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A descriptive epidemiological review of hospital admissions for UTI from long term care facilities and a systematic review of strategies to reduce the risk of catheter associated UTI in long term care facilities in order to reduce these admissions.

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A descriptive epidemiological review of hospital admissions for UTI from long term care facilities and a systematic review of strategies to reduce the risk of catheter associated UTI in long term care facilities in order to reduce these admissions.

By

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Capstone

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A descriptive epidemiological review of hospital admissions for UTI from long term care facilities and a systematic review of strategies to reduce the risk of catheter associated UTI in long term care facilities in order to reduce these admissions.

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Urinary tract infection (UTI) is a significant source of morbidity and mortality in the elderly. Urinary catheter use greatly increases the risk of contracting a UTI. Use of a urinary catheter has been shown to increase the risk of contracting a UTI-accounting for up to 40% of nosocomial infections in one (older) study. A number of studies and reviews of studies have been done to assess strategies for reducing the risk of such catheter associated UTI (CA-UTI) in the acute setting. However, there has been less work done in long term care facilities (LCTF), a setting where UTI incidence is already high and urinary catheter use is increasing. LTCF have a number of issues that increase the difficulty in applying strategies developed for more acute care settings, including higher percentage of comorbid conditions and reduced staffing and funding. This Capstone project has two aims. It will first examine the Texas Health Care Information Collection (THCIC) database to find the number and attributes of hospital admissions from LTCF for UTI in order to describe the epidemiology of the problem. Second, it aims to do a systematic review of the literature and assess strategies for reducing risk of CA-UTI in LTCF, especially in terms of feasibility and economic impact. The author will be initially using the PubMed database and concentrating on English language articles. Keywords include Long-Term-Care-Facility, UTI, and Urinary Catheter. Expansion into other databases will be done as needed.

TABLE OF CONTENTS

List of Tables

List of Figures

List of Abbreviations

CA-UTI	Catheter Associated Urinary Tract Infection
GSBS	Graduate School of Biomedical Science
LTCF	Long Term Care Facility
NOS	Not Otherwise Specified
NEC	Not Elsewhere Classifiable
RCT	Randomized Controlled Trial
TDC	Thesis and Dissertation Coordinator
THCIC	Texas Health Care Information Collection database
UTI	Urinary Tract Infection
UTMB	University of Texas Medical Branch

Chapter 1 Introduction

Problem Statement and Rational

Urinary tract infections are a significant source of morbidity and mortality in the elderly. Complications include delirium and bacteremia that if not caught and treated early can lead to sepsis, septic shock and death. Use of a urinary catheter has been shown to increase the risk of contracting a UTI-accounting for up to 40% of nosocomial infections in one (older) study[1]. The increased risk is believed to be due to a number of factors, including bacterial colonization of the urinary catheter and bacterial colonization of residual urine volume left in the bladder[10]. The pooled cumulative incidence of bacteriuria in patients with indwelling catheters over 2-10 days was 26%. Of patients with bacteriuria, UTI symptoms will develop in at least 24%, and bacteremia in 3.6%[2]. One case of symptomatic UTI has been estimated to cost at least $676, and if bacteremia develops this cost jumps to at least $2,836[2]. This presents a significant public health burden, since urinary catheters are used in large numbers in a variety of settings-one study found an indwelling catheter in up to 25% of hospitalized patients[3].

In long term care facilities (LTCF) such as nursing homes or skilled nursing facilities, intermittent urinary catheters are used for patients unable to manually void, and indwelling urinary catheters are used long term (> 30 days) for incontinent patients unable to void and unable to manually straight catheterize themselves; 3-10% of residents have indwelling urinary catheters, and as many as 57% of incontinent women and 25% of incontinent men have symptomatic bacteruria. The risk of asymptomatic bacteriuria developing into a UTI with symptoms when an indwelling urinary catheter is used is 0.7-1.1/100 catheter days, 3x the risk observed for residents without a urinary catheter[4]. Bacteriuria also accounts for 45-55% of cases of bacteremia in LTCFs; in one study, long term urinary catheterization was associated with a 39x increase in incidence of bacteremia[12, 13, 14, 15]. In addition, long term urinary catheterization may increase the risk of inflammation of the upper urinary tract, possibly due to repeat episodes of catheter associated bacteriuria and infections; one study found that acute inflammation of renal parenchyma was present in 38% of patients with a urinary catheter versus 5% in patients without urinary catheters[11]. UTI is the second most common infection, preceded by respiratory infections[5]. Many studies have been done to determine the best approaches to reducing this risk, not only for long term care facilities, but in the hospital as well. Guidelines have been formulated by multiple organizations such as the CDC and the American Nursing Association to reduce the incidence of catheter associated UTI (CA-UTI) in the hospital or other acute setting[19, 20]. However, there have been fewer guidelines for prevention of CA-UTI in LTCF. Existing guidelines for this setting mostly exist as small sections in reviews pertaining to guidelines in acute care settings, or as sections in reviews pertaining to general management of infections in LTCF.

LTCF face a number of challenges that more acute care settings do not, challenges which increase the difficulty in management and monitoring of the indwelling urinary catheters used by their patients. One challenge is the increased age and number of comorbidities faced by the typical LTCF patient compared to the average patient requiring an indwelling catheter in the acute care setting, as well as the increased length of time LTCF patients require an indwelling catheter compared to acute care settings. For example, diseases such as diabetes, stroke, or Parkinson's disease tend to increase bladder incontinence, increasing the need for indwelling catheterization while at the same time reducing immune effectiveness[5]. Another challenge is the increased patient to caregiver ratio in the typical LTCF, 10-20:1 or more compared to the typical acute care facility, where it is mandated to be 5-7:1[6, 7]. This increase makes it much more difficult for caregivers to pay as close attention to possible signs of infection or catheter derived trauma. In addition to having fewer caretakers per patient, caretaker skill level is also reduced-most LTCF generally have at most an RN on duty at all times, with an MD coming by on weekly to monthly visits. There is also less diagnostic equipment or rapid lab testing available in most LTCF. All of these factors reduce the ability of caretakers in LTCF to both diagnose and manage UTI, or most other serious infections or illnesses.

Research Question and Objectives

This Capstone Project will find and review options to reduce incidence of UTI in the LTCF setting, especially in terms of cost and feasibility of implementation. As noted above, insertion of a urinary catheter is one of the biggest risk factors for the incidence of UTI. As such, this Capstone will primarily focus on the impact of nursing care practices to reduce the risk of CA-UTI, including but not limited to urinary catheter change schedules, giving patients cranberry or other juices to reduce their risk of UTI, and methods to evaluate urinary catheter use in each patient so as to discontinue them when practical. This project will also review the evidence, if any exists, about the usefulness of placing an anti-reflux mechanism in the catheter tubing to reduce reflux of urine from the collection bag to the bladder (closed urinary catheter system). Studies of antibiotic impregnated urinary catheters for UTI prophylaxis have already been well reviewed and will not be a focus of this paper.

Chapter 2 Background/Epidemiology

To further explore the extent and characteristics of hospital admissions from LTCF due to UTI, the author examined the Texas Health Care Information Collection (THCIC), a database that records basic demographic, diagnosis, admission, and outcome data on all patients discharged from Texas hospitals. This would allow data collected within the last two to six years from a large state population to be used to estimate the epidemiology and cost of the problem. Specifics of methods and results are detailed in the sections below. A definition of CA-UTI and routes of infection are also given below.

Definition of CA-UTI and Routes of Infection

For the purposes of this paper, CA-UTI is defined using the CDC diagnosis criteria (Jan. 2015 version). To be diagnosed, the patient must meet three criteria. First, the patient must have an indwelling catheter in place for > 2 days prior to discovery of symptoms or contaminated urine culture (date of event). Second, the patient must have at least one of the following symptoms: fever > 38^{0}C, suprapubic tenderness, CVA pain or tenderness, urinary urgency or frequency, or dysuria. Finally, the patient must have a urine culture with bacterial count > 10^{5} CFU/mL.

Bacteria are introduced into the urinary tract via two main methods: through the insertion of the urinary catheter, and via ascension of bacteria from the urinary collection bag into the urinary tract through the catheter and collection tubing. Even if both the urinary catheter and urinary collection bag are initially sterile, either may become contaminated with bacteria any time the urinary collection bag is disconnected or emptied[10]. In addition to providing a pathway for bacteria, the urinary catheter provides a surface for bacteria to adhere and form a biofilm, creating a potential long term bacterial reservoir and source for repeated infection of the urinary tract. These films also offer bacteria increased opportunity to spread genes enhancing antibiotic resistance as well as direct protection from antibiotics flushed through the catheter, especially since any antibiotic flushed through the catheter will only have transient contact with the biofilm, allowing the antibiotic insufficient time to penetrate the outer layer of the biofilm to reach the bacteria underneath[16, 17]. These biofilms can move from the urinary catheter tubing to the bladder within 3 days of formation[18].

Database Review: Source and Methods

The THCIC was authorized in 1995 and consists of all patient discharge data collected from 450 hospitals in Texas. Broadly, the author wished to examine all patients who were admitted to a hospital from a LTCF with an admission or secondary diagnosis of UTI, in order to further ascertain the extent and cost of admissions for UTI. THCIC yearly data is divided into quarters. The most recent four years of data from the THCIC database were examined, from the first quarter of 2011 to first quarter of 2015, a total of 17 quarter years. The database collects 60 pieces of publicly available data per patient; the relevant pieces of data per patient examined here are:

1. Patient age
2. Patient gender
3. Patient race/ethnicity
4. Payment/insurance type
5. Patient discharge destination
6. Duration of and cost of hospitalization
7. Origin of admission
8. Primary, secondary and admitting diagnosis.

Raw data from the THCIC database, downloaded as plain ASCII text files, were loaded into the STATA statistics package. Two steps were taken for each year's data to select for patients admitted to a hospital from a LTCF. First, newborns were eliminated from the data set by selecting all patients whose type of admission variable was not 4 (the variable indicating newborn admission). This was done to eliminate any ambiguity as to source of admission, since the source of admission variable changed depending on whether the patient was a newborn. Second, all patients who did not have source of admission variable 5 (the variable value indicating admission from LTCF) were eliminated, leaving only those coming from the various types of LTCF: skilled nursing facility, intermediate care facility, or assisted living facility. Once this was done, the next step was to examine the primary and secondary diagnoses and select for "Urinary Tract Infection Not Otherwise Specified" or "Indwelling Catheter Complication Not Otherwise Specified". The THCIC used ICD-9 codes for diagnoses, and the relevant codes were 599.0 for "Urinary Tract Infection NOS" and 996.64 for "Infection and Inflammatory Reaction due to Indwelling Urinary Catheter". Patients were selected if their primary diagnosis was 599.0 or 996.64 or if their primary diagnosis was sepsis/septic shock (ICD-9 code 038), and their secondary diagnosis was either 599.0 or 996.64. Searches were made for other forms of UTI, such as codes 595.9 (cystitis) and 590.1 (acute pyelonephritis) as well but failed to turn up significant numbers of patients (N > 1 patient). A diagram of the steps taken is given by Figure 1.

Database Review: Results

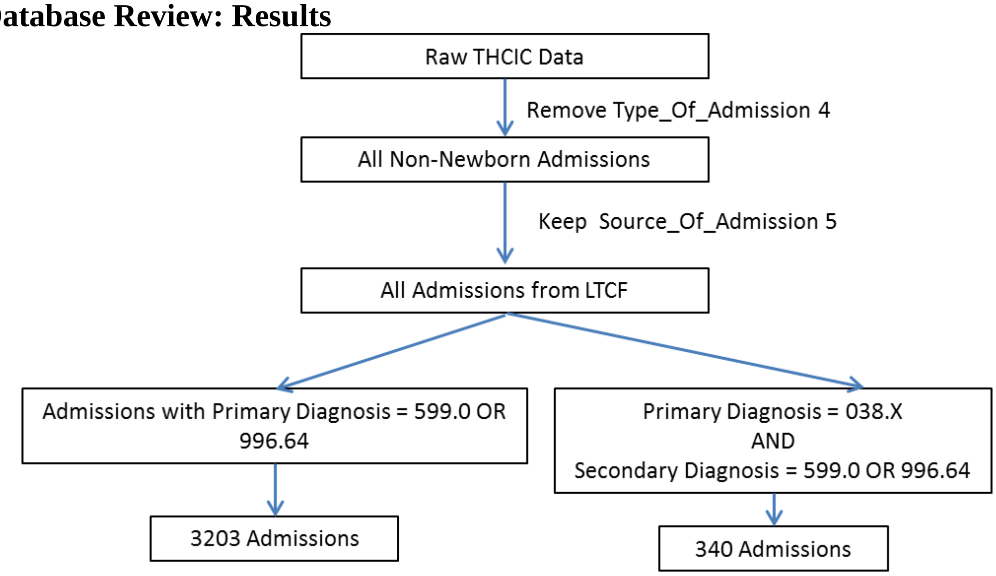

Figure 1 THCIC data extraction process

The above steps produced a total of 3,543 patients who were admitted to a hospital from a LTCF for a primary or secondary diagnosis of "UTI NOS" over the four years from 2011 to 2015. It should be noted that all but 36 of the 3,543 results found were for ICD-9 code 599.0 and not 996.64. Of these 3,543 admitted patients, 3,203 patients (90.4%) were admitted with "UTI NOS" as a primary diagnosis, and 340 patients (9.5%) were admitted with sepsis/septic shock secondary to UTI (sepsis/septic shock as primary diagnosis with UTI as secondary diagnosis). This is shown in Table 1.

Quarter	Total UTI Transfers	Principal	Secondary
2011Q1	305	266	39
2011Q2	269	240	29
2011Q3	282	251	31
2011Q4	215	177	38
2012Q1	245	216	29
2012Q2	240	221	19
2012Q3	260	228	32
2012Q4	213	194	19
2013Q1	230	217	13
2013Q2	157	146	11
2013Q3	134	126	8
2013Q4	183	175	8
2014Q1	156	141	15
2014Q2	169	158	11
2014Q3	156	143	13
2014Q4	180	162	18
2015Q1	149	142	7
TOTAL	3,543	3,203	340

Table 1: Hospital admissions for UTI between 2011 and 2015 per quarter year

It should be noted that the number of patients admitted for UTI as primary or secondary diagnosis has been decreasing from 2011 to 2015: from 2011 to 2012 the mean number of admissions for UTI as primary diagnosis was 254 patients, while the mean number of admissions for UTI as primary diagnosis from 2013-2015 was 168 patients, a decrease of 33.5%. The overall trend of admissions can be seen in Figure 2.

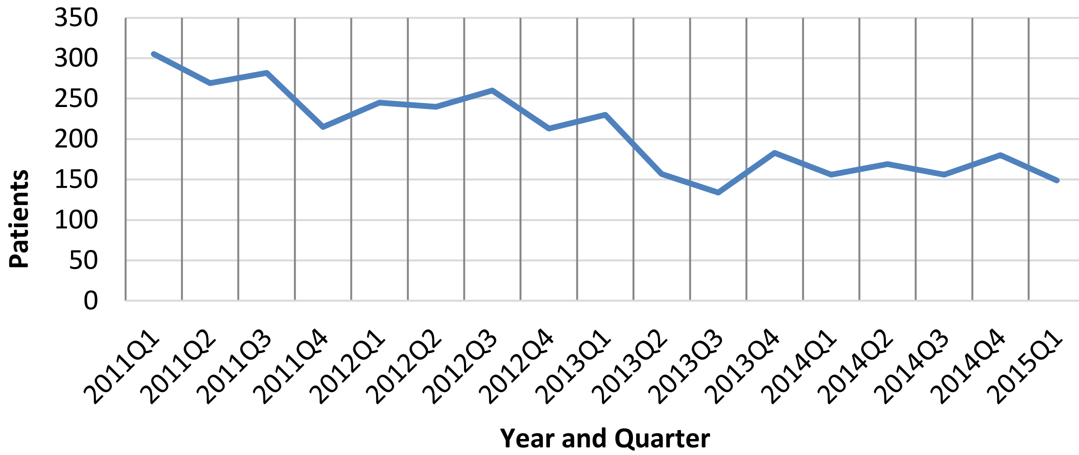

Figure 2: Hospital admissions for UTI between 2011 and 2015

Briefly, primary diagnosis is the diagnosis the treating physician decides is the main cause for admission to the hospital after sufficient examination of the patient, and secondary diagnosis is the supporting partner to, and often underlying cause of the primary diagnosis. The admitting/admission diagnosis is the initial complaint given by the LTCF at time of admission to the hospital, and may or may not be the final primary diagnosis. An examination of the admitting/admission diagnosis for these 3,543 patients with primary or secondary diagnosis of "UTI NOS" found that 1,021 patients (28.8%) were admitted with a complaint of "altered mental status" or delirium. Nearly a third of patients sent to the hospital for a UTI were not sent until the infection had progressed enough to cause delirium symptoms. In other words, almost a third of LTCF missed all signs of UTI until that point. Of the remaining over two thirds of patients, 948 (26.8%) were sent to the hospital with an admitting/admissions diagnosis of "UTI NOS", indicating that the LTCF caught the urinary symptoms, hopefully before the patient could develop complications. The remainders were sent for various reasons, the biggest being fever at 249 patients (7.6%) and malaise/fatigue at 169 patients (4.7%). Frank sepsis/septicemia as an admission diagnosis was relatively low at 113 patients (3.2%). The most common admitting diagnoses, accounting for more than 80 percent of all admissions, are reported in Table 2.

Admitting Diagnosis (ICD-9-CM code and description)	**Number of Patients**	**Percent**
780.97 altered mental status	1,021	28.8
599.0 urinary tract infection nos	948	26.8
780.60 fever nos	269	7.6
780.79 malaise and fatigue nec	165	4.7
038.9 septicemia nos	113	3.2
787.01 nausea with vomiting	68	1.9
789.00 abdominal pain unspecified site	64	1.8
780.2 syncope and collapse	61	1.7
599.70 hematuria nos	50	1.4
458.9 hypotension nos	49	1.4
780.09 other alteration of consciousness	47	1.3
786.05 shortness of breath	41	1.2
996.64 react-indwell urinary catheter	36	1.0

Table 2: Partial List of Admitting Diagnosis of Hospital Admissions for UTI

Illness severity was graded according to the All Patients Refined (APR) Diagnostic Related Group (DRG) scale. Of the 3,543 admitted patients, 1,790 (50.5%) were deemed to have major illness severity, 1,073 (30.3%) were deemed as having moderate illness severity, and 535 patients (15.1%) were deemed to have severe illness. Data are reported in Table 3.

Illness Severity	**Number of Patients**	**Percent**
Minor	145	4.1
Moderate	1,073	30.3
Major	1,790	50.5
Extreme	535	15.1
Total	3,543	100.0

Table 3: Illness Severity of Hospital Admissions for UTI

Of the 3,543 admitted patients, 2,379 patients (67.1%) were non-Hispanic whites, while 562 patients (15.9%) were African American, 395 patients (11.1%) were Hispanic, and the other 207 patients (5.9%) were a mix of other races. Compared to the general Texas population, the percentage of non-Hispanic white patients is greater, at 67.1% compared to 45.3% of the general Texas population, and a lower percentage of Hispanics at 11.1% versus 37.6% of the general Texas population. The percentage of African American and other were also reduced compared to the general Texas population: 15.9% African American patients versus 11.8% in the general Texas population, and 5.9% other patients versus 10.5% in the general Texas population. Data given in Table 4.

Race/Ethnic Recode	Number	Percent
Hispanic	395	11.1
Non-Hispanic White	2,379	67.1
Non-Hispanic Black	562	15.9
Non-Hispanic Asian/Pacific Islander	42	1.2
Other/Unreported	165	4.7
Total	3,543	100.0

Table 4: Race/Ethnicity of Hospital Admissions for UTI

Of the 3,543 patients, 2,390 patients (67.5%) were women, and 1,088 patients (30.7) were men. Gender report was suppressed for a small number of cases for whom a sensitive diagnosis was reported.

Gender	Number of Patients	Percent
Suppressed for confidentiality	65	1.8
Women	2,390	67.5
Men	1,088	30.7
Total	3,543	100.0

Table 5: Gender of Hospital Admissions for UTI

Of the 3,543 admitted patients, 2,875 (81.1%) were covered by Medicare Part A, with HMO Medicare Risk (280 patients, 7.9%) and Medicaid (161 patients, 4.5%) covering most of the rest. Data given in Table 6.

First Payment Source	Number of Patients	Percent
(Missing)	1	0.0
Self-Pay	11	0.3
Other Non-Federal	6	0.2
Preferred Provider Org (PPO)	28	0.8
Point of Service (POS)	1	0.0
Indemnity Insurance	7	0.2
HMO Medicare Risk	280	7.9
Blue Cross/Blue Shield	22	0.6
CHAMPUS	4	0.1
Commercial Insurance	69	1.9
HMO	35	1.0
Medicare Part A	2,875	81.1
Medicare Part B	11	0.3
Medicaid	161	4.5
Other Federal	2	0.1
Veteran's Administration	2	0.1
Charity, Indigent, Unknown	28	0.8
Total	3,543	100.0

Table 6: Payment Source of Hospital Admissions for UTI

The mean length of stay of the 3,543 admitted patients was 5.2±4.1 days, with a range of 1-57 days. The graph can be seen in Figure 2, and was heavily skewed to the right. Similarly, mean age of the 3543 admitted patients was 76.3 years old, with a range from 1 year old to 90 years old, heavily skewed to the left. The graph of the age distribution can be seen in Figure 3. Data given in Table 7.

Length of Stay in Days	Frequency	Percent
1	238	6.7
2	433	12.2
3	699	19.7
4	588	16.6
5	423	11.9
6	341	9.6
7	222	6.3
8	173	4.9
9	102	2.9
10	65	1.8
11	54	1.5
12	43	1.2
13	33	0.9
14	16	0.5
15	19	0.5
16	19	0.5

Table 7: Partial List of Length of Hospitalization for Patients Admitted with UTI.

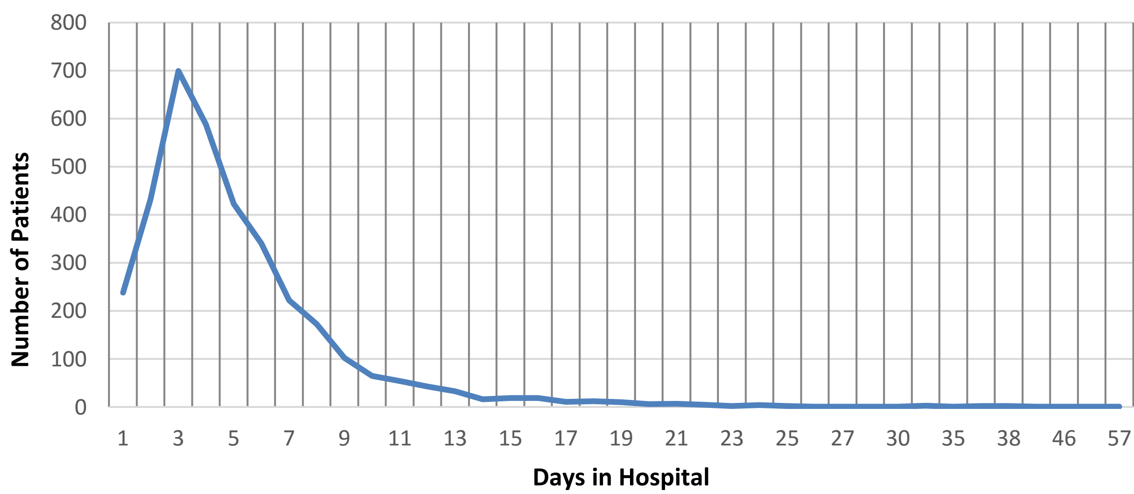

Figure 3: Length of Stay Histogram for Patients Admitted with UTI

Total cost of all patients per quarter year due to admissions for UTI from LTCF, given by Table 8, decreased from 2011 to 2015, ($9,131,368 in 1st quarter 2011 to $5,475,948 in 1st quarter 2015); however average cost per patient actually increased, from $ 29,938.91 in 2011Q1 to $36,751.33 in 2015Q1. These trends can be seen in the graphs of the total cost of all hospital admissions for UTI and average per patient cost in Figure 4 and Figure 5. The data is given in Table 8.

Quarter Year	Total Charges	Average Per Patient
2011Q1	$9,131,368	$29,938.91
2011Q2	$7,524,312	$27,971.42
2011Q3	$8,008,878	$28,400.28
2011Q4	$5,808,409	$27,015.86
2012Q1	$7,243,637	$29,565.87
2012Q2	$6,879,860	$28,666.08
2012Q3	$7,061,958	$27,161.38
2012Q4	$6,280,853	$29,487.57
2013Q1	$7,393,390	$32,145.17
2013Q2	$5,288,976	$33,687.75
2013Q3	$4,902,082	$36,582.70
2013Q4	$6,346,446	$34,680.03
2014Q1	$5,454,590	$34,965.32
2014Q2	$5,717,179	$33,829.46
2014Q3	$5,903,915	$37,845.61
2014Q4	$7,146,742	$39,704.12
2015Q1	$5,475,948	$36,751.33

Table 8: Total Cost and Average Patient Cost of Hospital Admissions for UTI

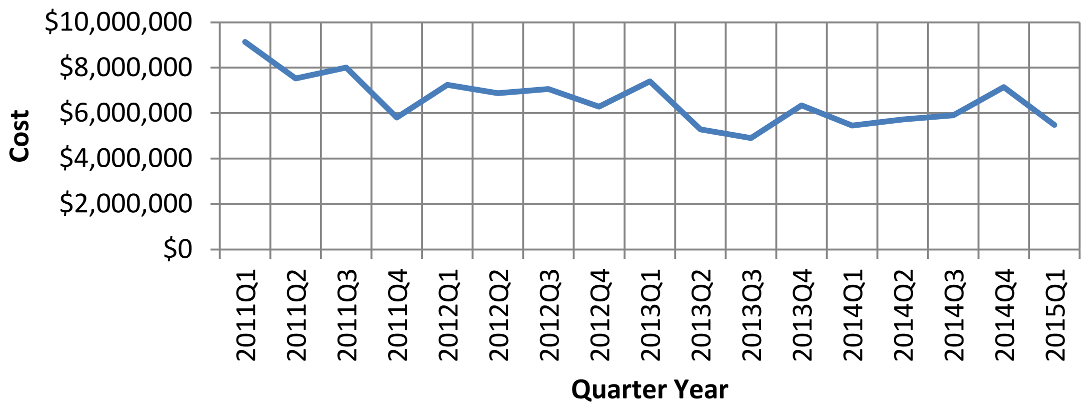

Figure 4: Total cost of Hospital Admission for UTI, 2011-2015

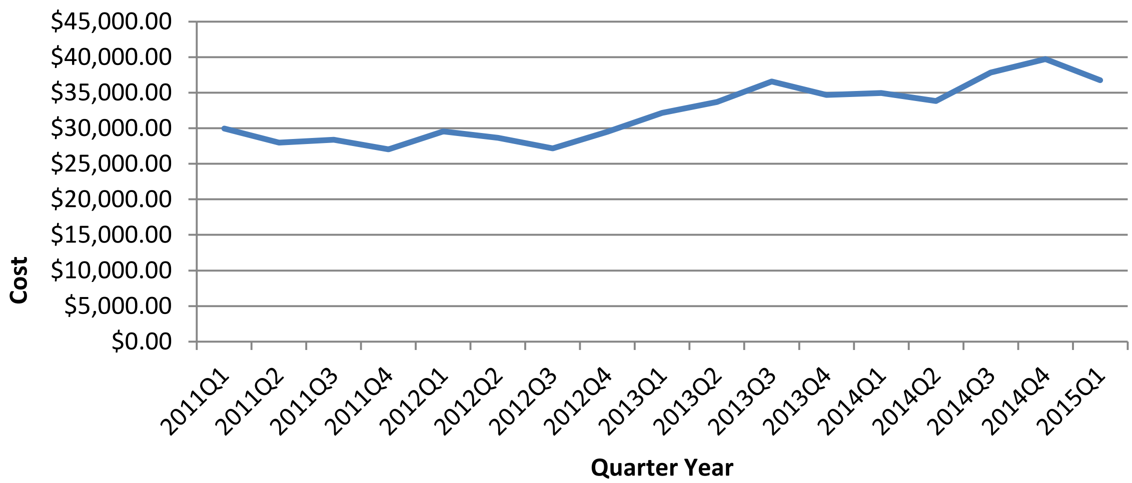

Figure 5: Average Cost per Patient of Hospital Admission for UTI from 2011-2015

Finally, of the 3,543 admitted patients, 2,802 (79.1%) were discharged back to a LTCF. It should be noted that 563 patients (15.9%) were discharged to their home or to home health, and 59 (1.7%) of patients expired. Data given in Table 9.

Discharge S	Number of Patients	Percent
Discharged to home or self-care	355	10.0
Discharged to Other Short Term General Hospital	16	0.5
Discharged to Skilled Nursing Facility	1,751	49.4
Discharged to Intermediate Care Facility	596	16.8
Discharged to Designated Cancer Center	1	0.0
Discharged to care of Home Health Service	210	5.9
Left against medical advice	6	0.2

Expired	59	1.7
Discharged to a federal health care facility	1	0.0
Discharged to hospice-home	51	1.4
Discharged to hospice-medical facility	109	3.1
Discharged within Institution to Medicare-app swing bed	5	0.1
Discharged to Inpatient Rehabilitation Facility	40	1.1
Discharged to Medicare-cert. Long Term Care hospital	195	5.5
Discharged to Medicaid-cert. nursing facility	104	2.9
Discharged to psychiatric hospital	33	0.9
Discharged to critical access hospital	1	0.0
Invalid	10	0.3
Total	3,543	100.0

Table 9: Discharge Setting of Hospital Admissions for UTI

Database Review: Discussion

It is interesting that of the 3,543 patients admitted with either primary or secondary diagnosis of UTI, 340 (9.5%) of them were diagnosed with sepsis/septic shock as a primary diagnosis, yet of their admitting diagnoses, the LTCF sending the patient recognized sepsis/septic shock and used it as admission diagnosis in only 1/3 of those cases (113 patients, 3.2%). The diagnosis criteria for sepsis are solid: the CDC published a list of seven symptoms easily found on physical examination of the patient or from their blood glucose measurement in its surviving sepsis bundle[50]. The fact that sepsis is being missed until arrival at the hospital in so many patients could indicate the need for further training of the nurses and other staff at LTCF or the need to hire additional staff if fatigue and overwork is the problem.

On the bright side, the numbers of patients per year admitted to Texas hospitals from LTCF for UTI has been falling, possibly as a result of increased awareness of the problem among nursing staff or a reduction in urine catheter use. It would be instructive for a study to confirm and search for the reason for this drop in cases, as it may be proof that the increased focus on UTI and reducing catheter use is having an effect;

understanding which intervention is most effective would allow better targeting and implementation.

Given the advanced age of admitted patients (average age of 76 years old and heavily weighted towards the higher age ranges), it shouldn't be surprising that 65.6% of them have illnesses graded major to severe. The DRG severity index counts comorbidities heavily, and patients in this age group, especially those in LTCF, tend to have many comorbidities, including hypertension, diabetes, heart disease, all of which would tend to increase the severity index. One implication of this is that if a patient in this age range does have an acute episode of disease odds are the hospitalization will be much longer and more painful than that of a younger patient, and so the best option is to not have catch the acute illness in the first place. This places a much higher emphasis on prevention, whether it be reducing urinary catheter usage, fall prevention, medication avoidance and simplification, or reliably giving them vaccinations, as examples. The gender disparity of approximately 2/3 female, 1/3 male is not very surprising-females tend to get UTI more often in general due to having a shorter urethra for bacteria to traverse.

While it is good sign that total cost from cases of UTI appears to be going down, $5.5 million each quarter year (or $20+ million yearly) spent on UTI patients (from LTCF alone) is not something to downplay either. The fact that although overall UTI costs are going down, average costs are going up does not bode well, and could be from a number of reasons. Complexity of each patient could be going up, increasing the cost per patient even as fewer patients admitted means lower costs overall. Rising overall healthcare costs could be partly to blame. A more in depth study comparing costs per patient per year, especially in different areas of Texas, would probably be instructive.

Overall, even though the number of patients being admitted for UTI is slowly trending downwards, as are total costs, UTI or its complications, likely from an inserted urinary catheter, is still one of the most common reasons for hospital admission as well as a significant drain of healthcare funds, and further efforts to reduce the incidence of UTI should still be pursued.

Chapter 3 Literature Review Methods

Studies outlining ways to reduce incidence of UTI in LTCF were found via the PubMed database. Keywords included Long-Term-Care-Facility, UTI, and Urinary Catheter. Studies regarding urinary catheter and tubing design were also found using the PubMed database. Keywords included urinary catheter design, UTI risk, catheter tubing design, catheter tubing position. Study inclusion criteria initially included randomized controlled trial (RCT), study done within the last 45 years, and patient age > 45. Due to lack of sufficient trials in several areas, inclusion criteria were broadened to include prospective/retrospective cohort and crossover studies as well as described in the sections below. Steps to reduce incidence of CA-UTI recommended by each study were analyzed based on strength of evidence cited by the study and estimated cost of implementation of the recommendation. Given the plethora of possible means to reduce incidence of UTI, studies found were to be grouped by their means of risk reduction and analyzed within their groups.

Primary and secondary outcome data were extracted from each group of studies, and either the odds ratio or the incidence rate ratio was examined depending upon the group of studies. Incidence rate ratio or odds ratio was calculated for studies where they were not given. Quality of a study was based on type of study, sample size, presence of a control group, and possible biases present.

Chapter 4 Literature Review Results

Search Results and Selection Process

A total of 421 citations were identified through the initial PubMed search. After duplicate removal, the titles and abstracts of 363 articles were screened and 331 were excluded based on relevance, leaving 19. A diagram of the steps taken is given by Figure 6.

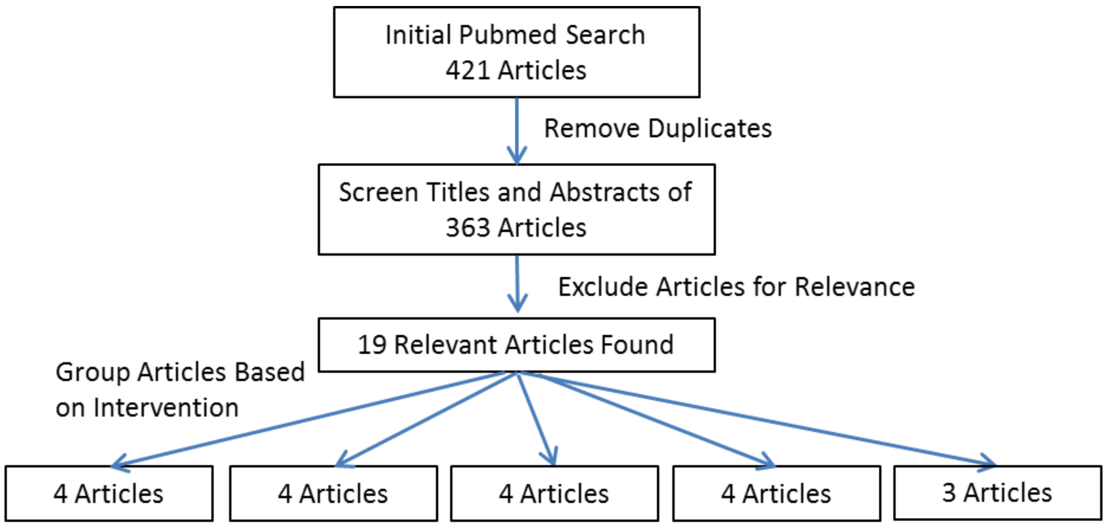

Figure 6: Literature Review Search Process

These 19 studies were separated into five groups based on the primary method of reducing UTI risk. Each group was analyzed separately, with a recommendation for or against their method of UTI risk reduction given based on the studies in each group. Placed into question form:

1. Does drinking supplements such as cranberry juice, chokeberry juice, or vinegar significantly reduce the incidence of CA-UTI?
2. Does the maintenance of a closed urinary catheter system (via an anti-reflux mechanism) significantly reduce the incidence of CA-UTI?
3. Does using “sterile” technique when inserting a urinary catheter confer any significant benefit in relation to reducing incidence of CA-UTI as compared to

merely "clean" technique? "Sterile" meaning using sterile gloves, sterile draping, and/or a prepackaged urinary catheter kit, whereas "clean" technique meaning using non-sterile gloves, non-sterile draping, but still cleaning the perineum area prior to insertion.

4. Does having a "reminder system" such as a daily paper note or popup on electronic records to "remind" the caretaker to check a patient's urinary catheter and determine if it is necessary significantly reduce the incidence of CA-UTI? Alternatively, would having automated paper or electronic stop orders to discontinue the urinary catheter after a set duration significantly reduce the incidence of CA-UTI?
5. Should an indwelling urinary catheter be changed at regular intervals, and if so, is there evidence to recommend a specific change schedule in order to reduce incidence of CA-UTI?

Question 1: Does drinking supplements such as cranberry juice, chokeberry juice, or vinegar significantly reduce the incidence of CA-UTI?

Historically, cranberry juice was thought to exert a protective effect against the development of bacteriuria and UTI through its acidification of the drinker's urine via the benzoic acid in the juice[8, 9]. Newer theories attribute this protective effect to various proanthocyanadin molecules that inhibit attachment and biofilm formation of E. coli and other gram positive and gram negative bacteria[8, 9]. While a number of studies have been done examining the effect of cranberry juice or extract on incidence of bacteriuria or UTI, the majority of studies either included patients younger than 65 y/o, were focused on hospitalized patients, or specifically excluded patients with indwelling urinary catheters. Of the studies meeting the inclusion criteria, (Age > 65, long term care facility, and not excluding use of indwelling urinary catheters), four studies were found examining the effects of cranberry juice or cranberry extract on development of bacteriuria or incidence of UTI. All studies were RCTs.

The four studies were carried out between 1994 and 2014. Three studies were carried out in the United States; one was carried out in the Netherlands. All were carried out in long term care settings, but only two specifically targeted patients with indwelling catheters. One other stratified them in its analysis, while the last article did not take presence of indwelling catheters into account. A list of the four studies is given in Table 10 below. The four studies had differences in patient populations; while all four selected patients of similar age from LTCF, only 2 specifically selected for patients with indwelling urinary catheters. In addition, two studies were exclusively female, while a third was largely (> 70%) female. Results from the four trials are given in Table 11 below. Unfortunately, outcome measures for the four trials were not uniform; two compared incidence of UTI, while the other two studies compared presence of bacteriuria and pyuria in treated vs control groups, with or without active symptoms indicating a UTI. The strict UTI diagnosis criteria in the Van Den Hout study and the UTI diagnosis criteria in the Hess study matched the CDC CA-UTI diagnosis criteria. The Van Den Hout study also had a separate analysis using looser criteria: this only took clinical symptoms into account without a urine culture. Results were mixed: while the earlier and smaller study by Hess et al. found a significant reduction in incidence of UTI (OR = 0.3) among cranberry treated patients, the later, and larger study by Van Den Hout found no significant decrease in incidence of similarly defined UTI (calculated OR = 1.03), although it did find a significant decrease in incidence of more loosely defined UTI (calculated OR = 0.303): that is, UTI diagnosed only with clinical symptoms but without a positive urine culture. The two studies examining presence of bacteriuria also differed in result: the earlier (and larger) study by Avorn et al. found a significant difference in presence of bacteriuria between cranberry treated and placebo (OR = 0.42) while the later (and smaller) trial by LInsenmeyer did not find any significant difference [list OR for

Linsenmeyer study when found]. Of note, the Linsenmeyer study was much shorter than any of the other three, being limited to a month in duration. The other three studies all found that there was at least a month long delay before treatment with cranberry extract was seen to have any effect. The differences in outcome measures, study sizes, and inconsistency in outcomes preclude a meta-analysis of the included trial results.

It should be noted that while the Avorn study did find a significant reduction in bacteriuria (with or without pyuria), the actual reduction in symptomatic bacteriuria was much lower and not statistically significant (20 of 473, or 4% of urine samples in cranberry group had concurrent bacteriuria and urinary symptoms, compared to 37 of 498, or 7% of urine samples in the placebo group, P > 0.05). Since asymptomatic bacteriuria with or without pyuria is not treated, this meant that in the Avorn study the presence or absence of cranberry extract actually made no clinical difference, since there would have been no statistically significant difference in medical treatment between the two groups.

Study	When Trial Conducted	Duration	Country	Trial Setting
Avorn[9]	1993-1994	6 months	United States	LTCF
Linsenmeyer[28]	2003	4 weeks	United States	LTCF
Hess[8]	2002-2004	12 months	United States	LTCF
Van Den Hout[29]	2013-2014	12 months	Netherlands	LTCF

Table 10: List of Studies Reviewed for Question 1

In the end, only one of the four studies (Hess 2008) found that using cranberry juice or extract had a significant effect on the incidence of UTI in elderly patients with indwelling urinary catheters in LTCF. Given the small sample size of the study, the fact that the results differed so greatly from a more recent and much larger study, it is likely further studies would be needed to make a confident recommendation. Whether or not cranberry juice will be of benefit also depends on the treatment style of the healthcare provider. A more conservative provider, taking into account the advanced age of the patient and the increased probability of complications from a UTI may well decide to treat based on symptoms alone, in which case, based on the results of the Van Den Hout study, cranberry extract could help reduce the number of antibiotics given out to patients based only on clinical symptoms. In addition, cranberry juice itself is not harmful to the body in moderate amounts, and has a good amount of required vitamins, so drinking it daily should be of benefit to health regardless of its possible effect on CA-UTI rates. However, there is insufficient solid consistent evidence to recommend the ingestion of cranberry juice or extract as a means of reducing the incidence of CA-UTI

Study	Study Size	Outcome	Result
Avorn (1994)[9]	N = 153 female patients	Odds of bacteriuria (defined as urine bacteria > 10^5/mL)	OR of bacteriuria of 0.42 in cranberry treated vs placebo. 95% CI: 0.23 – 0.75. P = 0.004
Linsenmeyer (2004)[28]	N = 21 patients with indwelling catheters.	Incidence of bacteriuria (defined as urine bacteria > 10^5/mL) or increased urine WBC count (WBC > 10/hpf)	No significant difference in incidence of bacteriuria between cranberry and control group.
Hess (2008)[8]	N = 47 patients with indwelling catheters	Incidence of UTI (defined as bacteria count > 10^4/mL, UTI symptoms, urine RBC > 4/hpf or WBC > 10/hpf).	OR of UTI of 0.3 in cranberry treated vs placebo. 95% CI: 0.1-0.7. P = 0.01.
Van Den Hout (2014)[29]	N = 928 patients. 70% female.	Incidence of UTI (UTI either clinically/symptomatically defined or strictly defined based on symptoms and positive urine culture)	Hazard Ratio of 0.74 for clinically defined UTI in cranberry treated vs placebo. 95% CI: 0.57-0.97. P = 0.03. Hazard Ratio of 1.02 for strictly defined UTI. 95% CI: 0.68-1.55. P = 0.91.

Table 11: Results of Studies Reviewed for Question 1

Question 2: Does the maintenance of a closed urinary catheter system significantly reduce the incidence of CA-UTI?

It has been known for decades that ascent of bacteria from the urinary collection bag or tubing to the bladder via the urinary catheter is one method of contracting bacteriuria and consequently UTIs[10]. Various attempts have been made to lessen the risk of bacterial ascent. For example, the rise of pre-connected and pre-sealed (the urinary collection bag and tubing is connected to the urinary catheter and sold as one sterile unit) urinary catheters was due in part to studies conducted in the 1960's, 1970's, and 1980's showing a significant decrease in development of bacteriuria in pre-sealed, pre-connected catheters without air contact[21, 22]. This is the original meaning of a closed urinary catheter system: that there was an airtight connection between the urinary catheter and tubing and the urinary collection bag, keeping the urinary catheter and tubing from contact with bacteria in the surrounding environment[21]. However, this did not prevent the reflux of urine from the urinary collection bag back into the tubing and the catheter; the urinary collection bag has to be emptied periodically, introducing bacteria into the collection bag which can then ascend into the urinary catheter and bladder with any urinary reflux. More recently, as healthcare facilities have switched to sterile units with the urinary catheter and its tubing pre-connected to the urinary collection bag, a closed urinary catheter system changed to mean one with a mechanism to prevent reflux of urine from the urine collection bag back into the urinary catheter[23, 24, 25, 26, 27]. This is in contrast to an open system, which has no such mechanism, and relies on the position of the urinary collection bag relative to the patient's bladder to prevent backflow. Standard nursing practice is to remind nurses to ensure that the urine collection bag is below the level of the patient's bladder at all times. The idea of an anti-reflux mechanism is not new-clinical studies were done as early as 1970 testing such a mechanism. However, urinary catheters with such mechanisms cost far more than a standard open urinary catheter. The question remains: are closed urinary catheters with anti-reflux mechanisms more effective than open urinary catheters at reducing incidence of bacteriuria and urinary tract infection.

Study	When Trial Conducted	Duration	Country	Trial Setting
Thornton[24]	1970	3-25 days	United States	Hospital
Wilson[23]	1997	3 months	England	LTCF
Leone[25]	2001	2-30 days	France	Hospital
Panitchote[26]	2015	3-20 days	Thailand	Hospital

Table 12: List of Studies Reviewed for Question 2

Four clinical studies concerning the efficacy of non-reflux mechanisms to prevent bacteriuria or urinary tract infection and matching search criteria were found. All studies were RCTs. Since only one study was found specifically examining patients in LTCF, the decision was made to expand the criteria in this case to include patients in hospital wards requiring long term catheterization (8+ days). These four studies were carried out between 1970 and 2015 across multiple countries: (England, the United States, France, and Thailand). One study examined LTCF patients specifically, while another two examined patients in the ICU and hospital wards that required extended urinary catheterization (duration > 8 days). The last examined patients in hospital wards who required short and long term catheterization (2-8 day duration). Two studies were RCT's, and two were prospective cohort studies, one with no control group. All four studies used predominantly male patients (+70% of patients in each study were male). A list of the four studies is given in Table 12 below. Results from these four studies are given in Table 13 below. It should be noted that the Thornton study examined incidence rate and time to bacteriuria of urine in the collection bag versus incidence rate and time to bacteriuria of urine from the bladder. This was an attempt to show whether or not the anti-reflux valve would slow the spread of bacteria from the urine collection bag to the bladder; if there was significant delay (> 2-3 days) between bacteriuria detected in the bladder and the collection bag, the reflux valve was deemed to have worked in at least delaying the spread of bacteria back up the catheter[24]. The Thornton study also had no control group, meaning incidence rate ratio, the outcome measure used to compare the other three studies, could not be calculated[24]. The Thornton study did, however, show a delay of 24 hours or more between bacteriuria in the urine collection bag and bacteriuria in the bladder itself in a statistically significant number of patients (20 of 23 patients who ultimately had bacteriuria in both their bladder and urine collection bag, $p < 0.05$)[24]. This suggested to the authors that the anti-reflux valve was helping to delay rapid spread of bacteria as it was designed to do. However, the fact that bacteria eventually did breach the valve and moved up to the bladder indicates that the anti-reflux valve was a temporary solution at best, insufficient for prevention of bacteriuria and UTI long term. Unfortunately, no other study found has replicated the same measurements. The study by Wilson was the only one that examined truly long term (> 30 days duration) indwelling catheterization with an anti-reflux valve, especially one in a true LTCF environment. The ratio of incidence rate of UTI of patients using an anti-reflex valve equipped catheter and patients using standard urinary catheters was 0.868, $p > 0.05$; hence as noted in the study, there was no significant difference in incidence rate of UTI between the two groups[23]. Similar results were found by Leone and Panitichote in their independent studies, with incidence rate ratios of 0.852, $p > 0.05$ and 0.71, $p > 0.05$[25, 26]. One positive result of the Wilson study was that users of the anti-reflux valve equipped experimental catheter reported a much higher satisfaction rate (95% vs 35%, $p < 0.05$), indicating that the presence of the valve allowed them much more freedom of movement without worrying about the positioning of their urine collection bag[23].

As seen from Table 3, three of the four studies suffer from relatively shorter duration of catheterization, as well as measuring incidence of bacteriuria rather than symptomatic UTI, and as mentioned, the Thornton study lacks a proper control group. The fact that the vast majority of studies were done in a hospital setting rather than LTCF was also concerning, but exceptions were made given the low number of LTCF studies in general. By and large the patients in these studies were older (> 50 y/o), and required several days to weeks of indwelling catheterization.

Given the issues associated with the limited number of studies done on anti-reflux valve equipped catheters and their rather negative results, the author of this review does not recommend using them as a means of reducing incidence of UTI, whether in the hospital or the LTCF setting. The increased cost of new catheter models with this feature is probably not worth the one to two day delay in spread of bacteriuria, bacteriuria which may not progress to symptomatic UTI at all.

Study	Study Size	Outcome	Results
Thornton (1970)[24]	N = 51. 82% male patients.	Incidence Rate for Bacteriuria	Incidence rate of bacteriuria in collection bag: 27/51 = 52.9% **Incidence rate of bacteriuria in bladder: 23/51 = 45.1%**
Wilson (1997)[23]	N = 84 All male patients 41 patients in experimental group 43 patients in control group.	Incidence Rate Ratio of Bacteriuria	Incidence Rate of UTI in experimental group: 24/41 = 0.585 Incidence Rate of UTI in control group: 29/43 = 0.674. **Incidence Rate Ratio of Bacteriuria: 0.585 / 0.674 = 0.868**
Leone (2001)[25]	N = 224.	Incidence Rate Ratio of Bacteriuria	Incidence Rate of bacteriuria in experimental group: 13.5%. Incidence Rate of bacteriuria in control group: 11.5%. **Incidence Rate Ratio of bacteriuria: 0.115 / 0.135 = 0.852**
Panitchote (2015)[26]	N = 96	Incidence Rate Ratio of Bacteriuria	Incidence Rate Ratio for development of bacteriuria: 0.71

Table 13. Results of Studies Reviewed for Question 2

Question 3: Does using "sterile" technique when inserting a urinary catheter confer any significant benefit in relation to reducing incidence of CA-UTI as compared to merely "clean" technique?

Current CDC guidelines specify using "sterile" technique when inserting or caring for an indwelling urinary catheter in order to reduce the risk of introducing contaminating bacteria into a urinary catheter or a patient's urethra and providing the starting point for a possible UTI[19, 20]. "Sterile" technique involves using sterile gloves, sterile draping, sterile cleaning solution, and other sterilized products along with a more complicated procedure to avoid touching and contamination of the cleaned patient. This adds greatly to the time and monetary expense required for each urinary catheter insertion and cleaning. Recently, a few studies have been done to determine whether the full gamut of "sterile" technique is necessary, or whether using a less involved, less expensive "clean" technique could be used without significantly increasing the incidence of UTI or other complications. In these studies, "clean" technique was generally defined as using standard (non-sterile) latex gloves, non-sterile draping, cleaning the patient thoroughly with Betadyne or other antiseptic using standard cotton balls or other non-sterilized materials, and using a less complicated procedure that still attempts to minimize contact with the freshly cleaned patient. It should be noted that in both "sterile" and "clean" procedures, thorough hand washing prior to catheter insertion was still indicated.

Study	Year Trial Conducted	Trial Duration	Country	Trial Setting
Moore	1993	1 year	Canada	Hospital
Carapeti	1994	3 days	UK	Hospital
Prieto	1997	4 weeks	USA	Hospital
Dutta	2012	5 days	India	Hospital

Table 14: List of Studies Reviewed for Question 3

The literature search found numerous studies comparing various means of sterile technique, usually for intermittent catheterization. Very few studies were conducted on “sterile” versus “clean” technique for indwelling catheters. In addition, no studies set in the LTCF setting were found. Thus, the criteria were broadened to include general hospital patients and intermittent catheterization in addition to indwelling catheters in the LTCF setting. Four studies comparing the incidence of bacteriuria and UTI in patients with indwelling and intermittent urine catheters inserted via “sterile” versus “clean” technique were found[30,31,32,33]. All were RCTs. The four studies all followed their patients for 3-5 days post catheter insertion, and were conducted from 1993 to 2012. Two were conducted in the United States, one was conducted in England, and one was conducted in India. All studies were conducted in hospital settings. In addition, two studies examined intermittent catheterization, not simply indwelling catheters, and one study examined children with spinal cord injuries as well as the elderly. Characteristics of the four studies are given in Table 14. Of the four studies, two, Moore (1993) and Prieto (1997) could be considered long term with 4 week to 1 year study duration[30,32]. The other two were far shorter studies lasting 3 and 5 days respectively[31,33]. In addition, only the Carapeti (1994) study had significant numbers of participants ($n > 100$); the other three all had $N < 60$ participants.

Overall, of the four, only one study showed any significant difference in incidence rate of bacteriuria or UTI between use of “sterile” technique or “clean” technique. The Prieto (1997) study had an incidence rate ratio of 1.48 with $p < 0.05$; however, even in this study, the authors concluded that the added expense of sterile equipment (urinary catheter, gloves, draping, etc) for all patients outweighed the cost incurred from antibiotics and increased duration of hospitalization required to treat the additional cases of UTI: cost of antibiotics for the “sterile” group was 43% of the cost of antibiotics for the “clean” group, but the cost of sterile kits was 371% of the cost of non-sterile equipment[32]. Although two other studies showed incidence rate ratios > 1, (1.16 and

1.81), neither were statistically significant[31,33]. Overall results of the four studies are given in Table 15.

As mentioned above, there were issues with each of these studies. The study by Moore (1993) examined children and teenagers aged 3 to 16 years old, not the elderly. Their immune systems were presumably younger and healthier, and aside from the spinal bifida causing their neurogenic bladder, they had no other accompanying diseases[30]. The result of this study is interesting in that for the "clean" catheterization group, when split into male and female patients, the female patients had about the same incidence rate of bacteriuria whether they self-catheterized or had help from their parents (39% vs 40%), while the male patients showed a sharp drop in incidence rate when their parents helped them (25% vs 43%). The male patients could very well not be taking as much care in cleaning or hygiene during the process as the female patients or the parents of either group[30]. The small study size (N = 30) was also a concern, and the paper itself admitted some sub groups, such as the patients who self-catheterized, were too small for accurate statistical analysis.

The Carapeti (1994) study was the study with the fewest issues: it had a relatively large sample size (N > 100), and the age range was compatible: average age 66.8 years old. It also had a substantial number of both males and females, (54% and 46% respectively), and dealt specifically with indwelling catheters, although in the short term surgical setting instead of long term care setting; each patient was examined for development of bacteriuria and UTI for only three days post op[31]. The paper is still one of the most widely cited on this topic by review articles such as the reviews by Shapiro, Ercole, or Ming[34,35,36]. As far as extending its conclusions to long term catheterization, the paper brought up the interesting point that contamination during catheter insertion would primarily cause infection in the short term, within 1-3 days, since after that bacterial contamination generally came from bacteria deposited around the urethra or perineum post insertion moving into the catheter and ascending[37,38]. The other implication from this being that if this is true, future studies on this topic can be conducted within a week's time and do not need to stretch into weeks or months, greatly reducing the expense and complexity.

The study by Dutta (2012) seems to corroborate this result: this study also focused on indwelling catheters, elderly to middle aged patients (average ages of 46 y/o and 50 y/o in intervention and control groups respectively). The patients in this study came from different backgrounds ranging from ICU to ER to general surgery patients examined post op [insert citation]. However, the distribution of patients from these three areas was similar between the intervention group and the control group (no statistically significant difference in distribution). Similarly, although not all patients in the study were handled under the same conditions (some had fully closed urinary drainage systems, others didn't, some had clean urinary catheters, others didn't), the distribution of closed to open and clean to dirty urinary catheter systems was the same between the intervention and control groups, mitigating this potential source of bias. More than the origin of the patients or their care, both of which were accounted for in this study, the bigger problem was the small sample size of 50 patients. Even though the incidence rate ratio of bacteriuria was 1.81, indicating a large difference in incidence rate between intervention and control groups, this difference was still deemed not statistically significant, most likely due to low sample size.

Although there have been two RCTs examining "sterile" versus "clean" indwelling catheterization technique, and numerous other RCTs examining "sterile" versus "clean" intermittent catheterization all showing no significant difference in incidence of bacteriuria or UTI between the two techniques, the author hesitates to recommend switching to "clean" technique for indwelling catheterization due to the small sample size and other problems associated with these studies. Ideally, a long term study conducted in the hospital or LTCF setting could be done on a large (N > 200+) sample size of patients to more properly examine this issue.

Study	Study Size	Outcome	Results
Moore (1993)	N = 30.	Incidence rate of bacteriuria	Incidence rate of bacteriuria in "clean" group: 38%. Incidence rate of bacteriuria in "sterile" group: 38%. **Incidence Rate Ratio = 1**
Carapeti (1994)	N = 156	Incidence rate of UTI (bacteriuria > 10^5cfm)	Incidence rate of UTI in "clean" group: 11%. Incidence rate of UTI in "sterile" group: 9.5%. **Incidence Rate Ratio = 0.11 / 0.095 = 1.16.** **Not statistically significant (p > 0.05)**
Prieto (1997)	N = 29	Incidence rate of UTI (bacteriuria > 10^5cfm)	Incidence rate of UTI in "clean" group: 42.4%. Incidence rate of UTI in "sterile" group: 28.6%. **Incidence Rate Ratio = 0.424 / 0.286 = 1.48.** **Statistically significant difference (p < 0.05), but not financially viable**
Dutta (2012)	N = 53	Incidence rate of bacteriuria	Incidence rate of bacteriuria in "clean" group: 26.9%. Incidence rate of bacteriuria in "sterile" group: 14.8%. **Incidence Rate Ratio = 0.269 / 0.148 = 1.81.** **Not statistically significant (p > 0.05)**

Table 15: Results of Studies Reviewed for Question 3

Question 4: Does having a "reminder system" such as a daily paper note or popup on electronic records to "remind" the caretaker to check a patient's urinary catheter and determine if it is necessary significantly reduce the incidence of CA-UTI?

Numerous studies have shown that a key risk factor for the development of bacteriuria and UTI is catheterization duration[39,40]. In theory, decreasing the duration of catheterization and the number of patients with indwelling urinary catheters should have a beneficial effect on incidence of bacteriuria and UTI. As numerous studies have found, indwelling catheters are often forgotten by nurses or physicians and left unchecked in patients even after they have outlived their usefulness; one study found that up to 40% of the time a new attending physician was unaware a patient even possessed an indwelling urinary catheter.[41]. To act as a backstop and ensure timely discontinuation of the indwelling urinary catheter, variations on the theme of alarm systems and protocols using automatic written stop orders issued after a specified duration unless overridden by the physician have been studied. In addition, with the increased implementation and adoption of electronic medical records (EMR) comes the possibility of using EMR to remind physicians and nurses to check on patients with an indwelling urinary catheter and ensure its cleanliness and functionality as well as its continued necessity. All these systems will hopefully reduce the number and duration of indwelling urinary catheters and thus reduce incidence of bacteriuria and UTI. The obvious benefit of using an electronic system is to reduce human fallibility-the system will not have to depend on nurse memory or written orders being found. There are a number of possible strategies to implement this, but the focus here will be on prewritten or electronically generated indwelling catheter stop orders that activate after a set duration has passed unless overridden by the physician.

Study	Year Study Conducted	Trial Duration	Country	Trial Setting
Cornia[42]	2003	Crossover study. 16 weeks total, 8 weeks before crossover.	United States	Hospital ward
Topal[43]	2005	Prospective cohort study. 3 separate cohorts, each under surveillance for 53 days.	United States	Hospital ward

Stephen[44]	2006	Three phase study with each phase lasting the duration of a patient's hospitalization. Last phase occurred 2 years post intervention.	Switzerland	Hospital ward and ICU
Loeb[45]	2008	RCT with follow-up lasting 7 days past catheter removal.	Canada	Hospital ward

Table 16: List of Studies Reviewed for Question 4

Thirty studies were found during the literature search that used EMR or written/verbal reminders or stop orders to encourage nurses and physicians to check indwelling urinary catheters. Unfortunately, there was no RCT found during the literature search-the closest study to an RCT was a prospective crossover study; the criterion was broadened to RCT or prospective cohort study. In addition, no studies conducted strictly in LTCF were found, so that criterion was broadened to general hospital patients. Excluding the studies that didn't meet overall inclusion criteria for age, indwelling urinary catheter usage, or explicit use of stop orders versus reminders, four studies remained [42,43,44,45].

Two studies were conducted in the United States, one in Switzerland, and the last in Canada. Study size ranged from 70 to 1000+ separated into 3 cohorts. Study duration and follow-up ranged from seven days post catheter removal to two years post catheter removal. Due to lack of studies done in the LTCF setting, all studies were done on hospital wards, using either medical patients or post-surgical patients averaging between 50 and 70 years of age. Male to female ratio in all studies was approximately 50-50, from 47%-53% to 61%-39%. As noted earlier, two studies were prospective cohort studies, one was a crossover study, and only Loeb (2008) was a RCT. Study characteristics are given in Table 16. Cornia (2003) and Topal (2005) used the electronic medical records systems at their hospital to send automated stop orders once the indwelling urinary catheter had been placed for a set duration unless overridden by the physician. Stephan (2006) and Loeb (2008) used paper orders written at time of admission or insertion of the indwelling urinary catheter to achieve the same result. Stephan (2006) also allowed the nurse to discontinue the urinary catheter according to a series of guidelines independent of the physician.

A summary of study results are given in Table 17. All studies that included duration of catheterization as a primary outcome showed significant decreases in duration of indwelling urinary catheterization, decreasing about 2.8 days on average; alternatively, decreasing from 16% of patients with urinary catheters to 2-10% with urinary catheters in the post-intervention cohorts. However, only Topal (2005) and Stephan (2006) reported statistically significant decreases in incidence of UTI between pre-intervention cohorts and post intervention cohorts. In the case of the Cornia (2003) study, the lack of a statistically significant decrease in incidence of UTI could be attributed to an insufficient number of patients, as the study only had 70 compared to the 600-1000 of the other studies. It should be noted that this study also examined rate of catheter reinsertion to determine of patients were having their urinary catheters prematurely discontinued due to automatic stop orders. This study found no statistically significant increase in catheter reinsertions (of 5 patients who needed a catheter re-inserted, only 1 had it discontinued due to an automatic order).

Although the Topal (2005) study was a cohort study, the three cohorts were very well matched: equivalent age ranges (all averaged 70±17 y/o), average 58% female, and all had equivalent percentages (29-32%) of diabetics and other co-morbidities. Number of patient-days per cohort was also matched. As noted, the study found a statistically significant decrease in incidence of UTI post-intervention, from 36 per 1000 catheter days in the pre-intervention cohort to 19 and 11 per 1000 catheter days in the two post-intervention cohorts. It should be noted that this study examined a number of other interventions in addition to automated stop orders: nurses were encouraged to use bladder ultrasounds at bedside to determine necessity of indwelling urinary catheters, ED physicians were counseled on appropriateness of indwelling urinary catheters, and nurses on the hospital ward were further educated on appropriateness and care of the indwelling urinary catheters in their patients. These additional interventions could have greatly contributed to the reduction in incidence of UTI as well; no steps were taken in the analysis to isolate the effects of these multiple interventions[43].

Similarly, the Stephan (2006) study had three well matched cohorts. Each cohort was separated into orthopedic surgery patients and abdominal surgery patients; the abdominal surgery patients were used as a control group for each cohort and did not receive the interventions even in the post-intervention cohorts. It should be noted that although the study did find a statistically significant decrease in incidence of UTI between pre-intervention cohort and post-intervention cohort, there was a decrease in incidence of UTI between the pre-intervention and post-intervention abdominal surgery patients as well, from 2.4% to 1.25%, or a decrease of nearly 50%, only slightly smaller than the decrease in incidence of UTI between pre-intervention and post-intervention orthopedic patients (10.4% to 3.9%). It's possible that other factors, such as nursing staff, changes in physicians, or suppliers, could have aided the decrease in UTI in the hospital over the three years the study was conducted. Similar to the Topal (2005) study, this study also had other interventions besides pre-written stop orders, including restrictions on indwelling urinary catheter insertion and additional nursing education on care of indwelling urinary catheters. As before, the effects of these additional interventions are not isolated, and may have contributed to the decrease in incidence of UTI.

The Loeb (2008) study was the only RCT to examine pre-written automatic stop orders and their effect on urinary catheter duration and incidence of UTI. Unlike the other studies, this study also did not include any other interventions such as nursing education or physician guidelines. As noted, while it found a statistically significant decrease in duration of indwelling urinary catheter insertion of 1.7 days, it failed to find a statistically significant decrease in incidence of UTI: incidence of UTI in intervention group was 19% of patients, while incidence of UTI in the control group was 20% of patients. However, half of the patients in this study were given antibiotics as part of their treatment over the duration of this study, which would tend to decrease the number and severity of bacteriuria, even if that wasn't the indication for antibiotics. The authors themselves mention this as a possibility.

Given that all four studies found significant decreases in duration of catheterization and the established link between duration of catheterization and development of bacteriuria leading to UTI, and that two reasonable studies found a statistically significant decrease in incidence of UTI, it is recommended that some form of pre-written or automated stop order for indwelling urinary catheters, or at least a reminder system for the physician and nurses to check on them, be implemented. However, ideally more studies with large numbers of patients should be done to examine this, ideally with multivariate analysis built in if many different interventions are going to be used.

Study	Study Size	Outcome	Results
Cornia[42] (2003)	742 total patients, 70 with indwelling catheters inserted. N = 70 total. 36 in intervention, 34 in control.	**Primary:** Days of uretheral catheterization per patient with catheter. **Secondary:** Incidence of UTI in patients with catheter inserted. UTI defined as urine bacteria count of > 100 cfu of a single bacteria species.	Primary: **Intervention group had significant 3 day shortening** of catheterization duration ($p = 0.03$). Secondary: **No significant difference found in incidence of UTI** between intervention and control groups (8% vs 14%, $p = 0.71$)
Topal[43] (2005)	3 cohorts, 1 pre-interveiont, 2 post. Pre-intervention: 883 patients, 180 with pre-inserted indwelling catheters. Post-intervention 1: 894 patients, 81	**Primary:** Number of patients with indwelling catheters, and percentage of urinary **Secondary:** Incidence of CAUTI per 1000 catheter day.	Primary: **Two post intervention cohorts had significant difference in percentage of urinary catheterization compared to pre-intervention cohort** (16% vs 10% and 2%, $p < 0.001$) Secondary: **Two post-intervention cohorts had significant reduction in**

	with recently inserted indwelling catheters. Post-intervention 2: 895 patients, 58 with recently inserted indwelling catheters.		**incidence of CAUTI compared to pre-intervention cohort** (36 vs 19 and 11 CAUTI per 1000 catheter days, p < 0.001)

Table 17: Results of Studies Reviewed for Question 4

Study	Study Size	Outcome	Results
Stephen[44] (2006)	3 cohorts for 3 phase study. Pre-Intervention (Phase I): N = 529 Post-Intervention (Phase II): N = 499 Long Term Follow-up (Phase III): N = 300	Primary: Incidence rate of UTI (cases per 100 patients). Device associated incidence rate (cases per 1000 urinary catheter days) Secondary: Antibiotic use in post-surgical period (daily dose per 100 patient days)	Primary: Incidence rate of UTI in intervention: 6.6% to 2.6% pre vs post intervention**.** **Significant reduction in incidence of UTI in intervention group.** Incidence rate of UTI in control: 2.4% to 1.25%. **No significant reduction in incidence of UTI in control group.** 2 year follow-up: Incidence rate of UTI in intervention group: 3.7%, **still lower than pre-intervention.**
Loeb[45] (2008)	RCT. N = 692 patients. 347 in intervention group, 345 in control group.	Primary: Duration of urinary catheter insertion (days). Secondary: Incidence of UTI.	Primary: Mean urinary catheter duration was 3.7 days for intervention group, 5.4 days for control. **Significant difference in urinary catheter duration (p < 0.001)** Secondary: Incidence rate of UTI in intervention group: 19%.

		Incidence rate of UTI in control group: 20%. **No significant difference in UTI incidence between the two groups (P > 05).**

Table 17: Results of Studies Reviewed for Question 4 (continued)

Question 5: Should an indwelling urinary catheter be changed at regular intervals, and if so, is there evidence to recommend a specific change schedule in order to reduce incidence of CA-UTI?

Since one of the causes of CAUTI is bacterial ascension from the urinary drainage bag up the catheter, it follows that regular changing of the urinary catheter and drainage bag may prevent bacteriuria and development of UTI. In addition, regular changing also prevents encrustation of the urinary catheter, thus preventing blockage of the catheter and flow of urine back into the bladder. On the other hand, regular changing of the urinary catheter entails regular removal and insertion of a new urinary catheter, increasing the chances for contamination during insertion[46]. In addition, regular, short term changing is much costlier than changing the urinary catheter only for encrustation or blockage. Current CDC guidelines recommend against regular "arbitrary" changes of the indwelling urinary catheter[19].

Study	Year Study Conducted	Study Duration	Country	Study Setting
Priefer[47]	1982	6 months	United States	LTCF
White[48]	1995	6 weeks	United States	Home care
Keerasuntonpong[49]	2003	4-29 days	Thailand	Hospital ward

Table 18: List of Studies Reviewed for Question 5

Three studies were found matching general inclusion criteria outlined earlier: patient age > 45, study done < 45 years ago, and RCT, cohort, or crossover trial[47,48,49]. Two studies were RCTs, and one was a retrospective cohort study. A list of the three studies is given in Table 18. A summary of the results of the three studies is given in Table 19.

The Priefer (1982) study was a RCT conducted in Veteran's Administration nursing homes to determine whether regularly scheduled urinary catheter changes resulted in reduced incidence of UTI compared to changes scheduled as needed. Primary outcomes were incidence of UTI and number of catheter changes per month. Study follow-up time was 6 months. Seventeen patients were randomly divided into a group that had their urine catheter changed monthly and as needed, and a group that only had their urine catheter changed on an as needed basis for blockage, infection, or loss of function. Ten patients averaging 83 years old were in the monthly group, and 7 patients averaging 77 years old were in the as needed group. The monthly change group averaged about 1.3±0.6 catheter changes per month. The change as needed group averaged 0.64±0.04 catheter changes per month, a statistically significant difference. The study found that although the monthly change group had a lower incidence of UTI per patient than the change as needed group: (0.4±0.7 cases / patient / 6 months versus 1.0±0.6 / patient / 6 months), this difference was not statistically significant ($p > 0.05$), possibly due to the low sample size.

The White (1995) study was a retrospective cohort study examining the urinary catheter change schedule for 106 patients enrolled at a home health agency using patient medical records, of which 81 were found to be free of infection at baseline. Study follow-up time was 6 weeks. The authors divided the 81 clean patients into two groups based on whether they had their urinary catheters changed more or less than once every four weeks. Primary outcome was incidence of CAUTI as a percent of total patients in each group. Of those who had their catheters changed more often, catheters were usually changed every two weeks. Of those who had their catheters changed less often, catheters were usually changed every 4-6 weeks. The authors found that the patients who had their catheters changed more often than once every four weeks had a UTI incidence of 58%

(33/57 patients positive for UTI symptoms and bacteriuria), while patients who had their catheters changed every 4-6 weeks had a UTI incidence of 17% (4/24 patients). Relative hazard ratio of shorter than 4 week urine catheter change schedule was 11.94, a statistically significant difference.

In a similar vein, the Keerasuntonpong (2003) study was a RCT that examined the effect that changing the urinary collection bag instead of the entire urinary catheter on a three day schedule as opposed to leaving the bag unchanged would have on incidence of UTI. 153 patients were randomized into two groups: 79 would have their urine collection bag changed every three days, while 74 would keep their urine collection bag unchanged. Patients were followed until they either developed a UTI or had their urinary catheter discontinued a range of 4 to 29 days. Patients in the 3 day change group averaged 59 years old; those in the no change group averaged 58 years old. Patients in both groups had similar health profiles: similar percentages of diabetes, hypertension, renal disease, or other complications, and both had similar average urinary catheterization durations (10.1 versus 9.5 days). The authors recorded a UTI incidence of 13.8 cases per 1000 catheter days in the 3 day change group compared to a UTI incidence of 11.4 cases per 1000 catheter days in the no change group, a difference that was not statistically significant.

Of the three studies, Priefer (1982) is hampered by small sample size, leaving White (1995) and Keerasuntonpong (2003). The results from both those studies seem to reinforce each other, with one advocating a regular 4-6 week urinary catheter change schedule while the other implying that changing the urinary collection bag, or other part of the catheter too often increases the risk of introducing bacteria into the system and leading to a UTI. Unfortunately, the Keerasuntonpong (2003) study does not examine more infrequent urinary catheter changes, so no additional experimental evidence can confirm the recommendation for regular 4-6 week urinary catheter changes. Given the lack of solid, prospective cohort trials or RCT to confirm the efficacy of regular change schedules, this review cannot recommend regularly scheduled urinary catheter changes at this time. It should be noted that in practice, due to encrustations or blockage, urinary catheters will most likely be changed around once or so every 2 months in any case, as can be seen with the change as needed group of patients in the Priefer (1982) study.

Study	Study Size	Outcome	Results
Priefer (1982)[47]	RCT, N = 17	Primary: Incidence of UTI, given as infections per patient in 6 months. Secondary: Number of catheter changes per month.	Primary: Monthly catheter change: 0.4±0.7 UTI per patient per 6 months. PRN catheter change: 1.0±0.6 UTI per patient per 6 months. **No statistically significant difference in UTI incidence ($p > 0.05$)** Secondary: Monthly: 1.3±0.6 catheter changes per month. PRN: 0.64±0.04. **Statistically significant difference in number of catheter changes per month ($p < 0.05$).**
White (1995)[48]	Retrospective Cohort Study, N = 106.	Primary: Incidence of UTI.	Primary: Patients with urinary catheters changed more

	Examined frequency of urinary catheter change: more often than once every four weeks versus less often.		often than once every 4 weeks: UTI incidence rate of 58% (33/57 patients positive for UTI by 6 weeks). Patients with urinary catheters changed less often than once every 4 weeks: UTI incidence rate of 17% (4/24). **Statistically significant difference in UTI incidence rate ($p < 0.05$)**
Keerasuntonpong (2003)[49]	RCT, N = 153. 79 intervention, 74 control	Primary: Incidence of UTI, symptomatic and unsymptomatic.	Primary: 3-day change group: UTI Incidence: 13.9%, 13.8 / 1000 catheter days. Control group: UTI Incidence: 10.8%, 11.4 / 1000 catheter days. **No statistically significant difference in UTI incidence ($p > 0.05$)**

Table 19: Results of Studies Reviewed for Question 5

Chapter 5 Literature Review Discussion

Summary and Gaps in Evidence

The author reviewed studies covering five basic strategies to reduce the risk and incidence of UTI in patients with indwelling urinary catheters: have patients drink cranberry or other juice in order to add compounds to their urine that discourages bacterial adhesion or growth, place an anti-reflux valve in the urinary catheter to ensure one way flow and create a closed system, "sterile" versus "clean" technique when inserting urinary catheters, use an automated system to send paper or electronic reminders or stop orders to discontinue urinary catheters, and change the urinary catheter at fixed, scheduled intervals. While at least several studies have been done on all of these proposed strategies, as noted above, many of these studies have had small sample sizes, lacked proper/any control groups, or have had rather ambiguous results, such as finding a reduction in bacteriuria from the intervention but not any reduction in incidence of symptomatic UTI. For the purposes of this review, very few studies were actually conducted in LTCF settings; the vast majority of studies were conducted in the hospital setting, and a number examined intermittent catheterization instead of indwelling urinary catheters. Then too, many had a large age range: several of the studies examining "sterile" versus "clean" catheterization used patients from 6 years to 70 years old, although the average age was still in the 70's due to the high number of older patients. As noted, on the strategy of using automated paper or electronic stop orders, the author could only find one RCT; the others were all either crossover studies or prospective or retrospective cohort studies.

Keeping these limitations in mind, in regard to the five strategies:

1. The author does not recommend that patients ingest cranberry juice, citing three of four studies that showed no significant effect in reducing incidence of UTI, and the large increase in cost required for daily doses of cranberry or other type of juice. The one study that found a positive effect had a rather small sample size: 53 patients compared to the 153 or 928 patients in two other studies showing negative effect.
2. The author does not recommend that patients use indwelling urinary catheters with anti-reflux valves added to ensure one way flow and create a closed system. Again, three of four studies found no significant effect in reducing incidence of UTI, and the one study that found some effect lacked a control group.
3. The author hesitates to recommend that patients and caregivers can use "clean" technique instead of "sterile" technique when changing or inserting indwelling urinary catheters. Several studies have confirmed that "clean" technique is just as effective as "sterile" technique in reducing incidence of UTI for intermittent catheterization, and the official CDC report has recommended the use of "clean"

technique for intermittent urinary catheterization. However, far fewer studies have been conducted to examine indwelling urinary catheterization. The one study that is most often cited (Carapeti 1994) used surgical patients undergoing short term instead of long term urinary catheterization, although it does make a point that it is possible examination of short term urinary catheterization is all that is required. Another RCT, (Dutta 2012) had a rather small sample size and failed to find a statistically significant difference between “sterile” versus “clean” indwelling urinary catheterization.

4. The author does support using automated paper or electronic stop orders to discontinue urinary catheters after a set duration. All studies done on this subject found a significant reduction in duration of urinary catheterization, although only two found significant reduction in incidence of UTI with the intervention. Given the benefits of reducing duration of urinary catheterization (reduction in length of hospitalization, indirectly reduced risk for UTI), this in itself is beneficial and should be encouraged.
5. The author hesitates to recommend using a fixed indwelling urinary change schedule, as only one study found a statistically significant difference in incidence of UTI between a fixed change schedule and a change as needed schedule, and this study found that the fixed change schedule had a higher incidence of UTI. In this case, the fixed change schedule changed the urinary catheter fairly frequently: once every two weeks or so. The study leaves open the possibility that regular changes at longer periods of time, for example 4-6 weeks, may actually be beneficial. Given the lack of many studies on this subject, the CDC itself has not recommended a fixed schedule, except to say changing the urinary catheter at 4-6 weeks may be helpful[19].

There are enough issues with the studies conducted in this area that solid conclusions are hard to come by. Indeed, as noted, while the studies involving cranberry juice or alarm systems had up to 900 patients in a study, several other subjects, such as those examining urinary catheter change schedules, often had two or three dozen subjects at most. These studies were also conducted in the mid 1980's, and early 1990's, without many modern studies; alternatively, as in the case of testing automated stop orders, all but one were cohort studies. Clearly bigger studies need to be conducted, ideally RCT with dedicated control groups, large sample sizes, and set in the LTCF for best relevance. Failing that, studies with a single intervention would be helpful, though a few studies with multiple interventions did do multivariate analysis to determine the effect of each intervention.

Public Health Implications and Conclusion

The biggest implication of all this is that there is no single intervention that would provide a magic bullet-it will take a combination of interventions applied together to really reduce the risk and incidence of UTI in catheterized patients. In addition, the common theme running through most of these interventions is attention to detail from the caregiver, from examining the patient for urinary symptoms to regularly checking on the urinary catheter for blockages or encrustation. This would be rather hard to achieve, or to expect from nursing staff in LTCF if the patient to staff ratio continues to be the 15 – 20 to 1 it is now. Ideally more staff should be hired, or patients need to be better educated so they can find and report problems themselves. However, given the high cost of and risk of additional morbidity and mortality of hospitalizations of the elderly for UTI, it would probably cost less in the long run and improve patient and resident satisfaction to invest in bigger nursing staffs and better education for nurses and their patients or residents.

Appendix A: STATA Code for THCIC Data Extraction

```
/*SELECTS Transfers from Long-term care facilities*/
drop if TYPE_OF_ADMISSION=="4";
keep if SOURCE_OF_ADMISSION=="5";

/*defines isuti by principal diagnosis as UTI or secondary diagnosis as UTI if septicimia
is principal diagnosis*/
gen isuti=0;
replace isuti=1 if pr_diag ==" 599.0 " & POA_PRINC_DIAG_CODE=="Y";
replace isuti=1 if pr_diag ==" 996.64" & POA_PRINC_DIAG_CODE=="Y";
replace isuti=2 if substr(pr_diag,2,3)=="038" & (sec_diag==" 996.64" |
  sec_diag==" 599.0 ")
&  POA_OTH_DIAG_CODE_1=="Y" & POA_PRINC_DIAG_CODE=="Y";
```

Bibliography/References

1. Haley RW, Hooton TM, Culver DH, Stanley RC, Emori TG et a"Nosocomial infections in U.S. hospitals, 1975-1976: estimated frequency by selected characteristics of patients." *Am J Med* 1981;70, 947-59

2. Saint, S., "Clinical and economic consequences of nosocomial catheter-related bacteriuria*." Am J Infect Control* 2000; 28, 68-75.

3. Leuck AM, Wright D, Ellingson L, Kraemer L, Kuskowski MA, Johnson JR, "Complications of Foley Catheters-Is Infection the Greatest Risk," *Journal of Urology*, May 2012; 187, 1662-1666.

4. Nicolle LE, "Urinary Tract Infections in Long-Term-Care Facilities," Infection Control and Hospital Epidemiology, Mar 2001; 22:3, 167-175.

5. Genao L, Buhr GT, "Urinary Tract Infections in Older Adults Residing in Long-Term Care Facilities," *Annals of Long Term Care*, 2012; 20-24.

6. Spetz J, Donaldson N, Aydin C, Brown DS, "How Many Nurses per Patient? Measurement of Nurse Staffing in Health Services Research," Health Services Research, Oct 2008; 43:5, 1674-1692.

7. Zhang NJ, Unruh L, Liu R, Wan TTH, "Minimum Nurse Staffing Ratios for Nursing Homes," *Nursing Economics*, 2006; 24; 2, 78-85, 93.

8. Hess MJ, Hess PE, Sullivan MR, Nee M, Yalla SV, "Evaluation of cranberry tablets for the prevention of urinary tract infections in spinal cord injured patients with neurogenic bladder," *Spinal Cord*, 2008; 46, 622-626.

9. Avorn J, Monane M, Gurwitz JH, Glynn RJ, Choodnovskiy I, Lipsitz LA, "Reduction of bacteriuria and pyuria after ingestion of cranberry juice," *JAMA*, 1994;271:10, 751-754.

10. Hoonton TM, Bradley SF, Cardenas DD, Colgan R, Geerlings SE, Rice JC, Saint S, Schaeffer AJ, Tambayh PA, Tenke P, Nicolle LE, " Diagnosis, Prevention, and Treatment of Catheter-Associated Urinary Tract Infection in Adults: 2009 International Clinical Practice Guidelines from the Infectious Disease Society of America," *Clinical Infectious Disease*, 2010; 50:625-663.

11. Warren JW, Muncie HL Jr, Hall-Craggs M, “Acute pyelonephritis associated with bacteriuria during long-term catheterization: a prospective clinicopathological study,” *Journal Infect Disease*, 1988; 158:1341–1346.

12. Mylotte JM. Nursing home-acquired bloodstream infection. Infect Control Hosp Epidemiol 2005; 26:833–837.

13. Muder RR, Brennen C, Wagener MM. “Bacteremia in a longterm-care facility: a five-year prospective study of 163 consecutive episodes,” *Clinical Infect Disease,* 1992; 14:647–654.

14. Rudman D, Hontanosas A, Cohen Z, Mattson, DE. “Clinical correlates of bacteremia in a Veterans Administration extended care facility,” *Journal American Geriatric Society*, 1988; 36:726–732.

15. Stevenson K, “Standardized infection surveillance in long-term care: interfacility comparisons from a regional cohort of facilities,” *Infect Control Hospital Epidemiology*, 2005; 26:231–238.

16. Jacobsen SM, Stickler DJ, Mobley HL, Shirtliff ME. “Complicated catheter associated urinary tract infections due to *Escherichia coli* and *Proteus mirabilis*,” *Clin Microbiol Rev,* 2008; 21:26–59.

17. Bergqvist D, Bronnestam R, Hedelin H, Ståhl A. “The relevance of urinary sampling methods in patients with indwelling Foley catheters,” *British Journal Urology* 1980; 52:92–95.

18. Saint S, Chenoweth CE, “Biofilms and catheter-associated urinary tract infections,” *Infect Disease Clin North Am*, 2003; 17, 411–432.

19. Gould CV, Umschied CA, Agarwal RK, Kuntz G, Pegues DA, “Guidelines for Prevention of Catheter-Associated Urinary Tract Infections 2009, Healthcare Infection Control Practices Advisory Committee, 2009, 1-67.

20. Utilizing the American Nurses Association’s (ANA) Streamlined Evidence-Based RN Tool: Catheter Associated Urinary Tract Infection (CAUTI) Prevention. 2009. http://nursingworld.org/CAUTI-tool-Guidance. Accessed 7/10/2015.

21. DeGroot-Kosolcharoen J, Guse R, Jones JM, “Evaluation of a Urinary Catheter with a Preconnected Closed Drainage Bag,” *Infect Control Hosp Epidemiology*, 1988; 9:2, 72-76.

22. Quigley PA, Riggin OZ, “A Comparison of Open and Closed Catheterization Techniques in Rehabilitation Patients,” *Rehabilitation Nursing*, 1993; 18:1, 26-33.

23. Wilson C, Sandhu SS, Kaisary AV, "A Prospective Randomized Study Comparing a Catheter-valve with a Standard Drainage System," *British Journal of Urology*, 1997; 80, 915-917.

24. Thornton GF, Andriole VT, "Bacteriuria During Indwelling Catheter Drainage: Effects of a Closed Sterile Drainage System," *JAMA*, 1970; 214:2, 339-342.

25. Leone M, Garnier F, Dubuc M, Binar MC, Martin C, "Prevention of Nosocomial Urinary Tract Infection in ICU Patients: Comparison of Effectiveness of Two Urinary Drainage Systems," *Chest*, 2001; 120: 1, 220-224.

26. Panitchote A, Charoensri S, Chetchotisakd P, Hurst C, "Pilot study of a non-return catheter valve for reducing catheter-associated urinary tract infections in critically ill patients," *J Med Assoc Thai*, 2015; 99:2, 150-155.

27. Wenzler-Röttele S, Dettenkofer M, Schmidt-Eisenlohr E, Gregersen A, Schulte-Mönting J, Tvede M, "Comparison in a Laboratory Model between the Performance of a Urinary Closed System Bag with Double Non-return Valve and that of a Single Valve System," *Infection*, 2006; 34:4, 214-218.

28. Linsenmeyer TA, Harrison B, Oakley A, Kirshblum S, Stock JA, Millis SR, "Evaluation of cranberry supplement for reduction of urinary tract infections in individuals with neurogenic bladders secondary to spinal cord injury. A prospective, double-blinded, placebo-controlled, crossover study," *Journal of Spinal Cord Medicine*, 2004; 27:1, 29–34.

29. Van den Hout WB, Van Den Hout MAA, Putter H, Cools HJM, Gussekloo J, "Cost-Effectiveness of Cranberry Capsules to Prevent Urinary Tract Infection in Long-Term Care Facilities: Economic Evaluation with a Randomized Control Trial," *Journal American Geriatric Society*, 2014; 62, 111-116.

30. Moore KN, Kelm M, Sinclair O, Cadrain G, "Bacteriuria in Intermittent Catheterization Users: The Effect of Sterile vs Clean Reused Catheters," *Rehabilitation Nursing*, 1993; 18:5, 306-309.

31. Carapeti EA, Bentley PG, Andrews SM, "Randomised study of sterile versus non-sterile urethral catheterization," *Ann R Coll Surg Engl*, 1994; 76, 59-60.

32. Prieto-Fingerhut, T, Banovac K, Lynne CM, "A study comparing sterile and nonsterile urethral catheterization in patients with spinal cord injury," *Rehabilitation Nursing*, 1997; 22:6, 299-302.

33. Dutta M, Verma P, Mandal AK, "Comparison of effectiveness of sterile vs clean technique for indwelling catheter care in preventing urinary tract infection," Nursing and Midwifery Research Journal, 2012; 8:1, 29-38.

34. Shapiro M, Simchen E, Izraeli S, Sacks TG, “A Multivariate analysis of Risk Factors for Acquiring Bacteriuria in Patients with Indwelling Urinary Catheters for Longer than 24 Hours,” Infection Control, 1984; 5:11, 525-532.

35. Ercole FF, Macieira T, Wenceslau L, Martins AR, Campos CC, Chianca T, “Integrative Review: Evidences On The Practice of Intermittent/Indwelling Urinary Catheterization,” Rev. Latino-Am. Enfermagem, 2013; 21:1, 459-468.

36. Ming, YS, “A Critical Review of Indwelling Catheter Care in Acute Practice Settings,” Macau Journal of Nursing, 2006; 5:1, 33-37.

37. Roberts JA, Fussell EN, Kaack MB, “Bacterial adherence to urethral catheters,” *J Urol* 1990; 144: 264-269.

38. Farber BF, Wolff AG, “Salicylic acid prevents the adherence of bacteria and yeast to silastic catheters,” *J Biomed Mater Res*, 1993; 27: 599-602.

39. Garibaldi RA, Burke JP, Dickman ML, Smith CB, “Factors predisposing to bacteriuria during indwelling urethral catheterization,” *N Engl J Med.* 1974; 291, 215–219.

40. Platt R, Polk BF, Murdock B, Rosner B, “Risk factors for nosocomial urinary tract infection,” *Am J Epidemiol.* 1986; 124, 977–985.

41. Saint S, Wiese J, Amory JK, et al, “Are physicians aware of which of their patients have indwelling Foley catheters?” *Am J Med.* 2000: 109, 476–480.

42. Cornia PB, Amory JK, Fraser S, Saint S, Lipsky BA, “Computer-based order entry decreases duration of indwelling urinary catheterization in hospitalized patients,” *Am J Med* 2003; 114:5, 404–407.

43. Topal J, Conklin S, Camp K, Morris V, Balcezak T, Herbert P, “Prevention of nosocomial catheter-associated urinary tract infections through computerized feedback to physicians and a nurse-directed protocol,” *Am J Med Qual* 2005; 20:3, 121–126.

44. Stephan F, Sax H, Wachsmuth M, Hoffmeyer P, Clergue F, Pittet D, “Reduction of urinary tract infection and antibiotic use after surgery: a controlled, prospective, before-after intervention study,” *Clin Infect Dis* 2006; 42:11, 1544–1551.

45. Loeb M, Hunt D, O’Halloran K, Carusone SC, Dafoe N, Walter SD, ”Stop orders to reduce inappropriate urinary catheterization in hospitalized patients: a randomized controlled trial,” *J Gen Intern Med* 2008; 23:6, 816–820.

46. Willson M, Wilde M, Webb ML, Thompson D, Parker D, Harwood J, Callan L, Gray M, “Nursing interventions to reduce the risk of catheter-associated

urinary tract infection: part 2: staff education, monitoring, and care techniques," *J Wound Ostomy Continence Nurs*, 2009; 36:2, 137-154.

47. Priefer BA, Duthie EH Jr, Gambert SR, "Frequency of urinary catheter change and clinical urinary tract infection. Study in hospital-based, skilled nursing home," *Urology*, 1982; 20, 141–142.

48. White MC, Ragland KE, "Urinary catheter-related infections among home care patients," *J Wound Ostomy Continence Nurs.* 1995; 22, 286–290.

49. Keerasuntonpong A, Thearawiboon W, Panthawanan A, Judaeng T, Kachintorn K,"Incidence of urinary tract infections in patients with short-term indwelling urethral catheters: a comparison between a 3-day urinary drainage bag change and no change regimens," *Am J Infect Control.* 2003; 31, 9–12.

50. Dellinger RP, Levy MM, Rhodes A, Annane D, Gerlach M. "Surviving Sepsis Campaign: International Guidelines for Management of Severe Sepsis and Septic Shock: 2012," *Critical Care Medicine Journal* 2013; 41:2, 580-620.

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Han, W., Ovidiu, I., Numan, O., Werner, B. (2010). *Development of an Automated Process for Homology Based Prediction of Protein 3D Structure.* Poster presented at: 2010 Medical Student Summer Research Program; Galveston, TX.

Han, W., Wang, J. (2007). *Diffusion Tensor MR Imaging for Tracking of White Matter Fibers through Diffusion Anisotropy*. Poster presented at: MD Anderson Summer Research Internship; Houston, TX.

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Gupta, S., Han, W., Hurtubise, DR., Kim, MS., Beahm, EK., Reece, GP., Merchant, FA., Markey, MK. (2007). *Assessment of breast reconstruction surgery outcomes using 3D human body scans.*. Oral Presentation presented at: Biomedical Engineering Society (BMES) Annual Fall Meeting; Los Angeles, CA.

Han, W., Yao, J., Chen, J., Summers, RM. (2009). *Clinical Image Processing Engine. In: Advanced PACS-based Imaging Informatics and Therapeutic Applications.*. Oral Presentation presented at: Proceedings of SPIE 7; Lake Buena Vista, FL.

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