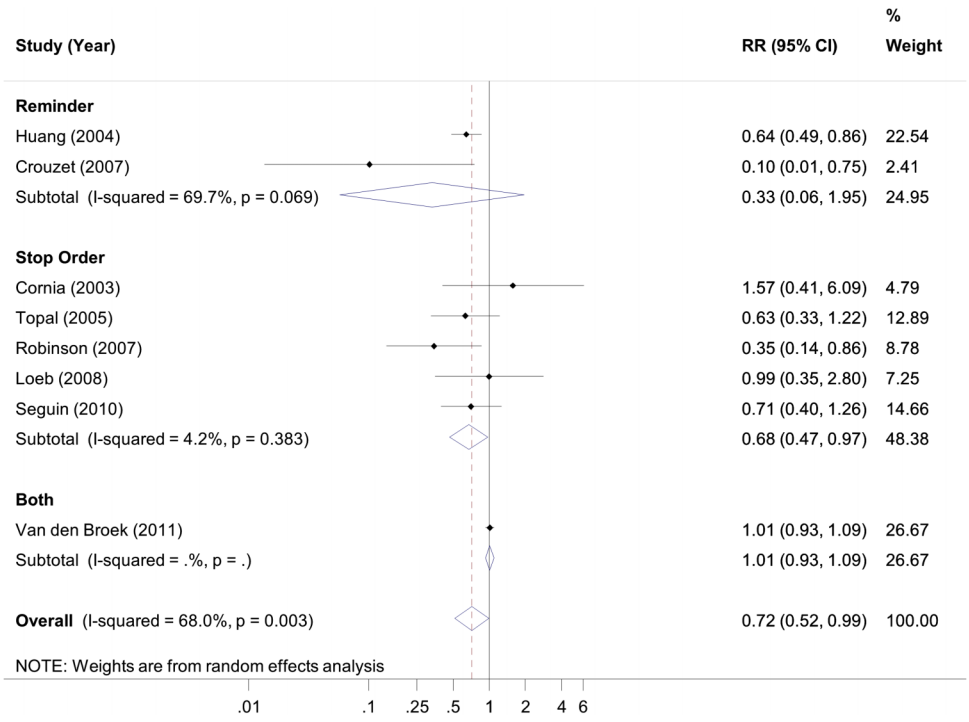

Figure 3 Meta-analysis of risk ratios for percentage of patients who developed catheter-associated urinary tract infection, for intervention versus control groups, stratified by type of intervention to prompt catheter removal.

technique and sterile equipment (with an exception being that clean technique is appropriate for chronic intermittent catheterisation) and (2) proper urinary catheter maintenance with a sterile, closed drainage system permitting unobstructed urine flow. Aseptic insertion is primarily recommended as a standard of care for which limited evidence exists. Stronger evidence (epidemiological and clinical) supports the

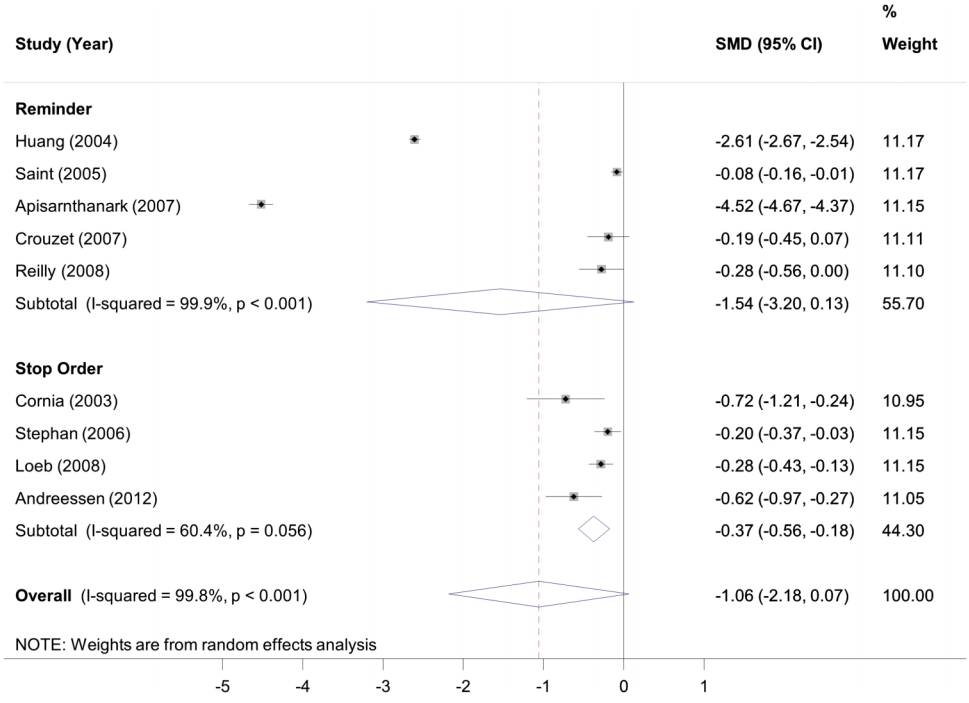

Figure 4 Meta-analysis of the standardised mean difference in days of urinary catheter use, for intervention versus control groups, stratified by type of intervention to prompt catheter removal.

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importance of a sterile, closed, unobstructed urinary drainage system.

A more controversial topic has been the use of antimicrobial catheters. Based on evidence available before 2010, the most recent CDC guideline recommended[14] that antimicrobial catheters should not be used routinely to prevent CAUTI. It suggested that further research was needed both on the effect of silver-alloy-coated catheters in reducing the risk of clinically significant CAUTI outcomes, and on the benefit of silver-alloy-coated catheters in selected patients at high risk of infection. In November 2012, a long-awaited multicentre RCT demonstrated a lack of effectiveness of antimicrobial catheters (including silver-alloy and nitrofurazone-releasing catheters) to provide significant and clinically important reductions in symptomatic CAUTIs.[63]

Bundles of interventions are also an important strategy, as part of a multimodal approach that focuses efforts on high-yield interventions. For example, one strategy that includes several of the components from the bladder bundle implemented by the Michigan Health and Hospital Association (MHA) Keystone Center for Patient Safety & Quality is the 'ABCDE' approach[19]:

- Adherence to general infection control principles is important (eg, hand hygiene, surveillance and feedback, aseptic insertion, proper maintenance, education).
- Bladder ultrasound may avoid indwelling catheterisation.
- Condom catheters or other alternatives to an indwelling catheter such as intermittent catheterisation should be considered in appropriate patients.
- Do not use the indwelling catheter unless you must!
- Early removal of the catheter using a reminder or nurse-initiated removal protocol appears warranted.

Several studies[24 28 44 46] have included bladder bundles as interventions for decreasing catheter use and/or CAUTI rates, including a statewide initiative[20] leading to significant increases in the proportion of catheters used for appropriate indications (from 44.3% to 57.6%, p=0.005).

IMPLEMENTATION CONSIDERATIONS

What methods have been used to improve the implementation of interventions to prevent catheter-associated urinary tract infections?

Because reducing unnecessary catheter use often requires changing well-established habits and beliefs of nurses and physicians, the challenge of implementation should not be underestimated. To facilitate implementation of practices to prevent CAUTI, the Michigan Keystone Bladder Bundle Initiative[19 20] used the Johns Hopkins University collaborative model for transformational change. This model is based, in part, on the 'four Es': Engage, Educate, Execute, Evaluate.[64] During the 'Engage' and 'Educate' steps, hospitals were provided information in multiple formats and a toolkit describing the intervention steps and outcomes measures. In the 'Execute' step, the hospital was strongly encouraged to choose one nurse champion[50 65] (eg, a case manager, nurse coordinator, or clinical nurse specialist) to lead the initiative and organise a bladder bundle team, including at least one physician, and to participate in workshops and conference calls with other participating hospitals to provide additional expert content and practical coaching. Also during the 'Execute' step, daily patient rounds (which in some hospitals were called a 'catheter patrol') were recommended to assess catheter presence and necessity, and provide feedback to specific units and re-evaluate strategies in progress. Hospitals were also encouraged to implement more active strategies for prevention, such as a catheter reminder system or promoting the use of catheter alternatives by developing protocols or making sure the necessary supplies were readily available. In the 'Evaluate' phase, hospitals were asked to assess improvements in catheter use and appropriateness according to specified indications and to address any barriers to progress and sustainability.

Implementation challenges within CAUTI prevention should be expected[66] and managed accordingly. Qualitative assessment focusing on HAI prevention has identified two important potential barriers to HAI preventive efforts: 'active resisters' and 'organisational constipators.'[67] Active resisters are hospital personnel who vigorously and openly oppose changes in practice, as a matter of habit or culture (eg, 'just not how they were trained'). Management of active resisters often requires those in authority to mandate compliance, collect data and provide feedback.[67] A 'champion' who is influential, or a peer of the resisting staff, may also help to overcome active resistance.[65 66] 'Organisational constipators' are usually mid-level or high-level executives who act as barriers to change by preventing or delaying certain actions needed to implement new practices.[67] Strategies to address an organisational constipator are to include this person in early discussions to improve buy-in and motivation, working around the person, or replacing the constipator.

A unique challenge to expect when implementing urinary catheter removal strategies is reluctance by some nurses to remove the catheter,[66] even when the nurse is 'empowered' to do so. In some cases, nurses may be active resisters due to disagreement with the catheter policy and/or a desire to avoid the inconveniences and increased frequency of patient contact required for the care of incontinence and catheter alternatives. There is also a competing pressure on nurses to mitigate development of hospital-acquired pressure ulcers—leading to perception that urinary catheters could lessen risk of skin breakdown despite being only indicated[14] for patients with incontinence and open sacral wounds. Other nurses report they simply do not feel comfortable[59] removing the

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catheter without explicit orders from the physician, which is ironic considering that many nurses place catheters without orders. Nursing comfort with catheter removal can be increased[59] with peer support and education, and may be facilitated by directly addressing the workload concerns associated with the removal of indwelling catheters. Indeed, a survey of nurses[30] during implementation of a nurse-empowered catheter removal protocol indicated increased nursing and patient satisfaction, despite the expected increase in workload. Recent successful and sustainable multimodal interventions to decrease catheter use including nurse-driven efforts had bedside nurses who, by survey,[62] viewed themselves as responsible for evaluation of catheter presence and need, had confidence in their knowledge, and viewed physicians as receptive to their requests regarding catheter removal.

Even though CAUTI is a very common HAI, Krein and colleagues reported that CAUTI preventive practice use is lagging behind efforts to prevent central line-associated bloodstream infection and ventilator-associated pneumonia,[68] with room for improvement in adopting catheter removal and CAUTI preventive strategies demonstrated again in two recent large surveys of hospitals[69] and ICUs.[70] Fortunately, many resources exist (http://www.catheterout.org) to help hospitals develop and implement programmes to decrease catheter use and prevent CAUTI, including a range of tools and educational materials to address implementation challenges. Hospital and unit-level leadership also play a key role in preventing infection.[71]

Monitoring and providing feedback on catheter use and CAUTI rates

Inappropriate urinary catheter use is an easy habit to start and a difficult one to break.[21] Consequently, many studies[20 33] have emphasised the importance of on-going surveillance and feedback as an intervention to reduce HAIs, such as CAUTI, and sustain[20 24 62] prevention efforts. New national efforts to reduce CAUTI (http://www.onthecuspstophai.org/stop-cauti/) incorporate periodic feedback to participating units on urinary catheter use and CAUTI rates. The CAUTI rates evaluated include the National Healthcare Safety Network (NHSN) and the newly described population-based rates.[72] The population-based CAUTI rate incorporates both the NHSN rate and the device utilization ratio, to account for interventions focused on reduction in catheter use and improvements in placement and maintenance.

Important next steps to address CAUTI involve developing strategies to decrease the effort, and resources required to monitor catheter use and CAUTI rates. Advanced informatics tools have recently been shown to increase the impact of this feedback loop to the extent that rates of CAUTI were lower in facilities that deployed these tools compared to those that did not.[73] Careful selection or development of datasets used for implementing hospital payment changes and public reporting for CAUTI events is also recommended. Unfortunately, the current administrative data used to implement non-payment[11] for hospital-acquired CAUTIs, and to publicly report hospital performance, likely captures few CAUTI events, given documentation and coding challenges[74] to translate a UTI event from a medical record into hospital-acquired CAUTI in the administrative datasets.

What is the cost of implementing a CAUTI prevention program?

The cost of implementing a CAUTI prevention programme will vary based on the level of technology used (eg, computerised vs preprinted catheter orders, and whether portable bladder ultrasounds are purchased) and the time invested in implementing and evaluating the interventions. Saint and colleagues, in their study of a written urinary catheter reminder generated by a research nurse to remind physicians which of their inpatients had urinary catheters,[52] found that the intervention was either cost-neutral or modestly cost-saving depending on the assumptions made. More recently, a study[38] of five hospitals in The Netherlands employed a multimodal intervention including reminders in four hospitals, and a stop order in the fifth hospital. The programme was found to be cost saving, with the mean amount saved being €537 (or ~US$700) per 100 hospitalised patients.

DISCUSSION

In summary, healthcare providers should strongly consider employing interventions to avoid unnecessary catheter placement (such as catheter placement restrictions) and to prompt removal of unnecessary catheters by reminders and stop orders, with special consideration for nurse-initiated removal protocols. The strength of the evidence is moderate to high. These interventions appear to be low cost, low risk, effective and sustainable[20 24 62] strategies to address a common hospital-acquired infection in the USA, with some unique but not impossible challenges for implementation. Moreover, UTIs are increasingly caused by multidrug-resistant organisms (MDROs) including strains that are resistant to all available therapeutic agents;[75 76] preventing CAUTI may help patients avoid MDRO infection.

Identifying and supporting an appropriate 'champion' who is influential among staff can be crucial to help overcome resistance to change behaviour regarding catheter use and facilitate the adoption of preventive strategies. Monitoring and providing feedback of catheter use and CAUTI rates is important in the implementation and continued use of CAUTI preventive strategies. Furthermore, reducing indwelling catheter use addresses the non-infectious complications of

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urinary catheter use such as catheter-related patient discomfort and immobility. Unfortunately, hospitals' surveys have repeatedly demonstrated low and only slowly improving adoption of CAUTI preventive strategies, such as reminders, stop orders and condom catheters compared to higher rates of adoption of antimicrobial urinary catheters in non-federal hospitals.[68] Yet, the negative results of a recent randomised controlled trial on the effectiveness of antimicrobial urinary catheters[63] is expected to translate into reduced use of these catheters.

Interest and resources for preventing CAUTI is likely to grow due to expanding national initiatives focused on reducing hospital-acquired infections, including CAUTI, being implemented with a combination of mandated public reporting and reduced pay to hospitals. Current prevention efforts include a 50-state initiative—'On the CUSP: Stop CAUTI'—that is funded by the AHRQ and led by the Health Research and Educational Trust (HRET) of the American Hospital Association. AHRQ has made available a toolkit for CAUTI prevention (http://www.onthecuspstophai.org/on-the-cuspstop-cauti/toolkits-and-resources/). This initiative is providing resources and implementation expertise to hospitals and state organisations that are beginning CAUTI prevention programmes, with a goal of reducing CAUTI rates by 25% by focusing on high-yield interventions such as those reducing urinary catheter use.

Key summary points

- Multiple before-and-after studies have found that interventions to decrease inappropriate catheter placement (such as catheter placement restrictions or urinary retention protocols) have resulted in decreased catheter use, fewer catheters in place without physician orders, and fewer catheters in place without an appropriate indication.
- An updated systematic review and meta-analysis found that catheter reminders or stop orders decreased catheter-associated urinary tract infections (CAUTIs) by 53%. An updated literature review identified many recent interventions with reminders or stop orders reducing CAUTI rates and/or urinary catheter use.
- Bundles of interventions focusing on strategies to reduce unnecessary catheter use (by avoiding unnecessary placement and prompting removal) and decrease CAUTI rates by general infection control principles (hand hygiene, surveillance/feedback, aseptic insertion, etc) have been successful, particularly when coupled with implementation strategies to address common barriers encountered when trying to change well-established habits of physicians and nurses.
- The role of antimicrobial catheters in preventing CAUTI has been addressed by a recent large randomised controlled trial showing no significant additional benefit in reducing symptomatic CAUTIs.
- CAUTI prevention costs vary by programme, but such programmes have been demonstrated to be cost saving.

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Contributors JM and SS designed the systematic review, conceived the manuscript, and assembled the authorship team. JM performed the systematic review and abstracted the data required for the review overall (as summarised in text and tables) and the meta-analysis, and wrote the first draft of the manuscript. JM and MAMR had full access to the data reviewed and analysed for this study; MAMR conducted the meta-analysis, and interpreted the results. JM and MAMR take responsibility for the integrity and accuracy of the data for the meta-analysis; JM (the guarantor) also takes responsibility for the integrity and accuracy of all data summarised in the manuscript. MAMR and SS also reviewed and revised the manuscript critically for important intellectual content. SLK, MGF, and RNO also contributed substantially to design of the manuscript, and reviewed and edited the manuscript for important intellectual content. All authors approved the final version to be published.

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Appendix Text A. Literature Searches

The 14 studies for the previously published systematic review and meta-analysis (Meddings et al, *Clin Infect Dis*, 2010) were obtained from a comprehensive search of the world's literature for interventions from 1950 to 2008 to decrease catheter-associated urinary tract infections by means of the MEDLINE and Cochrane databases (using Ovid), the PubMed Journals and Medical Subject Heading (MeSH) datasets, the ISI Web of Knowledge databases (Web of Science and Biosis Previews) and the CINAHL and EMBASE databases. The MEDLINE and Cochrane database searches were conducted by exploding and combining the following Medical Subject Heading (MeSH) terms: *urinary tract infection, urinary catheterization, indwelling catheter, inpatient, reminder system, device removal, intervention studies*. The MeSH *reminder system* was also searched separately. We included the following terms in a keyword search (with wildcard indicated with *): *urinary tract infection; ((urin* or uret*) and cath*)) or catheter*; nosocomial or inpatient or hospital*; reminder, removal, and intervention*. We used similar strategies with the other databases. A research librarian provided guidance to improve search completeness. This search yielded 6679 citations, including many duplicate citations. As our initial search was broad and yielded many guidelines and reviews published regarding prevention of catheter-associated urinary tract infection, we also evaluated these articles' reference lists for additional studies; 1 additional reference was located in this manner. More detailed review was required for 118 articles to determine whether they met inclusion criteria. After applying inclusion and exclusion criteria to focus on human studies of adults admitted to acute care hospitals reporting at least one outcome involving catheter use or CAUTI events as a result of the intervention, and with a comparison group (either pre- versus post-

intervention or a separate control group); this yielded 16 studies for further review. Two authors of the systematic review (J.M. and M.M.) independently reviewed and abstracted data from the 16 articles that appeared to meet inclusion criteria, including setting, study population, inclusion/exclusion criteria, definitions used, health outcomes, and quality issues. A third investigator (S.S.) resolved any differences in abstraction and reviewed the joint decisions made to exclude 2 of the 16 articles that no longer met inclusion criteria after further review. As a result, this systematic search in 2008 yielded the 14 articles reviewed in the previously published meta-analysis.[1-14]

To update the prior literature search for this manuscript, a search was performed of MEDLINE and Cochrane databases (using Ovid) and PubMed for intervention studies (published from August 2008 to February 2012) to reduce use of unnecessary urinary catheters in the acute care of adults, using the same detailed search strategy as employed in the 2008 search. Yet, unlike the 2008 search which was focused on removal of recently placed indwelling catheters (and which excluded emergency environments), the patient population for the 2012 search was expanded to include emergency department patients. The search was expanded because use of interventions to restrict initial placement was an additional topic of interest for this review. The 2012 search results were also supplemented with prior lists of articles excluded from the prior 2008 search that were focused on emergency department interventions. A secondary evaluation of the CINAHL database was also performed for interventions developed and implemented by nurses related to urinary catheter use. In light of the somewhat different terminology on the topic found in the nursing literature, we searched CINAHL using variations of the following terms: *reminder, removal, urinary catheter, nurse empowered, nurse directed,*

nurse protocol. No date limits were employed in the CINAHL search, which retrieved 5 records. Overall, the MEDLINE and CINAHL searches yielded 479 citations, including 353 from MEDLINE through Ovid, 9 additional from PubMed, 117 from the Cochrane EBM databases, and 7 duplicates. Studies were included if at least one outcome involving catheter use or CAUTI events (Appendix Table) was reported as a result of the intervention with a comparison group. A review of reference lists for additional studies was also performed, yielding one additional study. We applied inclusion and exclusion criteria to focus on human studies of adult patients with at least one outcome involving catheter use or CAUTI events reported as a result of the intervention, and with a comparison group. After applying this criteria, the updated search yielded 12 intervention studies published since the prior meta-analysis.[15-26]

An additional update of this literature search was performed October 23, 2012 (for literature published from February 2012 to October 23, 2012) using the same databases and search criteria that was performed in February 2012, yielding 97 additional citations for consideration. After applying the same inclusion/exclusion criteria as previously, 74 articles were excluded by title and abstract review yielding 23 studies to review further of the full text and reference lists. Of these 23 articles, 4 articles[27-30] were intervention studies with reminder or stop-order interventions were appropriate for inclusion (increasing the number of reminder and stop-order intervention studies to 16 since the prior meta-analysis). 1 article was a meta-analysis of bladder scanner protocols[31] as interventions to decrease catheter placement with a reference list that yielded 3 individual studies[32-34] for the Appendix Table.

Appendix Text B. Methods

As summarized in the previously published meta-analysis for the 14 selected studies from 2008 or earlier, a systematic review process was performed. Correspondence with 24 authors was initiated to clarify details regarding the interventions and outcomes with responses received from 11 authors, and 4 authors provided unpublished numeric data necessary for statistical pooling. Two physician reviewers performed a detailed abstraction of the 14 studies. Details of the statistical analyses for obtaining the pooled effects are detailed in the prior published analyses, and were not replicated or expanded for writing this review.

A similar review and abstraction process was performed by one physician (J.M.) for the 16 recent articles in the updated search. Contact was initiated with authors of 3 of the most recent articles[15,19,27] to obtain clarification of study population characteristics and/or results data. Dr. Adams reviewed the data and confirmed and provided the correct pre and post intervention daily catheter prevalence rates (which were correct in the published text), and also provided the number of patients studied. Dr. Johnson (corresponding author for Knoll et al [19]) responded to our queries but could not provide the number of patients in the study groups. Dr. Bruminhent did not respond to our queries. These 16 articles were analyzed and abstracted by J.M. as potential candidates for inclusion in the updated meta-analyses, and also summarized in a narrative method in Appendix Table and Table 3.

Important outcomes of the 30 studies with reminder and/or stop order interventions (14 studies from prior meta-analysis[35] and 16 more recently identified studies) as previously published in the meta-analyses were summarized in Table 3.. Additional details

(study design, country of origin, patient population size, care environment, all intervention details) are summarized in the Appendix Table.

Statistical Analyses. Analyses were conducted using Stata/MP, version 12.1 (StataCorp). Pooled estimates were obtained using DerSimonian-Laird random effects models. Heterogeneity among studies was assessed using between-study variance (τ^2) and the Higgins and Thompson I^2 (percentage of variability in the intervention attributable to heterogeneity). All tests were two-sided, and the type I error rate was set at 0.05.

Appendix Table. Characteristics of Studies with Interventions to Avoid Unnecessary Urinary Catheter Use.

Study (Country)	Study Design	Population, Total N	Interventions to avoid unnecessary catheter PLACEMENT	Interventions to prompt REMOVAL of unnecessary catheters	Other Interventions
Adams et al, 2010[27] (UK)	Pre-Post	Medical (non-ICU), N=136 patients	None	**Stop-order, nurse-empowered:** Nurse-led protocol to remove all urinary catheters that did not meet criteria.	None
Andreessen et al, 2012[28] (USA)	Pre-post	Med-Surg (unclear if ICU). N=141 patients	Computerized UC order required selection of an appropriate UC indication Promoted use of alternatives for indwelling UCs Bladder scanner protocol.	**Stop-order:** Automated computer stop order directed at physicians/providers, requiring reassessment and re-ordering every 24 hours, or discontinues use of catheter.	Bundle included UC care steps, standardized UC kits. Computer documentation of placement and maintenance care.
Apisarnthanarak et al, 2007[1] (Thailand)	Pre-Post	All Inpatients, N=2412 patients	None	**Reminder:** Nurse-generated daily bedside verbal reminders to encourage physicians to remove unnecessary UC.	None
Bruminhent et al, 2010[15] (USA)	Pre-Post	Med-Surg: Ward + ICU, N=400 patients	None	**Reminder:** Sticker applied to medical record to remind physicians to discontinue unnecessary UCs.	None
Cornia et al, 2003[2] (USA)	Non-randomized crossover trial	Medical (non-ICU), N=70 patients	Computerized UC order required selection of an appropriate UC indication	**Stop order:** Computer-generated stop order for physicians to discontinue/renew UC order 72 hours after placement.	UC care education
Crouzet et al, 2007[3] (France)	Pre-Post	All Inpatients, N=234 patients	None	**Reminder:** Daily reminders from nurses to physicians to remove unnecessary UC >=4 days after insertion.	None
Dumigan et al, 1998[4] (USA)	Pre-Post	ICU: Med-Surg, N=27103 patient-days	Guideline for appropriate UC indications	**Stop order, nurse-empowered:** Daily use of UC indication protocol by nurse empowered to remove UC no longer meeting criteria without requesting physician order.	UC care education

Elpern et al, 2009[16] (USA)	Pre-Post	ICU: Medical, N=337 patients	Appropriate indications for UC insertion were emphasized, and list of inappropriate reasons to insert was provided	**Reminder:** Daily review by nurses for UC indication to make recommendations for removal; removal required physician order.	None
Fakih et al, 2008[5] (USA)	Pre-Post with concurrent controls	Med-Surg (non-ICU) N=3736 intervention patient-days, and 4041 control patient-days	None	**Reminder:** Nurse generated reminder to physician to remove UC when no appropriate indication.	None
Fakih et al, 2010[36] (USA)	Pre-Post	ED, N=322 patients had UCs placed, of 2517 ED patients in sample	Institutional guidelines for appropriate UC placement, ED physician education regarding UC utilization	None	None
Fakih et al, 2012[37] (USA)	Pre-Post	Statewide, N=163 inpatient units in 71 hospitals	Education intervention to promote adherence to appropriate UC indications	None	None
Frederickson et al, 2000[33] (USA)	Pre-post by concurrent controls	Surgery N=103	Bladder ultrasound program compared with standard care by ISCs	None	None
Fuchs et al, 2011[17] (USA)	Pre-Post	ICU: Med-Surg, N=not provided	Urinary retention protocol, including use of bladder scanner Procedure-specific protocols for appropriate indications for UC placement	**Stop order:** Daily checklist for evaluating UCs; when not indicated, physician order was requested for removal. **Stop order:** Procedure-specific protocols for UC removal.	None
Gokula et al, 2007[38] (USA)	Pre-Post	ED, N=200 patients with UCs placed in ED	UC indication checklist attached to UC kits	None	None
Gotelli et al, 2008[18] (USA)	Pre-Post	Medical (not ICU), N=not provided	None	**Stop order, nurse-empowered:** Nurses were empowered to assess UC need by protocol and remove if not indicated.	None

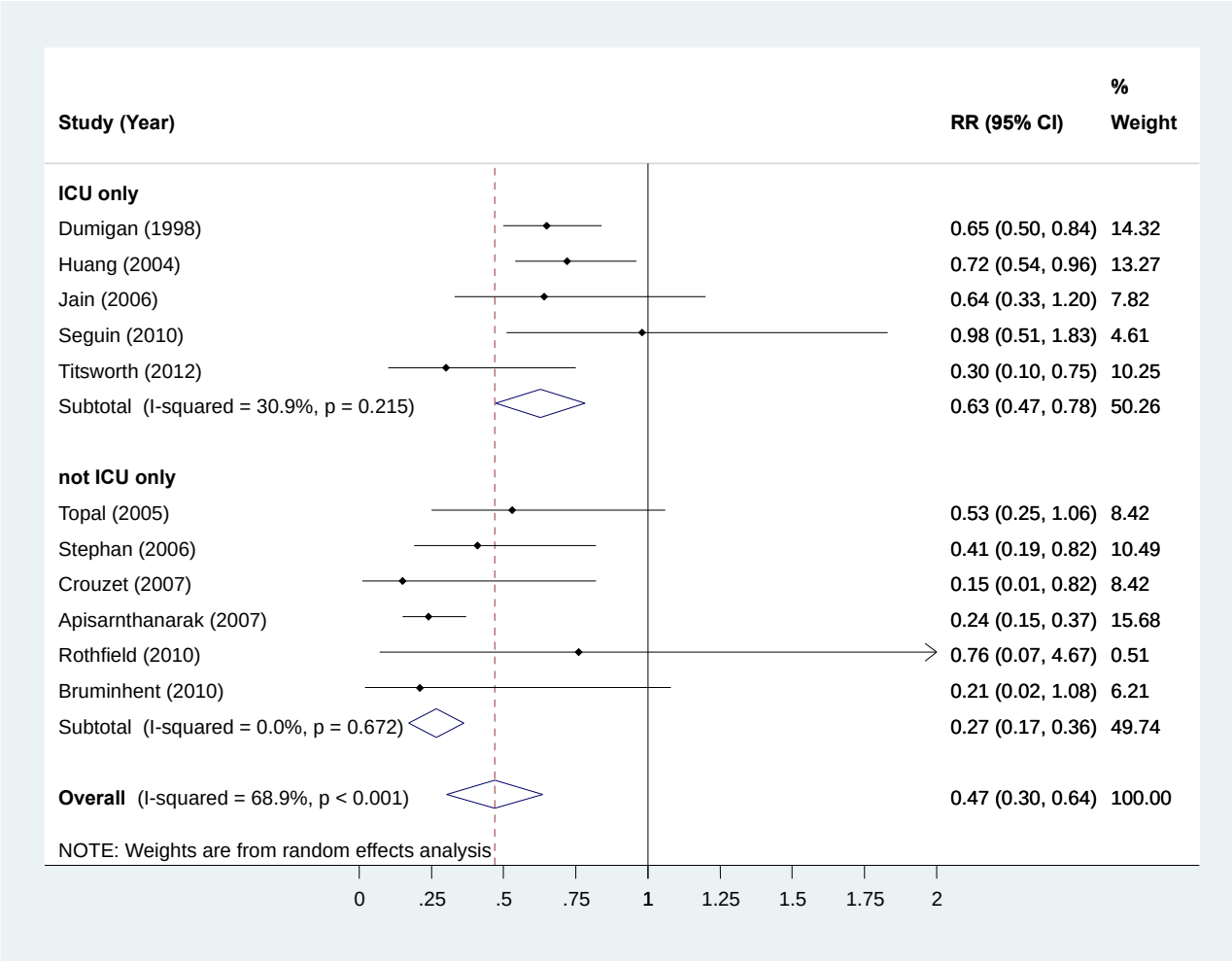
Huang et al, 2004[6] (Taiwan)	Pre-Post	ICU: Med-Surg, N=6297 patients	None	**Reminder:** Nurse generated daily reminder to physician to remove unnecessary UC 5 days after insertion.	None
Jain et al, 2006[7] (USA)	Pre-Post	ICU: Med-Surg, N=13471 catheter-days	None	**Reminder:** Daily use of checklist in multidisciplinary rounds to determine if UC still indicated, then nurse contacted physician for order to removal UC if no longer indicated.	Bundle included UC care steps, selected use of silver-alloy UC.
Knoll et al, 2011[19] (USA)	Pre-Post	All Inpatients, N=112,140 patient-days	Educational interventions about an approved hospital list of UC indications Computer UC order template with indication	**Stop order:** Computerized order for UC with indications and 72 h default stop date. **Reminder:** ICU daily checklist for UC necessity.	Bundle included UC care education, dedicated UC nurse.
Lee et al, 2007 [32] (Taiwan)	Pre-Post	Surgery (Neurosurgery) N=244 patients	Bladder ultrasound program	None	None
Loeb et al, 2008[8] (Canada)	RCT	Medical (non-ICU), N=692 patients	None	**Stop order, nurse-empowered:** Pre-written in chart for nurses empowered to discontinue UC based on criteria without an additional physician order.	None
Murphy et al, 2007[9] (USA)	Pre-Post	Not explained, N=Not provided	None	**Reminder:** Foley bag sticker with time/date of insertion to remind to nurse to notify physician when Foley in place >48h in order to request removal.	UC care education
Patrizzi et al, 2009[39] (USA)	Pre-Post	ED, N=Not provided	Computerized ED UC order with indications, UC alternatives promoted, urinary retention protocol with bladder scanner use	None	None
Reilly et al, 2008[10] (USA)	Pre-Post	ICU: Med-Surg, N=207 patients	Developed criteria for appropriate UC placement in ICU, implemented with educational interventions regarding UC indications, and urinary retention protocol	**Reminder:** Daily use of checklist of appropriate UC indications by nurse, reminding nurse to contact physician to recommend UC removal.	UC care education

Robinson et al, 2007[20] (USA)	Pre-Post	Med-Surg (non-ICU), N=69 patients		**Stop order:** Nurse identified patients without appropriate indications, then requested removal order from physicians.	None
Roser et al, 2012[29] (USA)	Pre-Post	Med-Surg (including ICU), N=not provided	Educational intervention described regarding appropriate reasons for insertion	**Stop order, nurse empowered:** nurse driven urinary catheter removal protocol, empowering removal of urinary catheter within 24 hours unless contraindicated.	AHRQ CUSP program to end all healthcare associated infections.
Rothfeld et al, 2010[21] (USA)	Pre-Post	Medical ICU step-down unit, N=99 patients	Developed list of appropriate indications for which UCs could be requested by nurses	**Stop order:** Nurses asked physicians for order to remove UCs when not indicated.	None
Saint et al, 2005[11] (USA)	Pre-Post with concurrent nonequivalent controls	Intervention Group: Medical, Control Group: Surgery. N=3027 patients	None	**Reminder:** Study nurse generated sticker placed in chart reminding physician to generate stop order after 48 hours of UC use if no longer needed.	None
Schultz et al, 2011[22] (USA)	Pre-Post	ICU: unclear type, N=Not provided	Urinary retention protocol, including use of bladder scanner	**Stop order, nurse-empowered:** Nurses were empowered to insert and remove UCs by protocol.	None
Seguin et al, 2010[23] (France)	Pre-Post	ICU: Surgical, N=1271 patients	None	**Stop order:** Daily assessment required by physicians to assess if UC is needed or not; when categorized as not indicated, then removed by nurses.	None
Slappendel & Weber, 1999[34] (Netherlands)	Pre-Post	Surgery: Ward + ICU N=4116 patients	Bladder ultrasound program	None	None
Stephan et al, 2006[12] (Switzerland)	Pre-Post with concurrent nonequivalent controls	Surgery: Ward+ICU <u>Intervention</u>: Orthopedic, N=539 <u>Control</u>: Abdominal, N=489	UC placement restrictions, urinary retention protocol	**Stop order:** Pre-operative written order to remove UC on post-operative day 1 or 2, depending on surgery.	UC care education

Titsworth et al, 2012[30] (USA)	Pre-Post	ICU (Neurologic)	UTI bundle included insertion criteria and promotion of UC alternatives including bladder scanning use.	**Stop order:** post-op removal of catheters by default by nurses if not explicitly ordered. **Reminder:** daily Foley rounds in ICU by nurses; if no clear indication found, patient name given to critical care medicine attending as reminder to place catheter removal order if no indication found.	Bladder Bundle: UC care steps, standardized UC kits. Modules for sterile catheter technique, antimicrobial catheters
Topal et al, 2005[13] (USA)	Pre-Post	Medical (non-ICU), N = 245 patients	Urinary retention protocol including bladder scanner	**Stop order:** Computerized order entry system order to prompt physicians to remove/re-order UC if placed in ED or in place >48 hours. **Stop order, nurse-empowered:** Nurses were also empowered to remove UCs no longer needed by protocol criteria.	UC care education
van den Broek et al, 2011[24] (Netherlands)	Pre-Post	All Inpatients, in 5 hospitals, N=2943 patients	Bladder scanner protocol in 2 hospitals	Intervention varied by hospital: **Reminders:** Used by 4 hospitals, placed in patient's record. **Stop order:** Fixed order for removal, employed by 1 hospital.	Specially trained UC nurse
Voss, 2009[25] (USA)	Pre-Post	Medical (non-ICU), N=187 patients age 65 or older	None	**Stop order, nurse-empowered**: Daily assessment by nurse for UC indications, with authority for nurse to remove if not indicated.	None
Weitzel, 2008[14] (USA)	Pre-Post	Medical (unclear if ICU), N=50 patients	None	**Reminder:** Daily use of protocol by nurse to review if UC still indicated, unclear if protocol allowed for UC removal without physician order.	None
Wenger, 2010[26] (USA)	Pre-Post	All Inpatients, N=Not provided	None	**Stop order, nurse-empowered**: Daily assessment by nurse of UC necessity, with authority to remove if not indicated.	UC care education, silver-alloy UC

ICU=intensive care unit; UC=urinary catheter; UTI=urinary tract infection

Appendix Figure 1. Meta-analysis of rate ratios (RRs) for catheter-associated urinary tract infection (CAUTI) episodes per 1000 catheter days, for intervention vs. control groups, stratified by focus on intensive care units (ICUs).
CI, confidence interval



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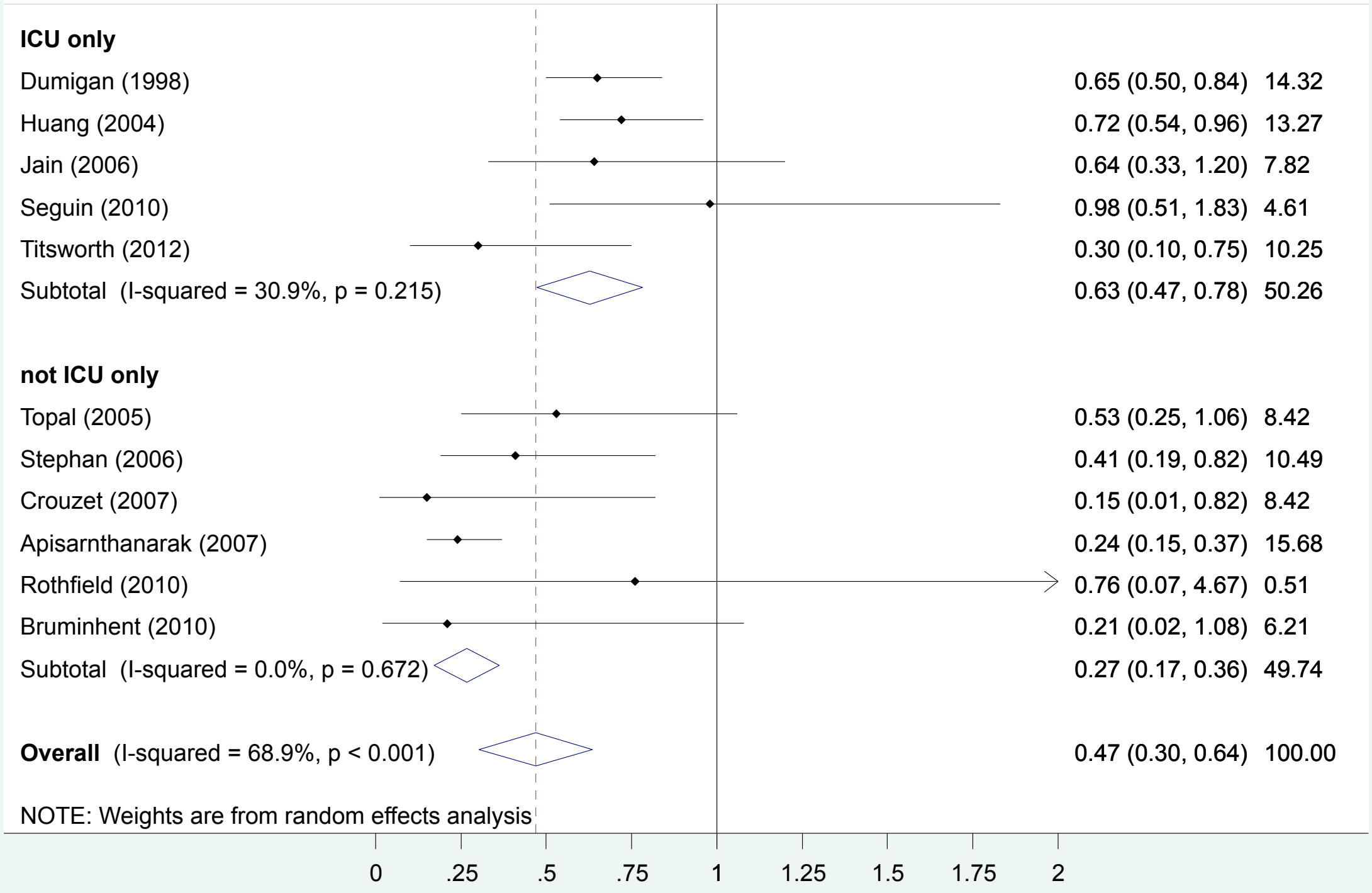

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