NEAR EAST UNIVERSITY

INSTITUTE OF GRADUATE STUDIES

DEPARTMENT OF MEDICAL AND CLINICAL MICROBIOLOGY

THE PREVALENCE OF CATHETER-RELATED BLOODSTREAM INFECTIONS AT THE NEAR EAST UNIVERSITY HOSPITAL DURING 2022-2023

M.Sc. Thesis

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Nicosia

January, 2024

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Approval

We certify that we have read the thesis submitted by **Samuel S. Suah** titled **"The Prevalence of Catheter-Related Bloodstream Infections at the Near East University Hospital during 2022-2023"** and that in our combined opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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Declaration

I hereby declare that all information, documents, analysis, and results in this thesis have been collected and presented according to the academic rules and ethical guidelines of the Institute of Graduate Studies, Near East University. I also declare that as required by these rules and conduct, I have fully cited and referenced information and data that are not original to this study.

SAMUEL S. SUAH

31/01/2024

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Samuel S. Suah

Özet

2022-2023 Yıllarında Yakın Doğu Üniversitesi Hastanesi'nde Kateter İlişkili Kan Dolaşımı Enfeksiyonlarının Prevalansı

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Danışman: Doç. Dr. Emrah Ruh

Ocak 2024, 70 sayfa

Amaç: Bu çalışma, 2022-2023 yılları arasında Yakın Doğu Üniversitesi Hastanesi'ndeki üç yoğun bakım ünitesinde santral kateter ilişkili kan dolaşımı enfeksiyonlarının sıklığını incelemek amacıyla yapılmıştır.

Yöntem: Bu çalışma, Yakın Doğu Üniversitesi Hastanesi'nde yürütülmüştür. Veri toplama işlemi, Yakın Doğu Üniversitesi Hastanesi'nin elektronik bilgi sistemi aracılığıyla elde edilen tıbbi kayıtların retrospektif olarak incelenmesini içermiştir.

Bulgular: Santral kateter ilişkili kan dolaşımı enfeksiyonlarının toplam görülme yoğunluğu 1000 kateter günü için 17,0'dır. Etkinlik oranı genel yoğun bakım ünitesinde 1000 kateter günü için 30,2 olup, kalp damar cerrahisi yoğun bakım ünitesinde 1000 kateter gününde 0,0 oranında en düşük seviyedeydi. Gram-negatif bakteri olan *Klebsiella pneumoniae* (16/49, %32,7) santral kateter ilişkili kan dolaşımı enfeksiyonlarının en yaygın nedeni idi.

Sonuç: Çalışmadan elde edilen bulgular, hastanenin yoğun bakım ünitelerinde, santral kateter ilişkili kan dolaşımı enfeksiyonları açısından koruyucu önlemlerin uygulanmaya devam edilmesi gerektiğine işaret etmektedir.

Anahtar Kelimeler: Kateter, insidans yoğunluğu, yoğun bakım üniteleri, kateter ilişkili kan dolaşımı enfeksiyonları, santral venöz kateter

Abstract

The Prevalence of Catheter-Related Bloodstream Infections at the Near East University Hospital during 2022-2023

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January 2024, 70 pages

Aim: The aim of this study was to examine the incidence density of bloodstream infections caused by central venous catheters in three intensive care units at the Near East University Hospital during 2022-2023.

Methods: This study was a retrospective investigation carried out at the Near East University Hospital. The data collection procedure involved the examination of medical records obtained through the electronic information system of the Near East University Hospital.

Results: The overall incidence density of catheter-related bloodstream infections was 17.0 per 1000 catheter days. The incidence rate was prevalent in the general intensive care unit at 30.2 per 1000 catheter days and lowest in the cardiovascular surgery intensive care unit at 0.0 per 1000 catheter days. *Klebsiella pneumoniae* (16/49, 32.7%) which is a gram-negative bacterium, was the main causative agent of the catheter-related bloodstream infections.

Conclusion: The findings obtained from the study indicate that protective measures should continue to be implemented in hospital intensive care units in terms of catheter-related bloodstream infections.

Key words: Catheter, incidence density, intensive care units, catheter-related bloodstream infections, central venous catheter

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List of Abbreviations

CRBSIs:	Catheter-Related Bloodstream Infections
PLABSIs:	Peripheral Line-Associated Bloodstream Infections
CVC:	Central Venous Catheter
PVC:	Peripheral Venous Catheter
HAIs:	Hospital-Acquired Infections
IV:	Intravenous
PIVC:	Peripheral Intravenous Catheters
GWX:	Guide Wire Exchange
CRS:	Catheter-Related Sepsis
ICU:	Intensive Care Unit
CICU:	Coronary Intensive Care Unit
GICU:	General Intensive Care Unit
CVSICU:	Cardio Vascular Intensive Care Unit
MRSA:	Methicillin-Resistant Staphylococcus Aureus
VISA:	Vancomycin-Intermediate Staphylococcus Aureus
VRSA:	Vancomycin-Resistant Staphylococcus Aureus
IJ:	Internal Jugular
SC:	Subclavian
FEM:	Femoral
IDSA:	Infectious Diseases Society of America

CDC: Centers for Disease Control and Prevention

CNS: Coagulase-Negative Staphylococci

ESBL: Extended-Spectrum B-Lactamases

DTTP: Difference in Time to Positivity

EUCAST: European Committee On Antimicrobial Susceptibility Testing

SIR: Standardized Infection Ratio

YDU: Yakin Dogu Universitesi

NEU: Near East University

CRP+: C-Reactive Protein Positive

PCT+: Procalcitonin

WBC: White Blood Cells

MRS+: Methicillin-Resistant Staphylococcus

APACHE II: Acute Physiology and Chronic Health Assessment II Score

CL: Central Line

CHAPTER I

Introduction

This chapter presents a comprehensive introduction to catheter-related bloodstream infections, including a description of the problem, the study's purpose, a research question, the significance of the study, limitations, and the definition of key terms relevant to this research.

Catheter-related bloodstream infections (CRBSIs) continue to be a major problem in healthcare institutions due to their association with increased rates of hospitalizations and death and the high costs associated with healthcare (Gahlot et al., 2020). Furthermore, both central venous catheter-associated bloodstream and peripheral line associated bloodstream infections (PLABSIs) contribute to this burden of CRBSIs. According to the Agency for Health Research and Quality, CLABSIs mostly affect individuals who have a central venous catheter (CVC) or have been diagnosed with a disease within 48 hours after CVC implantation. PLABSIs affect individuals who have a peripheral venous catheter (PVC) or are diagnosed within 48 hours of PVC insertion (The Agency for Health Research and Quality, 2015).

Most significantly, CRBSIs' rate varies drastically across different nations and settings. Based on a recent systematic review conducted by Li et al. (2018), the total occurrence rate of CLABSIs differed between wealthy and impoverished nations. Li et al. observed that in countries with higher incomes, the rate was 1.14 per 1,000 catheter-days, while in poorer countries, the rate was 2.45 per 1,000 catheter-days. Moreover, PLABSIs have garnered increased attention in recent years, despite their original perception as being less perilous than CLABSIs (Bauzá et al., 2019). Recent research indicates that the occurrence of PLABSIs has a major role in the overall prevalence of CRBSIs, with incidence rates ranging from 0.1 to 1.9 per 1,000 catheter-days (Ista et al., 2021).

As a matter of fact, various risk factors are linked to the occurrence of CRBSIs. These include patient attributes such as age and pre-existing medical conditions, as well as variables relating to the catheter itself, such as material, type, insertion location, and length of use (Kaye et al., 2021). Moreover, it is crucial for healthcare personnel to strictly follow an aseptic method while inserting and maintaining medical devices to avoid the incidence of CRBSIs (Koh et al., 2019).

Undoubtedly, the use of approaches such as skin antisepsis, maximum sterile barrier precautions, good hand hygiene, and catheter site care has considerably reduced the prevalence of CRBSI (Alkubati et al., 2018). Furthermore, studies have shown that the usage of antimicrobial lock solutions and catheters impregnated containing antimicrobial agents could tremendously decrease the rate of CRBSIs. (Gahlot et al., 2020). A thorough understanding of the disease's epidemiology is crucial for successfully fighting CRBSI. Given this, the aim of this study is to investigate the incidence density or rate of catheter-related bloodstream infections within the coronary, cardiovascular surgery and general intensive care units at the Near East University Hospital during 2022-2023.

Statement of the Problem

Several clinical data indicate that most bloodstream infections are linked to the use of catheters (CVC and PVC) (Ruiz-Giardin et al., 2019; Ista et al., 2021). Consequently, these infections are widely recognized as frequent and preventable causes of sickness and death in hospitals. Furthermore, healthcare-associated infections are a significant issue that affects people globally, presenting serious threats to their health and lives (Gahlot et al., 2020). In addition, due to these infections' high rates of morbidity, mortality, and costs, it is imperative that ongoing procedures be in place to prevent them.

Without a doubt, catheters are essential for a significant number of patients to receive crucial drugs, such as nutritional supplements, dialysis, antibiotics, and chemotherapy; hence, without these catheters, some patients would die. the aim of this study is to investigate the incidence density or rate catheter-related bloodstream infections within the coronary, cardiovascular surgery and general intensive care units at the Near East University Hospital during 2022-2023.

Purpose of the Study

The primary objectives for this study were specified as follows: Assess the incidence density or rate of bloodstream infections linked to CVC, at the Near East University Hospital during 2022-2023. And identify the specific microorganisms responsible for causing CVC infections at the Near East University Hospital throughout the years 2022–2023.

Research Question

The study was driven by the following problem-oriented questions:

1. What is the incidence density or rate of CVC related bloodstream infections in the coronary, cardiovascular and general intensive care units at the Near East University Hospital during 2022 to 2023?

2. Which microorganisms were the causal agent of CVC related bloodstream infections in the coronary, cardiovascular and general intensive care units at the Near East University Hospital during 2022-2023?

Significance of the Study

The study's results could potentially offer researchers valuable details that strengthen the importance of vigilance and prevention of CRBSIs. Public health personnel, infection control department personnel, intensive care unit personnel, medical laboratory personnel, and pharmacy personnel may find this research to be beneficial.

In addition, this study may inspire additional research in the area of catheter-associated bloodstream infections among clinicians, academics, and professionals in the healthcare industry.

Limitations

The small sample size is attributed to the poor statistical power and generalizability of the findings. Moreover, just a single hospital used the application of the study. This may limit the generalizability of the findings to other healthcare facilities. Furthermore, healthcare practitioners inputted the data into the electronic medical record, which might introduce bias, gaps, incomplete information, or reliance on previously collected data. The study's length of two years may not sufficiently capture the long-term prevalence of CLABSI rates. Finally, the analysis of the study's results did not include any confounding variables, such as changes to staff training programs, infection control protocols, or other interventions implemented during the research period.

Definition of Terms

CLABSI refer to infections that arise in the bloodstream after the insertion of a central line, and these infections do not occur simultaneously with any other kind of infection.

Hospital-acquired infections (HAIs) are illnesses that arise during the course of a patient's hospitalization and were not present at the time of admission.

Clinical guidelines are carefully crafted statements designed to assist clinicians in making well-informed judgments about the optimal therapy for certain clinical problems.

Catheter-associated bloodstream infections occur when microorganisms are introduced into the circulation via a central line or catheter site.

Central line is a type of catheter that is inserted into a blood vessel for various purposes, such as administering fluids, withdrawing blood, monitoring the heart's function, or connecting to different parts of the heart and major blood vessels.

Central venous catheters (CVC) are placed into a central vein of the body to acquire venous access.

CHAPTER II

Literature Review

The focus of this literature study will be central venous catheters., including their kinds, use in healthcare, and complications. A significant portion of this literature review will focus on the post-insertion consequences of CRBSI, including discussions of the pathophysiology of this infection and preventative measures. The paper will conclude by discussing the diagnostic techniques devised for catheter-associated infections.

Overview of Catheters

A catheter is a tube that facilitates the administration or removal of fluids from the body. Notably, modern medical practice is reliant on their utilization, and they have had a significant influence on a number of medical specialties, including critical care, cancer, gastroenterology, hematology, nephrology, trauma, and burns (Ruiz-Giardin et al., 2019; Ista et al., 2021). In general, the two primary kinds of catheters that are commonly used in healthcare facilities are the urinary catheter and the intravenous catheter. Nevertheless, for the purpose of this review, the intravenous catheter (also known as venous access devices) and its type will be discussed in this section.

Intravenous Catheters

Intravenous (IV) catheters are pliable tubes made of plastic material suitable for medical use. Furthermore, healthcare professionals administer IV catheters by inserting them through the epidermis into a vein. Thus allowing access to the venous system for the purpose of administering fluids or medication or to provide intravenous nutrition (Wallis et al., 2014; Marsh et al., 2020). Importantly, IV catheters can be divided into the following types based on the site of access: Central venous catheters and peripheral intravenous catheters.

Peripheral Intravenous Catheters

Peripheral intravenous catheters (PIVCs) have an overall failure rate ranging from 35% to 50% in healthcare (Marsh et al., 2020; Wallis et al., 2014). More precisely, healthcare providers insert these catheters into the peripheral veins located in the arms and legs. Besides that, most problems with PIVC are not infectious. These include phlebitis, infiltration/extravasation, blockage/occlusion, leakage, and dislodgement (Zingg et al., 2023). Nevertheless, there are instances of local site infections and bloodstream infections (BSI) as well. Recent meta-analyses have shown that phlebitis and infiltration/extravasation are the most common non-infectious consequences of PIVCs (Lv & Zhang, 2019; Marsh et al., 2020;). Importantly, PIVCs are often only trustworthy for a period of three to five days.

Central Venous Catheter

A catheter is inserted into an artery or vein with the intention of placing its distal end within a central artery or vein, often the inferior or superior vena cava. This comprises subcutaneous ports or reservoirs, central and pulmonary arterial catheters, tunneled and non-tunneled CVC, and peripherally inserted central catheters (Bang et al., 2023). Unlike peripheral catheters, central venous catheters (CVC) are distinguished by their length, which is somewhat longer, and they are designed to be used for considerably longer periods of time (Zhang et al., 2023). CVCs are recommended as a treatment option when there is a need for sustained access to a specific vein, which might last anywhere from a few weeks to several months. In their study, Zhang et al. (2023) found that healthcare practitioners frequently utilize the internal jugular veins, subclavian veins, and femoral veins for insertion purposes. According to a research conducted by Kehagias et al. (2023), short-term and long-term CVCs are now universally acknowledged as the ideal approach for a variety of central venous treatments, including chemotherapy, antibiotic therapy, fluid administration, and parenteral nutrition.

In addition, CVCs are composed of a tubular structure, known as a lumen, that terminates in a sealed hub located at the proximal region. The catheter spans from the hub to the terminal end, which is often referred to as the catheter "tip." Catheter might possess a maximum of four lumens, each capable of independent usage for infusing liquids, measuring venous pressures, or extracting blood samples. The primary classifications of CVCs are as follows:

Peripherally Inserted Central Catheter (PICC). Like peripheral catheters, the PICC is inserted through the extremities, particularly the upper arm. The fact remains that it does not terminate in a vein in the periphery. In its place, it is driven through these veins until it reaches the larger veins, which have a wider diameter and are located in close proximity to the heart (Urtecho et al., 2023). Currently, PICCs are widely used in the treatment of patients who are hospitalized. Furthermore, these lines have a low insertion risk and a low incidence of complications, and they enable long-term outpatient intravenous (IV) access, allowing for the early release of patients who need continuous IV medications and regular blood withdrawals (Maki et al., 2006).

Midline Peripheral Intravenous Catheters. In order to provide a feasible substitute for PICC lines, a midline catheter has been developed. Similarly, the midline catheter is inserted into the arm, culminating in the axillary or basilic vein instead of the central venous system (Chen & Liang, 2022). Furthermore, these devices have the advantage of long-lasting accessibility while having a smaller size and reduced surface area, which decreases the potential danger of blood clot formation and contamination and perhaps lowers the incidence of infection (Lu et al., 2021).

Notably, midline catheters have a usage period of up to four weeks, which is shorter than the duration of use for PICC lines, which can be used for weeks to months. However, midline catheters are more robust than peripheral intravenous lines (Chen & Liang, 2022). Furthermore, they are an enticing choice for the short to medium duration, which is a significant advantage. In spite of this, Urtecho et al. (2023) revealed that the utilization of midline catheters was linked to an increased probability of developing venous superficial thrombosis.

Tunneled Catheter. Using ultrasonography and fluoroscopy, the healthcare provider first places a tunneled catheter into a vein in the neck area and then directs it into a nearby large vein close to the heart. The other end of the catheter is put under the skin at the same time, and it is ultimately brought out of the chest via the lateral side (Kehagias et al., 2023). Research has shown that tunneling is an excellent method for securing the catheter in place and lowering the risk of infection. Kehagias et al. (2023) highlight that tunneled catheters have a projected use duration of over one month and, in some cases, even years.

Implanted Port. Implantable ports are tunneled devices that have a long lifetime and the additional benefit of being easy to conceal due to the fact that they are entirely inserted, which gives them an extra inconspicuous look (Kehagias & Tsetis, 2019). It is particularly important to note that ports could be inserted either in the upper extremity (the arm) or thoracic region (the chest). Although accessing the needle may be rather irritating, it is essential to keep in mind that the infusion flow is limited by the 19-20G needle, thereby slowing down the rate at which the fluid is administered (Annetta et al., 2022).

Complication Associated with Catheter

Although there are a number of benefits connected with the use of CVCs, there have been challenges related to their utilization ever since their beginnings. It is possible for complications to emerge with CVCs either during the procedure of inserting the catheter or at any moment during the catheterization of the patient (after the catheter has been implanted) (Drugeon et al., 2023; Canton & Garnacho, 2019). While advancements have been made in the fields of materials science, design, and production of catheters, as well as innovations in insertion methods, there has not been a total reduction in the number of complications. With that being said, this section discussed some complications that are associated with catheters.

Central Venous Catheters Insertion’s Complications

A recent comprehensive review noted that the rates of complications related to the insertion of CVCs vary depending on the selected site of insertion, method used, type of catheter, and the proficiency and expertise of the operator (Canton & Garnacho, 2019). Nevertheless, the kind and comparative occurrence of complications are consistent throughout the majority of research. The potential risks of insertion include access failure, catheter misplacement, laceration of adjacent arteries, haemothorax, hydro-mediastinum, air embolism, pneumothorax, and cardiac perforation (María et al., 2021). Additional rare challenges including cardiac tamponade, catheter rupture, cardiac dysrhythmia, and nerve injury.

Post-Insertion Complications

After the proper insertion of a CVC, around ten percent of patients may have complications related to the insertion or use of the catheter (María et al., 2021). Zhong et al. (2021) categorized these outcomes into three groups: thrombosis, occlusion, or infection. Furthermore, there are other infrequent post-insertion problems that may occur, such as hydrothorax resulting from vascular erosion and mechanical issues that are not linked to obstruction, such as leaking of the CVC.

Catheter Occlusion. As observed by Zhong et al. (2021), one of the characteristics of catheter occlusion is the inability to remove blood or infuse liquids through the catheter while it is in place. Patency loss, also known as a decline in the rate of flow via the catheter (complete blockage of the CVC) may be caused by a variety of circumstances. Some of these causes include the insertion of the CVC in the wrong location inside the vein, the bending of the CVC, which results in restricted flow, the buildup of fibrin, which results the formation of a clot in the CVC and a sheath on the CVC. (María et al., 2021). Thus, intravenous (IV) solutions and precipitated total parenteral nutrition (TPN) are some of the other potential causes of obstruction.

Catheter Thrombosis. Evidence demonstrates that thrombosis occurs upon the insertion of a CVC into the bloodstream since the surface of the catheter promptly becomes covered by plasma proteins (María et al., 2021; Liu et al., 2022). CVCs are associated with two distinct types of blood clot formation: vascular occlusive thrombosis and fibrin sheath thrombosis. In addition, fibrin sheath thrombosis develops on the outer side of the catheter and can extend along its entire length (Liu et al., 2022). Vascular occlusive thrombosis, on the other hand, happens when clots aggregate to stop the flow of fluids from the CVC via the vein. This frequently happens at the tip of the catheter (Evans & Ratchford, 2018). Urokinase and other thrombolytic medicines may be utilized in some situations to lyse the thrombus and reestablish patency in an occluded CVC. Conversely, catheter removal may be the sole option in situations involving kinks or mechanical blockages.

Catheter-Associated Infections. Catheter-related bloodstream infection is a significant complication that leads to extended hospital stays, elevated hospitalization expenses, and poses a potential risk to patient safety and well-being (Chen & Liang, 2022). In addition, several studies have shown a strong correlation between CRBSI and heightened patient morbidity and death rates, as well as an extended duration of hospitalization (Zhang et al., 2023). According to research published by Gahlot et al. (2020), there are more than 500,000 cases of CRBSI that are recorded yearly in Western Europe and the United States of America, and there is a possibility that these illnesses are responsible for as many as 100,000 deaths.

Catheter Removal

Conventional CVC Removal

The methods used for the removal of catheter will differ based on the specific kind of caterer (CVC) and the rationale for their removal (Fisher et al., 2019). It is important to remember that temporary CVCs are only inserted for a short period of time (less than ten days) and that they are simple to "pull" out when CVC removal is required.

Nevertheless, the removal of long-term CVCs poses a greater challenge (Selby et al., 2021). This is due to the infiltration of the tissue into the cuff, necessitating surgery. Zhang et al. (2023) claim that long-term tunneled CVCs, such as Hickman® and Broviac® CVC, may be utilized forever by using an antibiotic lock approach. This involves instilling a strong dosage of antibiotic into the CVC for twelve hours, effectively treating infections without the need for catheter removal.

Conventionally, healthcare providers regularly withdraw and change CVC used in critical care units for short-term usage, especially non-cuffed CVCs. This is predicated on the assumption that regular replacement of CVCs would decrease the rates of infection, since it’s well accepted that the longer a catheter is in place, the greater the likelihood of CRBSI (Johnson & Grossman, 2013; Htay & Johnson, 2019).

Nevertheless, just replacing CVCs as a regular practice does not inherently prevent infection, and there is no substantiated data to support this commonly held idea. On the contrary, the act of replacing and reinserting CVCs actually heightens the likelihood of encountering mechanical problems related to CVC insertion. Johnson & Grossman (2013) point out that CVCs should be maintained until there are clinical indicators necessitating a change in CVC.

Catheter Replacement by Guide Wire Exchange (GWX)

Guide wire exchange is a procedure that involves inserting a guide wire via a single CVC lumen. After removing the catheter from the patient's vein, the guide wire is left in place, and a novel CVC is implanted over it (Chaves et al., 2018).

After retrieval, the healthcare provider removes the tip from the CVC and sends it to the laboratory for further evaluation. If significant numbers of pathogens are found, healthcare providers will withdraw the recently inserted CVC and replace it with a new central venous catheter in a different area (Canton-Bulnes & Garnacho-Montero, 2019). As a consequence of this, the use of GWX is only advantageous in situations where the amount of pathogenic microorganisms that inhabit the depleted catheter is relatively low.

According to Bang et al. (2023), GWX is the procedure of choice in situations when the CVC has been subjected to mechanical harm, especially when being bent or twisted, or when the catheter has to be relocated inside a patient. In situations like these, GWX decreases the risk of disease since there is no infection, and it also eliminates the complications that may occur when a CVC is inserted in a different place. In situations where there is a limited amount of accessible new insertion sites, mainly in the population of protracted hemodialysis patients that depend on the utilization of CVC for an extended period of time, this method achieves the highest success rate.

Catheter-Associated Infections

CVCs are responsible for more than 90% of confirmed CRBSIs, while peripheral catheters are associated with the remaining cases (Lu et al., 2020; Chen & Liang, 2022). Indeed, the impact of CRBSI on the hospitalized population is consistently growing. In the last three decades, several labels have been used to designate infections linked to catheters. Certain writers have used the term catheter-related sepsis (CRS) to describe this form of infection, whereas others prefer names such as catheter-related bacteremia or CRSBI.

Definition of CRBSI

Throughout history, there has been a lack of consensus and widespread acceptance about the definition of a catheter-associated infection. The reasons for this stem from the multitude of techniques used for culturing catheters and the significant disparity in defining an "infected catheter."

Thus, CRBSI, which is sometimes referred to as CRS (catheter-related sepsis) is the presence of bacteremia or mycoemia together with fever within forty-eight hours after an intravenous catheter insertion or removal (Lu et al., 2020; Chen & Liang, 2022). While it is true CLABSI and PLABSI are avoidable, CDC assert that they are responsible for thousands of fatalities annually and billions of dollars in additional expenses to the healthcare system in the United States of America and the globe (Pitiriga et al., 2020; Moriyama et al., 2022).

Clinical Presentation of CRBSIs

CRBSI may present with changes in body temperature (such as fever or hypothermia), low blood pressure, rapid heart rate, impaired blood flow, rapid breathing, and changes in mental function (Chaves et al., 2018; Canton & Garnacho, 2019). One may also consider the possibility of a CRBSI when there are atypical skin symptoms (such as redness, discomfort, swelling, or discharge) around the CVC exit site, the subcutaneous tunnel, or the port pocket (Bang et al., 2023).

However, Bang et al. asserted that the lack of skin symptoms does not always mean that a CRBSI is ruled out, and moreover, a compromised CVC device, such as one with a damaged or leaking line, hub, or caps, does not necessarily need antibiotic therapy, prophylaxis, or blood culture. However, if any of these issues are present with the compromised device, it would raise suspicion for CRBSI.

Several factors contribute to the risk of catheter's infection, which can result in various morbidities, prolonged hospital stays, and increased costs (Lu et al., 2020; Pitiriga et al., 2020). These factors include those related to the patient, healthcare practices, and central venous catheter usage. María et al. (2021) assert that catheter-associated bacteremias are more prevalent in intensive care units (ICUs) and in specialized services including oncology, haematology, and nephrology.

Interestingly, bacteremias associated with central catheters are more common than those associated with peripheral catheters, despite the fact that peripheral catheters are used more often than central catheters (Ruiz-Giardin et al., 2019).

According to the findings of the study conducted by Ruiz-Giardin et al., central catheters accounted for 77% of catheter-related bacteremias, whereas peripheral catheters were responsible for 23%. A study by Sato et al. (2017) also discovered that gram-positive bacteria (58.0%), gram-negative microorganisms (35%), Candida spp. (6.2%), and polymicrobials (25.8%) were the main pathogens of CRBSI.

Implications and Effects of CRBSI

Cost Implications

CRBSI is the primary reason of nosocomial bacteremia in extremely ill patients. It occurs in up to 16% of catheters and results in higher rates of illness, death, and expenses. Researchers have estimated that CRBSI costs range from $69,332 to $71,443 in the USA and from €13,585 to €29,909 in Europe (Chaves et al., 2018; María et al., 2021; Chen & Liang, 2022). Zhang et al. (2023) did research on the financial consequences of CRBSI at a healthcare institution.

The cost of each CRBSI case was calculated using the following parameters: 1) antimicrobial agent, 2) non-antimicrobial agent, 3) expenses related to beds, 4) technical services related to healthcare, 5) care provided by nurses, 6) analysis conducted in a laboratory, 7) materials used in medical procedures, and 8) others. Based on this study, Zhang et al. found that the mean expenses associated with each incidence of CRBSI in the ICU amounted to $67,923.

Treatment of CRBSI

The management of CRBSI is contingent upon the specific type of catheter and the patient's underlying disease. In some cases, CRBSI is often managed by first removing the catheter; nevertheless, this decision depends on the accessibility of other access (Chen, 2015). Subsequently, practitioners have the option to prescribe antibiotics or, in simple instances, refrain from antibiotic treatment (Yan et al., 2022). Importantly, the selection of the antibiotic should be based on the most probable microorganism that is expected to be present.

Yan et al. (2022) recommend that vancomycin should be taken into consideration if there is suspicion of the presence of coagulase-negative staphylococci. In addition, it is recommended to provide initial antibiotic treatment, such as aminoglycoside or cephalosporin, in order to combat gram-negative pathogenic organisms (Chaves et al., 2018). Moreover, for Candida albicans infection, clinicians may recommend antifungal medication like fluconazole (Bang et al., 2023). Notably, Methicillin-resistant Staphylococcus aureus (MRSA), Vancomycin-intermediate Staphylococcus aureus (VISA), and Vancomycin-resistant Staphylococcus aureus (VRSA) are distinct strains of Staphylococcus bacteria that have acquired resistance to antimicrobial drugs including oxacillin, methicillin, penicillin, and vancomycin (Yan et al., 2022; Chaves et al., 2018). Optimal antimicrobial treatments should be customized based on the specific microorganism detected and its susceptibility to the drugs (Bang et al., 2023).

The choice of antimicrobial therapy and its length will be selected according to the kind of catheter and the specific organisms discovered in the cultures. It is advisable to consult with infectious diseases doctors when *Staphylococcus aureus*, Enterococcus spp., *Pseudomonas aeruginosa*, multi-drug-resistant organisms, or Candida spp. are the causal pathogens of a CRBSI (Bang et al., 2023; Chaves et al., 2018).

Antibiotic lock therapy may be used to treat infected catheters that do not exhibit indications of infection at the exit site or tunnel, with the intention of salvaging the catheter (Canton & Garnacho, 2019; Almeida et al., 2022). Patients presenting with numerous positive catheter blood cultures that yield CNS (coagulase-negative staphylococci) and simultaneously a negative result peripheral blood cultures may receive antibiotic lock treatment for a duration of 10–14 days without the need for systemic medication (Chaves et al., 2018). For all other cases, antibiotic locks should not be used as a standalone treatment. Instead, they should be used along with systemic antimicrobial medication, both of which should be delivered for a period of 7–14 days (Chaves et al., 2018). For cases of CRBSI caused by *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and Candida species, it is very advisable to remove the catheter rather than using antibiotic lock therapy and keeping the catheter in place.

Consequences of Untreated CRBSI

The consequences of sepsis are the same regardless of its origin, whether it is a surgical wound, a collection of pus, inflammation of the abdominal lining, or a medical device such as a catheter. When an infectious organism invades the bloodstream, it releases several substances in the body. Invading bacterial and fungal cell walls contain endotoxins, including lipopolysaccharide, which stimulate macrophages and other host blood cells. (Abd El-Hamid El-Kady et al., 2021). Furthermore, in the absence of intervention, if the patient progresses to this level, there are few options available for treatment. In reality, a significant malfunction of several organ systems occurs, which is then followed by the failure of multiple organ systems and ultimately leads to death.

Factors Influencing the Risk of CRBSI

Microbial exposure to the CVC eventually causes a catheter-associated infection. The next section extensively addresses the specific bacteria and yeasts responsible for CVC colonization. Thus, it is crucial to emphasize the conditions that might contribute to the colonization and infection of a CVC by microorganisms. The following sections will discuss these aspects:

Underlying Health Status

Sato et al.'s (2017) observation indicates that the likelihood of catheter colonization, which may result in infection and eventually CRBSI, is elevated in certain categories of patients who are hospitalized. Consequently, patients who have weakened immune systems, such as those with AIDS or neutropenia, underlying diseases, higher APACHE II (Acute Physiology and Chronic Health Evaluation II) scores, SOFA (Sequential Organ Failure Assessment) scores, active neoplasia, and advanced age, are more likely to experience CRBSI (Singer et al., 2016; van Vught et al., 2016).

Moreover, the hospital setting can increase the patient's vulnerability to colonization and sickness due to the microbial surroundings in which they are cared for. In addition, the hospital setting may serve as reservoir for bacteria, particularly MRSA (Methicillin-resistant Staphylococcus aureus) and other antibiotic-resistant isolates (Singer et al., 2016). Nosocomial infections, often known as infections acquired in hospitals, have become a growing issue.

Catheter Insertion

Inserting a central venous catheter in the femoral vein or the internal jugular vein may lead to a greater incidence of CRBSI (Ray-Barruel et al., 2019). Recently, it has been discovered that the internal jugular (IJ) and subclavian (SC) insertion sites are safer than the femoral (FEM) site in terms of both CLABSIs and catheter colonization (Pitiriga et al., 2020). Furthermore, according to IDSA (Infectious Diseases Society of America) guidelines, the subclavian vein is the preferred location for catheterization, after which are the femoral vein and internal jugular vein. (Chen, 2015).

It’s worth noting that the proficiency of the individual doing the CVC insertion is crucial, and research has shown that when performed by a highly skilled team, it may result in enhanced care for the catheter site (María et al., 2021). In general, CVCs are placed by anesthetists, surgeons, or interventional radiologists, whereas PICCs may be inserted by any of these professionals as well as clinical nurse specialists (Pitiriga et al., 2022). Furthermore, healthcare professionals must thoroughly clean the insertion site and conduct the process in a sterile environment. It is for this reason that long-term tunneled catheters are mounted in the operating room. However, healthcare providers often place several short-term CVCs directly at the patient's bedside inside the hospital’s ward. Thus, performing a catheter insertion operation in such nonsterile setting would heighten the likelihood of exposing the central venous catheter and patient to a possibly harmful microorganism (Ray-Barruel et al., 2019).

Duration of Catheterization

Some researchers hypothesize that the extended duration of catheterization is associated with an upsurge in CRBSI (Peng & Lu, 2013). Therefore, several medical professionals advise regular replacement of CVCs; however, there is no evidence to support that this practice decreases the incidence of CRBSI (Zhang et al., 2018; Chen, 2015). Furthermore, there is disagreement over whether the risk of infection per catheter per day upsurges with the length of time the catheter is in place. The Centers for Disease Control and Prevention recommends expressing the incidence of CRBSI per 1000 catheter days of catheterization due to the disparity in catheter-residence time (Zhang et al., 2018).

Post-Insertion Care

Stringent aseptic protocols are required for insertion and subsequent management of central venous catheters. Through the implementation of maximum sterile barrier protocols during the insertion process, Htay & Johnson (2019) effectively decreased the likelihood of subsequent infections linked with catheters. The selection of dressing applied to the CVC post-insertion is crucial.

For optimal results, the dressing should be permeable to water, since dressings that retain moisture tend to have elevated levels of microflora (Htay & Johnson, 2019). In their study, Almalki et al. (2023) discovered that gauze had a low level of colonization on the skin. However, they did not see any difference in colonization between catheters and CRBSI.

Pathogenesis of Catheter-Associated Infection

There is still much to learn about the complicated pathogenesis of infections linked to catheter use. However, it is well acknowledged that in order for microbes to cause catheter-associated infections, they must initially enter the internal and/or exterior lumens of the catheter, where they may stick to and then colonize (Ahmed et al., 2020).

According to Schritt & Voß (2023), the attachment of microbes to the external part of the catheter is influenced by the catheter's physical properties, the distinctive traits of the bacteria that adhere to it, the presence of proteins from the host, and changes in the behavior of the attaching bacteria. The subsequent section will elaborate on the mechanisms through which various microorganisms infiltrate CVCs, the microorganisms implicated in catheter-associated infections, and the consequential effects on catheter colonization and catheter-associated diseases.

Microorganisms Implicated in Catheter-Associated Infections

Pinto et al. (2022) conducted a study to identify the specific microorganisms responsible for CRBSI. The findings of the study showed that coagulase-negative staphylococci (CNS) were the primary causative agents of CRBSI, followed by *Staphylococcus aureus*. Moreover, several investigations have consistently shown that *S. aureus* and CNS, specifically *Staphylococcus epidermidis*, are the predominant pathogens responsible for infections linked to various kinds of implanted medical devices (Peace, 2011; Doski, 2023). Table 2.1 lists the microorganisms (namely bacteria and fungi) that are mostly linked to CRBSI.

Table 2.1

Microorganisms associated with CRBSI

Bacteria	**Fungi**
Staphylococcus aureus	*Candida albicans*
Staphylococcus epidermidis	*Candida parapsilosis*
Enterococcus faecalis	*Candida glabrata*
Proteus mirabilis	*Candida tropicalis*
Staphylococcus haemolyticus	
Klebsiell pneumoniae	

Table 2.1 (continued)

Enterobacter species
Acinetobacter baumannii
Klebsiella oxytoca
Enterococcus species
Acinetobacter spp.
Providencia stuartii
Corynebacterium
Fusobacterium
Gemella morbillorum
Serratia marcescens
Enterobacter cloacae
Escherichia coli
Pseudomonas aeruginosa

Source: (Peace, 2011; Doski, 2023; Pinto et al.; 2022)

Staphylococcus Species

Coagulase-negative staphylococci are a significant constituent of the indigenous surface microbiota of the human body. A considerable number of investigations have reported the isolation of coagulase-negative staphylococci, specifically *Staphylococcus epidermidis*, from intravascular devices (Drugeon et al., 2023). Conversely, *Staphylococcus aureus* is a coagulase-positive staphylococcus whose role as a pathogen in humans is well documented (Pinto et al., 2022).

For many years, *Staphylococcus aureus* infections have been a leading cause of illness and death in hospitals among patients with CRBSI. According to Durgeon et al. (2023) research, Staphylococci were found to be the cause of 90% of infections, with *Staphylococcus aureus* being responsible for 75% of the Staphylococci-related infections. Additionally, another study found that *Staphylococcus aureus* and coagulase-negative *Staphylococcus epidermidis* accounted for 24.1% and 36.2% of CRBSIs, respectively, with Staphylococci being the most common causative agent at 62.0% (Pinto et al., 2022).

Klebsiella

Klebsiella often resides in the human gut without causing any illness, and it is also present in human feces (CDC, 2011a). Moreover, Klebsiella is among a group of Gram-negative bacteria that may cause infections in the bloodstream and other parts of the human body. It is important to note that Klebsiella bacteria are becoming more resistant to carbapenemase (KPC) and extended-spectrum β-lactamases (ESBL). According to the CDC (2011a), people who have medical devices such as ventilators and CVCs and who undergo extended antibiotic treatments are at a higher susceptibility to Klebsiella infections.

Candida

The species of candida are ubiquitous yeasts present throughout the whole of the gastrointestinal system of human. Candida species account for a minimum of 9% of bloodstream infections acquired in hospitals, and the occurrence of Candida fungaemia poses a significant challenge in this medical situation (Phua et al., 2019). In addition, fungal infections provide significant challenges in terms of therapy since the available therapies, such as amphotericin B, may have a high level of toxicity for the patient (Duzgol et al., 2021). Moreover, Candida species often cause bloodstream infections, particularly in individuals with impaired immune systems, in hospital settings.

Notably, *Candida parapsilosis* and *Candida glabrata* were responsible for 6.8% of catheter-related bloodstream infections (CRBSIs), which is consistent with the well-established link between candidemia and catheterization (Chen, 2015; Zhang et al., 2018; Pinto et al., 2022). This finding is particularly significant given the recent outbreaks of *Candida auris* in healthcare facilities.

Modes of Colonization

There are five primary pathways by which microorganisms might enter the catheter and establish a colony. Table 2.2 displays the definitions of these five mechanisms.

Table 2.2

The Path the Microbe Takes to Colonize CVC and The Standards That Are Used

Mechanism	**Underlying Criteria**
Intraluminal spread	The interior of the CVCs and the hub are colonized. Furthermore, the identical organism is isolated from both the hub and the tip, as well as from a blood culture. Additionally, there is a skin culture that is negative for that organism.
Extraluminal spread	Blood, the tip, the skin, and the subcutaneous segment are all found to contain the same organism. A negative hub culture exists.
Haematogenous seeding	From a blood culture, the hub, and the tip, the same organism is recovered.

Table 2.2 (continued)

Contamination of infusion fluid	Blood, the hub, the tip, and the TPN are all found to contain the same organism. There is a skin culture that is negative.
Contamination of the tip on insertion	The tip of the catheter is already contaminated before being inserted on the patient. When the tip of the catheter is culture is shows positive.

Source: (Ahmed et al., 2020; Schritt & Voß, 2023)

The CDC states that the routes via which pathogens may cause central line-associated bloodstream infections (CLABSI) are either extraluminal or intraluminal. Whereas extraluminal refers to the movement of pathogens over the catheter external surface, often occurring within seven` days following catheter implantation, and intraluminal refers to the movement of pathogens along the catheter's inner surface, which occurs after seven days following catheter implantation (Pitiriga et al., 2022).

Biofilms

Microorganisms adhere in a thin layer to the surface of either organic or inorganic materials to form biofilms., along with the polymers they release (Pitiriga et al., 2020). Microorganisms often do not live as individual entities but rather form biofilms, which increase their resistance to antimicrobial agents and frequently lead to recurring infections (Almeida et al., 2022). Consequently, the formation of fully developed biofilms in human hosts via medical devices like CVCs may lead to infections that are resistant to antibiotics, hinder the host's immune response, and contribute to the development of a long-lasting illness (Bryers, 2008). In addition, microorganisms on the surface catheter may be seen developing in one of two distinct habitats, similar to other biofilm structures (Burmølle et al., 2014). The "sessile bacteria" multiply on the surface of the catheter inside a biofilm, while the "planktonic bacteria" grow unrestrictedly in the surrounding fluids, dwelling at the boundary between the biofilm and the fluid.

Measures to Reduce the Rates of CRBSI

Several advancements in clinical practice are now under investigation, with the potential to reduce infection rates in patients using catheters. These enhancements include advancements in the methods of inserting catheters, improved aseptic practices, alterations to the catheter hubs, and the implementation of intravenous treatment teams (Whitfield, 2019; Bell & O'Grady, 2017; Masuyama et al., 2021).

Protocols for avoiding infections related to the maintenance and insertion of central venous catheters have been developed. The details may be found in Table 2.3 and were created by a team of healthcare professionals, including infection control practitioners, clinical microbiologists, researchers, and other professionals. These instructions include procedures ranging from the selection of catheters to the methods used for replacing and removing them.

Table 2.3

Guidelines for Preventing CRBSI

Intervention	**Guidelines associated with intervention**
Choice of catheter type	a) If numerous lumens are not necessary for patient care, use a single-lumen catheter.
	b) Only use one lumen at a time to administer TPN.
	c) Use an implanted or tunneled VAD if a catheterization is expected to last more than 30 days.
	d) If an adult patient is at high risk of developing CRBSI and needs a short-term central venous catheterization (less than 10 days), take into consideration using antimicrobial-impregnated catheters.
Choosing the site for catheter insertion	e) Compare the risks of a mechanical problem with the risk of infection.
	f) For non-tunneled catheter implantation, wherever feasible, utilize the subclavian site rather than the jugular or femoral sites.
	g) Take into account using PICCs as an alternative for jugular vein or subclavian catheter implantations.

Table 2.3 (continued)

Optimal aseptic procedure for catheter insertion	a) Use the best aseptic procedure possible for inserting CVCs, including gloves, a sterile gown, and a sterile drape.
Cutaneous antisepsis	b) Cleanse the skin location with an alcoholic chlorhexidine gluconate solution and let it dry before inserting the CVC. When treating individuals who are known to be allergic to chlorhexidine, use an alcoholic povidone-iodine solution.
	c) Avoid using antibacterial ointment or organic solvents (ether or acetone) on the skin before inserting a catheter.
Catheter and catheter site maintenance	d) Unless the manufacturer instructs otherwise, sterilize the hub of the catheter and connecting ports' external surfaces using a water-based solution containing chlorhexidine gluconate or alcohol before gaining access to the system.
	e) Apply sterile gauze or a transparent bandage to the catheter site. When a catheter site dressing consisting of gauze and tape becomes contaminated, wet, or when an examination of the insertion site is required, it is imperative to replace the dressing.
	f) Avoid using antimicrobial ointment as a regular catheter site care procedure on CVC insertion sites.
	g) Use an anticoagulant to routinely flush indwelling CVCs unless the manufacturer instructs otherwise.

Table 2.3 (continued)

Methods of replacement	a) As a preventative measure against catheter-related infections, do not frequently replace non-tunneled CVCs.
	b) If there's no indications of infection at the catheter's site, replace a faulty catheter using the GWX procedure. The catheter should be withdrawn and replaced at a different location if a subsequent catheter-associated infection is found.
	c) For patients with CRI, avoid using GWX. If a new catheter is needed, it should be inserted at a different location and the old one should be withdrawn.
	d) Replace all intravenous tubing when the CVC is changed; if not, replace it every 24 hours. If intravenous tube is used to provide blood, lip emulsions or blood products, replace it every 72 hours.
Antibiotic prophylaxis	e) In order to avoid catheter colonization, avoid regularly giving systemic antibiotics before to or during the use of CVC.

Source: (Almalki et al., 2023; Johnson & Grossman, 2013; Htay & Johnson, 2019)

Insertion Technique

Implementing rigorous aseptic measures during the insertion of a CVC can decrease the occurrence of catheter-related bloodstream infections (Bell & O'Grady, 2017; Sumrall, 2022). It is advised that the surgeon utilize a cap, sterile gown, sterile gloves, mask, and a large sterile drape when inserting all CVCs. According to Chittick and Sherertz (2010), since the skin is where many of the microbes linked to CRBSI come from, it is important to use an antiseptic or disinfectant solution to get rid of these microbes and lower the risk of contamination during insertion.

In a 900-bed hospital in the Midwest, Duncan et al. (2017) carried out a quasi-experimental quality improvement study. The purpose was to investigate the compliance rates of a PIV maintenance bundle that included disinfection caps and tips. The goal was to determine whether implementing this bundle would result in a reduction in PLABSI rates. The findings revealed a 90% adherence rate when using disinfection caps and tips, and the use of a PLABSI bundle effectively reduced the incidence of primary bloodstream infections.

Mimoz et al. (2007) examined the effectiveness of chlorhexidine-based solutions as a skin cleansing agent prior to inserting CVCs, as compared to povidone-iodine or alcohol-based preparations, with the aim of minimizing skin contamination during insertion. Mimoz et al. documented a 50% reduction in catheter colonization with the use of chlorhexidine solutions. Their research indicates a 95% confidence interval and an adjusted relative risk of 2.01. The use of povidone iodine solution yielded an adjusted relative risk of 1.87, accompanied by a 95% confidence interval and a reduction of 22.2%.

Therapy Teams

Research has shown that employing highly skilled personnel, specifically educated in the placement and upkeep of VADs inside the hospital, may result in a significant improvement in the management of catheter sites (Sumrall, 2022; McCauley, 2010). The study conducted by Peace (2011) revealed that treatments, including educational awareness, are considered the main approach for reducing CLABSI. In addition, evidence-based medical procedures and treatments tend to be very effective, particularly when performed within a medically diverse group of practitioners, such as a physician's office, surgical suite, or critical care unit in a hospital environment (Devries, 2016; Duncan et al., 2017).

Nearly two decades ago, Ranji (2007) found out that active educational interventions seem to be the most successful in lowering the risk of CLABSI. These educational interventions include the use of web-based and video lessons that specifically direct the clinician's attention towards preventative techniques and provide guidance on how to better comply with such interventions. Their investigation was conducted using two controlled before-and-after studies. These studies included educational interventions and checklists to facilitate healthcare professionals' compliance with catheter insertion and care protocols (Ranji, 2007).

Devries (2016) conducted a study on a 625-bed community hospital in Indiana. The study focused on the collaboration between infection control and nursing to establish a policy, an insertion bundle, and a maintenance bundle. The aim was to enable an extended dwell time for IV catheters, specifically from 72 to 96 hours, without increasing the likelihood of bloodstream infections. The researchers carried out a prospective, observational study in which they observed existing behaviors directly and then evaluated evidence-based recommendations. Following a duration of 12 months, the organization recorded a noteworthy decrease of 37% in CLABSIs and a 19% decrease in PLABSIS. The authors' conclusion is that implementing a well-designed strategy for inserting and maintaining instructional and insertion bundles might lead to a reduction in bloodstream infections and related expenses.

Diagnosis of Catheter-Associated Infections

When is it appropriate to suspect CRBSI?

Patients having IV catheter and presenting with chills, fever or other indications of sepsis should be considered potential cases of CRBSI, despite the absence of apparent signs of infection at the catheter site (Chaves et al., 2018). It is particularly important when no other possible source of infection has been detected. In addition, patients with IV catheters who develop disseminated infections due to the spread of pathogens via the bloodstream should also be strongly considered for the presence of CRBSI (Canton-Bulnes & Garnacho-Montero, 2019; Bang et al., 2023).

Furthermore, if patients with intravenous catheters have recurring or persistent bloodstream infection caused by bacteria that have a tendency to infect or colonize the skin, it should raise concern about CRBSI (Bang et al., 2023). Thus, when a patient does not show any clinical signs or symptoms of infection, blood cultures have limited usefulness and may raise the chance of administering improper therapy for contaminants found in the blood culture.

Conservative Diagnosis - Diagnosis performed without removing the catheter:

In order to maintain the accuracy of blood cultures, it is important to collect them before starting antibiotic treatment, unless the patient is in an unstable or critical condition. In such cases, healthcare providers must initiate antimicrobial therapy immediately, regardless of whether blood cultures have been obtained (Bang et al., 2023). Additionally, when taking blood samples from the skin, it is important to prepare the skin using appropriate measures. Ensuring enough time is allocated for the process and allowing sufficient time for the disinfectant to work effectively are important measures to prepare the skin. Low levels of contamination are linked to products containing alcohol.

It was found that alcohol chlorhexidine solutions work better than water-based povidone-iodine at keeping blood cultures clean (Chaves et al., 2018). Furthermore, individuals suspected to have CRBSI, two sets of blood cultures should be collected. One set of blood should be collected from a vein in the arm (or peripheral vein), while the second set should be drawn from the catheter itself (Chaves et al., 2018). In the case of multiple-lumen venous catheters, it is necessary to collect blood culture samples from each individual lumen.

CRBSI Diagnosis by Catheter Removal

Catheter cultures should be collected only in cases where there is suspicion of a catheter-related bloodstream infection. Significantly, the most dependable diagnostic procedures for catheter culture techniques are quantitative (vortex or sonication methods) and semi-quantitative (roll plate).

In addition, qualitative cultures, namely the culture of the catheter tip by broth immersion, lack reliability in differentiating between contamination and infection. As a result, they are not appropriate for diagnosing CRBSI (Chaves et al., 2018; Bang et al., 2023).

CRBSI Diagnosis Interpretation

A CRBSI is confirmed when two samples of blood are obtained, one from the central venous catheter and one from a peripheral location, both show the growth of the same microorganism with a substantial difference in time to positivity (DTTP) (Chaves et al., 2018). Chaves et al. further noted that when it is not possible to collect a peripheral blood culture, diagnosis may be established by identifying the presence of the same organism in two or more lumens of a CVC. Moreover, if a catheter is present and there is at least one positive culture showing microorganism growth from any of the site, along with clinical indications of illness and no other identifiable cause for the infection, CRBSI is suspected.

At times, blood cultures that test positive for skin flora might indicate a genuine illness. When repeated positive blood cultures from various places show the growth of the same organism, it is important to evaluate the possibility of a genuine infection, even if the microorganism is often regarded as a commensal microorganism (Bang et al., 2023). If a blood culture from both the catheter and peripheral site shows the growth of coagulase-negative staphylococci and the patient is experiencing clinical symptoms that suggest a probable CRBSI, then treatment for the infection is necessary (Canton-Bulnes & Garnacho-Montero, 2019). Therefore, patients with CRBSI accompanied by endocarditis, septic metastasis, septic shock, suppurative thrombophlebitis, non-resolving CRBSI, extraluminal infections, and immunocompromised status should be categorized as having complicated CRBSI.

CHAPTER III

Methodology

This chapter provides a detailed explanation of the research design, the process of selecting participants, the materials used for data collection, the processes followed for data collection, and the plans for data analysis. In addition, the study also addresses ethical and practical considerations, as well as the validity and dependability of the research.

Study Design

This study was a retrospective investigation conducted in the ICUs at the NEU Hospital, namely the coronary care ICU, cardiovascular ICU, and general ICU. NEU Hospital is one of the most prominent and largest medical facilities in, Northern Cyprus. The hospital maintains an affiliation with the Near East University Faculty of Medicine. Comprising 209 private patient rooms, eight operating theaters, a 30-bed Intensive Care Unit, a 17-bed Neonatal Intensive Care Unit, laboratories, and a cutting-edge diagnostic imaging center, the NEU Hospital encompasses a total area of 55,000 square meters. A specialized "International Patient Coordination Center" has been established at the NEU Hospital in order to accommodate the varied requirements of patients traveling from overseas (Home-page - Near East University Hospital, 2023; Near East University Hospital - Wikipedia, 2023). This study investigated the medical records of patients admitted to the ICUs who had central venous catheter insertions over the preceding two-year period (2022–2023). This study investigated the incidence density or rate of CRBSI, together with the microorganisms associated with CRBSI.

Participants

The only participants in this research were adult patients who were at least 18 years old, had been hospitalized in the ICUs during the study period (2022–2023), and had a central venous catheter inserted upon admission.

Data Collection Tools/Materials

The process of collecting data included analyzing medical records that were accessible via the electronic information system of the NEU Hospital. Additionally, data was collected on patient demographics, underlying medical conditions, the kind and site of catheter insertion, the duration of catheterization, and any recorded cases of catheter-related bloodstream infections (CRBSIs).

Data Collection Procedures

Cultures of blood were taken from the central veins of the patient whenever a CRBSI was believed to be present. Additionally, healthcare professionals collected blood samples using aseptic procedures and transferred them to the specialized microbiology laboratory using proper blood culture vials. The blood culture bottles were incubated for a minimum of five days in an automated blood culture system, such as the BACTEC or BacT/ALERT system, at the microbiology laboratory. The purpose of this step was to identify any bacterial or fungal growth that may have occurred. The organisms that were responsible for the infection were isolated by sub-culturing positive blood cultures on the appropriate solid agar medium. These media included blood agar, Sabouraud dextrose agar. MacConkey agar

Furthermore, the organisms that were isolated were evaluated using conventional microbiological methods, such as Gram staining and other biochemical assays that are associated with it. The European Committee on Antimicrobial Susceptibility Testing (EUCAST) guidelines 2023 were adhered to when conducting the antibiotic susceptibility test, which involved the utilization of an automated apparatus, such as the VITEK 2, and the Kirby-Bauer disk diffusion method.

Data Analysis Procedure

Descriptive statistics were used to summarize the patient demographics and any other pertinent factors. The incidence density or rate of CRBSIS was calculated by dividing the number of CRBSI by the total number of CVC days multiply by 1000. In addition, the standardized infection ratio (SIR) was calculated as follows:

SIR was obtained by dividing the number of observed CRBSIs by the number of predicted or threshold value of CRBSI. This was done in order to assess the major outcome measure included in this investigation. The SPSS application was used in order to carry out the analysis of the data.

Ethical Approval

The study was approved by the Near East University Ethics Review Board (project number: NEU/2023/115-1728).

CHAPTER IV

Results

This chapter will begin by providing sample demographic data in order to analyze the composition and representativeness of the data. Subsequently, the study aims and research questions will be evaluated by examining the rate or incidence density, the standardized infection ratio (SIR), and the causal microorganisms. 1. What is the prevalence of catheter-related bloodstream infections in the coronary, cardiovascular, and general intensive care units at the Near East University Hospital during 2022-2023? 2. Which microbes caused bloodstream infections associated with central venous catheter use in the cardiovascular, general, and coronary critical care units at the Near East University Hospital during 2022-2023?

Of the patients who underwent central venous catheter (CVC) installation at the NEU Hospital's Coronary, Cardiovascular Surgery, and General Intensive Care Units throughout the research period (2022–2023), 48 developed CRBSIs. The patients' age distribution had a mean of 72, a minimum of 40, a maximum of 89, and a standard deviation of 11.18. Among the 48 patients, there were 29 males, accounting for 60.4% of the total, and 19 females, representing 39.6%. According to the annual distribution of CRBSI cases, there were 25 cases, representing 52.1%, diagnosed in 2022 (January–December), and 23 cases (47.9%) confirmed in 2023 (January–December). The General Intensive Care Unit (GICU) had the highest number of occurrences of CRBSI, accounting for 72.9% (35 out of 48 cases). The Coronary Intensive Care Unit (CICU) had 27.0% (13 out of 48 cases), while the Cardiovascular Surgery Intensive Care Unit (CVSICU) had 0% of the total CRBSI cases (Table 4.1)

43 out of 48 individuals diagnosed with CRBSIs tested positive for one or more of the following: 12 patients, accounting for 25% of the total, had elevated levels of C-reactive protein (CRP+). Additionally, 12 patients, also representing 25%, had elevated levels of both C-reactive protein (CRP+) and procalcitonin (PCT+).

Furthermore, seven patients, making up 14.6%, had elevated levels of both C-reactive protein (CRP+) and white blood cells (WBC+). Additionally, six patients, accounting for 12.5%, tested positive for elevated levels of all the three laboratory findings: white blood cells (WBC), procalcitonin (PCT), and C-reactive protein (CRP). Out of the total number of patients, four individuals, accounting for 8.3% of the sample, tested positive for white blood cells (WBC+). Two out of the total, accounting for 4.2%, tested positive for PCT. Among the 48 patients, five individuals, accounting for 10.4% of the total, did not exhibit any of the identified laboratory findings (Table 4.1).

Table 4.1

Demographic Characteristics and Distribution of Patient with CRBSIS

	No. CRBSI (n = 48)
Age	Mean: 72; ±:11.176; Med 74 (Max 89, Min)40
Male	29(60.4%)
Female	19(39.6%)
Yearly Distribution	
2022	25(52.1%)
2023	23(47.9%)
ICU Distribution	
CICU	13(27.1%)
CVSICU	0(0%)
GICU	35(72.9%)

Table 4.1 (continued)

Laboratory findings	
CRP +	12(25%)
WBC +	4(8.3%)
PCT +	2(4.2%)
CRP +, PCT +	12(25%
CRP +, WBC +	7(14.6%)
WBC + , CRP +, PCT +	6(12.5%)
Negative CRP, PCT, WBC +	5(10.4%)

Note. Standard Deviation: ±

During the research period, there were a total of 48 cases of CRBSIs observed, with a cumulative duration of 2817 CVC days. This resulted in an overall incidence density or rate of CRBSIs of 17.0 per 1000 catheter days. According to the annual CRBSI rate distribution, there were 25 CRBSIs in 2022, for a total of 1319 CVC days. This resulted in an incidence density, or CRBSI rate, of 18.9 per 1000 catheter days. In 2023, there were 23 cases of CRBSI recorded. The total number of CVC days was 1418, resulting in a CRBSI rate of 15.5 per 1000 catheter days. The General Intensive Care Unit (GICU) had a CRBSI rate of 30.2 per 1000 catheter days, with a total of 35 CRBSI cases and 1159 CVC days. The Coronary Intensive Care Unit (CICU) had a CRBSI rate of 9.5 per 1000 catheter days, with a total of 13 CRBSIs and 1362 CVC-days. The Cardiovascular Surgery Intensive Care Unit (CVSICU) achieved zero CRBSI out of a total of 296 CVC days, resulting in a CRBSI rate of 0.0 per 1000 catheter days (Table 4.2).

Table 4.2

Incidence Density of CRBSIs

	No. CRBSI	NO. OF CVC days	Incidence density per 1000 catheter days
Yearly Distribution			
2022	25	1319	18.9
2023	23	1498	15.5
Over all	48	2817	17.0
ICU Distribution			
CICU	13	1362	9.5
CVSICU	0	296	0.0
GICU	35	1159	30.2
Over all	48	2817	17.0

The Standardized Infection Ratio (SIR) for cases of Central Line-Associated Bloodstream Infections (CRBSIs) is as follows: The overall SIR for CRBSI cases was 9.6, with a total of 48 observed cases. In 2022, the accumulated SIR was 5.0, followed by a SIR of 4.6 in 2023. When examining the SIR of CRBSI cases in different Intensive Care Units (ICUs), the General Intensive Care Unit had a SIR of 7.0, the Coronary Intensive Care Unit had a SIR of 2.6, and the Cardiovascular Surgery Intensive Care Unit had a SIR of 0.0 (Table 4.3).

Table 4.3

Standardized Infection Ratio (SIR) of the CRBSIs Cases

	Observed number of infections	**Predicted number of infections**	**Standardized infection ratio (SIR)**
Yearly Distribution			
2022	25	5	5.0
2023	23	5	4.6
Over all	48	5	9.6
ICU Distribution			
CICU	13	5	2.6
CVSICU	0	5	0.0
GICU	35	5	7.0
OVERALL	48	5	9.6

The distribution of several isolates (microorganisms) obtained from the CRBSI patients. Out of the 48 patients that had CRBSI, 49 bacterial isolates were obtained by culturing. There were a total of 26 gram-negative bacteria, which accounted for 53.1% of the 49 bacterial isolates. *Klebsiella pneumoniae* was the predominant causative agent among the gram-negative bacteria, accounting for 32.7% (16/49) of cases. *Proteus mirabilis*, on the other hand, represented 8.2% with four isolates. There were two isolates of *Acinobacter baumannii* and two isolates of *Enterobacter cloacae*, which together accounted for 4.1% of the isolates, respectively. *Escherichia coli* and *Pseudomonas aeruginosa* were the least common gram-negative bacteria, with each species representing 2.0%. There were a total of 23 gram-positive isolates, which accounted for 46.9% of the 49 bacterial isolates (Table 4.4).

Within the gram-positive isolates, *Staphylococcus epidermidis* was the predominant species, accounting for ten isolates, or 20.0% of the total. This was followed by *Staphylococcus haemolyticus*, which accounted for seven isolates, or 14.3%. Two isolates each of *Staphylococcus aureus* and *Staphyococcus hominis* comprise 4.1%, respectively. *Enterococcus faecalis* and *Kocuria kristinae* each account for 2.0% (1/49) of the total (Table 4.4).

Table 4.4

Distribution of Various Bacteria Isolates (n=49)

Pathogen	**No. (%)**
Gram-negative bacteria	26 (53.1)
Klebsiella pneumoniae	16 (32.7)
Proteus mirabilis	4 (8.2)
Acinobacter baumannii	2 (4.1)
Enterobacter cloacae	2 (4.1)
Escherichia coli	1 (2.0)
Pseudomonas aeruginosa	1 (2.0)
Gram-positive bacteria	23 (46.9)
Staphylococcus epidermidis	10 (20.4)
Staphylococcus haemolyticus	1 (14.3)
Staphylococcus aureus	2 (4.1)
Staphylococcus hominis	2 (4.1)
Enterococcus faecalis	1 (2.0)
Kocuria kristinae	1 (2.0)
Overall	49 (100)

The distribution of Methicillin-Resistant Staphylococcus (MRS +) and extended-spectrum beta-lactamase positive (ESBL +) isolates: Sixteen out of the 49 isolates obtained from patients with CRBSI tested positive for ESBL. Among these, 12 isolates were identified as *Klebsiella pneumoniae*, followed by three isolates of *Proteus mairablis* and one strain of *Escherichia coli*. Out of the 17 MRS-positive isolates, ten were from *Staphylococcus epidermidis*. These were followed by five from *Staphylococcus haemolyticus* and two from *Stayphylococcus hominis* (Table 4.5)

Table 4.5

Distribution of ESBL Positive and Methicillin-Resistant Staphylococcus Positive Isolates

	No.
ESBL +	16
Proteus mirabilis	3
Klebsiella pneumonia	12
Escherichia coli	1
MRS +	17
Staphylococcus haemolyticus	5
Staphylococcus hominis	2
Staphylococcus epidermidis	10

CHAPTER V

Discussion

The primary objectives of this study were to investigate the rate of bloodstream infections associated with central venous catheters and to identify the specific microorganisms responsible for these infections at the Near East University Hospital during 2022-2023. The study aimed to answer the following questions: 1. What is the incidence density or rate of catheter-related bloodstream infections in the coronary, cardiovascular, and general intensive care units at the Near East University Hospital during 2022-2023? 2. Which microorganisms caused catheter-related bloodstream infections in the coronary, cardiovascular, and general intensive care units at the Near East University Hospital during 2022-2023?

Key Findings

The overall incidence density or rate of CRBSI was 17.0 per 1000 catheter days, based on a total of 2817 CVC days and 48 CRBSI cases. It's worth noting that in 2022, the highest rate of CRBSI cases was recorded, with a rate of 18.9 per 1000 catheter days. This was based on 1319 CVC days and 25 CRBSI episodes. However, in 2023, the incidence density decreased to 15.5 per 1000 catheter days, for a total of 1498 CVC days, resulting in 23 CRBSI. Furthermore, the incidence density or rate of CRBSI per intensive care unit reveals that the GICU unit had the highest incidence density, with a rate of 30.2 per 1000 catheter days. whereas the CICU follows with a rate of 9.5 per 1000 catheter days. Interestingly, the CVSICU had the lowest rate of 0.0 per 1000 catheter days among all units in terms of overall incidence density. In addition, out of the total of 48 CRBSI cases, the GICU accounted for a significant percentage of CRBSI cases, namely 72.9% (35/48). Whereas, the CICU was responsible for 27.1% (13/48), with no occurrences documented in the cardiovascular surgery unit.

Importantly, among the 48 cases with CRBSI, the etiology was identified to be 49 different bacteria isolates. Out of the 49 isolates, gram-negative bacteria were the most common, accounting for 53.1% (26/49). Among the gram-negative isolates, *Klebsiella pneumoniae* was the most prevalent, with 16 out of 49 isolates. *Proteus mirabilis* was the second most common, with four out of 49 isolates. *Acinobacter baumannii* and *Enterobacter cloacae* each had two isolates, while *Escherichia coli* and *Pseudomonas aeruginosa* had one isolate each. Furthermore, gram-positive isolates made up 46.9% (23/49) of the total bacterial isolates. Thus, the most prevalent gram-positive isolates were Staphylococcus species (21/23), with *Staphylococcus epidermidis* being the most common (ten isolates), followed by *Staphylococcus haemolyticus* (seven isolates), *Staphylococcus aureus*, and *Staphylococcus hominis* (two isolates each). Finally, there was one isolate each of *Enterococcus faecalis* and *Kocuria kristinae*.

Discussion/Interpretation of Findings

The Incidence Density or Rate of CRBSI

The total incidence density of catheter-related bloodstream infections (CRBSI) was 17.0 per 1000 catheter days, surpassing the CRBSI rate of 5 per 1000 catheter days reported in the research by Abd El-Hamid El-Kady et al. (2021) and the rate of 3.52 per 1000 catheter days observed in a similar investigation done by Zhang et al. (2023). This study revealed that the highest incidence density or rate of CRBSI was 18.9 per 1000 catheter days in the year 2022. However, in 2023, there was a reduction in the CRBSI rate to 15.5 per 1000 catheter days. The factors that contributed to the higher rate of CRBSI were the age of the patients, elevated levels of CRP, PCT, and WBC, and the type of intensive care unit where the patients were admitted. Recent research conducted by Zhong et al. (2021), Drugeon et al. (2023), and Lu et al. (2020) supports these findings.

In terms of age, the patients had an average age of 72, with the maximum age being 89. This indicates that almost all of the patients were elderly. At this age, the immune system tends to weaken, resulting in a reduced ability to fight infections and longer recovery times. Consequently, the patients experienced increased sick days and longer stays in the ICUs. Regarding the increased levels of C-Reactive Protein (CRP +), Procalcitonin (PCT +), and White Blood Cell (WBC +), 43 out of 48 patients diagnosed with CRBSIs tested positive for at least one of these risk factors, whereas 10% (5/48) did not test positive for any of these risk factors. Furthermore, an elevated level of C-reactive protein (CRP) indicates the presence of inflammation in the body and is also associated with a heightened likelihood of experiencing heart attacks. Similarly, an elevated concentration of procalcitonin in the bloodstream serves as an indication of a severe infection or sepsis.

Likewise, an increased white blood cell count indicates the presence of an infection, an underlying medical condition, or a weakened immune system. These explanations indicate that the majority of CRBSI patients (43 out of 48) were in critical condition, as shown by their high acute physiology and chronic health assessment II (APACHE II) score. This factor contributes to the high incidence density of CRBSI. A multivariate study revealed that the presence of an acute physiology and chronic health assessment II (APACHE II) score resulting from underlying disorders was identified as an independent predictor linked with catheter-related bloodstream infections (Chen, 2015).

In addition, the GICU had a prevalence of 72.09% (35 out of 48) for CRBSI, with a total CRBSI rate of 30.2 per 1000 catheter days and a total of 1159 CVC days. Whereas, the CICU accounted for 27.1% (13 out of 48) of CRBSI cases, with a CRBSI rate of 9.5 per 1000 catheter days and a total of 1362 CVC days. Furthermore, the CVSICU has a 0% (0/48) CRBSI case, with a rate of 0.0 per 1000 catheter days and a total of 296 CVC days. Out of the three ICUs, the GICU had the largest number of CRBSI patients and the highest incidence density. On the other hand, the CICU had fewer CRBSI cases with a lower incidence density, but it had the highest number of CVC days. Notably, the CVSICU documented no cases of CRBSI with the shortest duration of CVC-day and a 0.0 incidence density.

In order to have a better understanding of the incidence density of CRBSI cases, a standardized infection ratio (SIR) was computed. The total standardized infection ratio (SIR) was 9.6. The GICU had a SIR of 7.0, whereas the CICU alone had a SIR of 2.6. The CVSICU had a SIR of 0.0. Note that when the SIR is equal to 1, it means the number of observed infections is equal to the number of expected infections. And when the SIR is below one, it means the actual number of infections is lower than the projected number of infections. Moreover, if the SIR is more than one, it indicates that the actual number of infections exceeds the projected or expected number of infections (the threshold value). The predicted threshold value for CRBSI was five. According to the SIR of the three ICUs, the general and coronary ICUs had a higher number of observed infections compared to the predicted number, which also confirms a high incidence density, especially in the general intensive care units. Whereas the cardiovascular surgical intensive care unit had a lower number of observed infections than the other ICU.

Causal Agent of CRBSI

Forty-nine bacterial isolates were responsible for the occurrence of 48 cases of CRBSI. Among these isolates, gram-negative bacteria were predominant, accounting for 53.1% (26/49). Gram-negative isolates most often found were *Klebsiella pneumoniae* (16/49), then *Proteus mirabilis* (4/49), two of each *Acinetobacter baumannii* and *Enterobacter cloacae*, and one of each *Escherichia coli* and *Pseudomonas aeruginosa*. Zhang et al. (2023) also observed *Klebsiella pneumoniae* as the most common pathogen causing CRBSI (15/82, 16.67%), which aligns with this finding. In contrast to this study, several other studies have reported gram-positive bacteria as the most frequently isolated pathogens in CRBSI cases (Chen, 2015; Abd El-Hamid El-Kady et al., 2021; Sato et al., 2017; Ruiz-Giardin et al., 2019).

CHAPTER VI

Conclusion and Recommendations

This chapter will provide a concise summary of the main research results with regard to the research purpose and research questions, as well as their significance and contribution. It will provide recommendations based on the findings from the research as well as recommendations or prospects for further investigation.

Conclusion

This research sought to examine the incidence rate of catheter-related bloodstream infections in the coronary, cardiovascular surgery, and general critical care units at the Near East University Hospital during 2022-2023. The findings reveal that 48 individuals were diagnosed with CRBSIs, with an average age of 72 and the highest recorded age being 89. Out of the total number of diagnosed patients, 60.4% (29 out of 48) were male. Moreover, out of the three critical care units, the general intensive care units had the highest number of CRBSI cases, accounting for 72.9% (35 out of 48 cases), but no CRBSI cases were reported from the cardiovascular surgery intensive care units.

Furthermore, almost all of the patients (43 out of 48) who were diagnosed with CRBSI were positive for at least one, two, or all three of the following laboratory findings: high levels of C-reactive protein, procalcitonin, and white blood cells. During the study period, the overall rate of catheter-related bloodstream infections was 17.0 per 1000 catheter days. The general intensive care unit had the highest rate of CRBSI, with 30.2 per 1000 catheter days, while the cardiovascular surgery intensive care unit had the lowest rate of 0.0 per 1000 catheter days.

In addition, this research found that a total of 49 bacterial isolates were isolated from 48 cases of CRBSI. Among these isolates, gram-negative bacteria were the most common, accounting for 53.1% (26 out of 49), followed by gram-positive bacteria at 46.9% (23 out of 49). *Klebsiella pneumoniae* was the most prevalent bacterium, followed by *Staphylococcus epidermidis.* Significantly, almost all of the *Klebsiella pneumoniae* tested positive for extended-spectrum beta-lactamases. Additional findings reveal that the overall standardized infection ratio (SIR) for the CRBSI cases was 9.6. The general intensive care unit had the highest SIR, followed by the coronary intensive care unit and the cardiovascular surgical intensive care unit.

Recommendations

The study findings suggest that the hospital should continue to implement control and preventative measures for catheter-related bloodstream infections in the intensive care units. Moreover, elderly individuals who have a central venous catheter should be regarded as being at a heightened risk for catheter-related bloodstream infections. Consequently, they should get increased care and attention. Furthermore, individuals who have a central venous catheter and have an increased level of either C-reactive protein, procalcitonin, or white blood cells should be regarded as being at a heightened risk for catheter-related bloodstream infection. Lastly, in order to effectively provide antibiotic therapy, antibiotic susceptibility tests should be performed for all of the bacteria isolated from patients with CRBSI.

References

Abd El-Hamid El-Kady, R., Waggas, D., & AkL, A. (2021). Microbial Repercussion on Hemodialysis Catheter-Related Bloodstream Infection Outcome: A 2-Year Retrospective Study. *Infection and Drug Resistance, Volume 14*, 4067–4075. https://doi.org/10.2147/idr.s333438

Agency for Healthcare Research and Quality. (2007). Closing the quality gap: A critical analysis of quality improvement strategies. Retrieved August 19, 2010, from shttp://www.ncbi.nlm.nih.gov/bookshelf/br.fcgi?book=techrev9v6

Ahmed, S., khamis, A., Mahdy, A., & Bauiomy, H. (2020). Applying endoluminal catheter colonization surveillance cultures in renal dialysis unit - an effort to reduce CRBSI rate. *Microbes and Infectious Diseases*, *0*(0), 0–0. https://doi.org/10.21608/mid.2020.39751.1052

Almalki, A. I., Alghamdi, H. A., & Tashkandy, N. A. (2023). Assessment of Knowledge, Attitude, and Adherence to National Guidelines for Preventing Central Line-Associated Bloodstream Infections Among ICU Nurses of Adult Patients in Jeddah, Saudi Arabia: A Cross-Sectional Survey. *Cureus*. https://doi.org/10.7759/cureus.42304

Alkubati, S. A., Ahmed, N. T., Mohamed, O. N., Fayed, A. M., & Asfour, H. I. (2018). Health care-associated infections in pediatric cancer patients: Results of a prospective surveillance study from university hospitals in Egypt and Germany. American Journal of Infection Control, 46(5), 547-552.

Almeida, B. M., Moreno, D. H., Vasconcelos, V., & Cacione, D. G. (2022). Interventions for treating catheter-related bloodstream infections in people receiving maintenance haemodialysis. *Cochrane Database of Systematic Reviews*, *2022*(4). https://doi.org/10.1002/14651858.cd013554.pub2

Annetta, M. G., Ostroff, M., Marche, B., Emoli, A., Musarò, A., Celentano, D., Taraschi, C., Dolcetti, L., Greca, A. L., Scoppettuolo, G., & Pittiruti, M. (2021). Chest-to-arm tunneling: A novel technique for medium/long term venous access devices. *The Journal of Vascular Access*, *24*(1), 92–98. https://doi.org/10.1177/11297298211026825

Baang, J. H., Inagaki, K., Nagel, J., Ramani, K., Stillwell, T. L., Mack, M., Wesorick, D., Mack, M., Wesorick, D., & Proudlock, A. (2023). Inpatient Diagnosis and Treatment of Catheter-Related Bloodstream Infection. Michigan Medicine University of Michigan.

Bae, S., Kim, Y., Chang, H. H., Kim, S., Kim, H. J., Jeon, H., Cho, J., Lee, J., Chae, H., Han, G., & Kim, S. W. (2022). The effect of the multimodal intervention including an automatic notification of catheter days on reducing central line-related bloodstream infection: a retrospective, observational, quasi-experimental study. *BMC Infectious Diseases*, *22*(1). https://doi.org/10.1186/s12879-022-07588-9

Bauzá, R. G., Sáez, M. A. O., & Riera, A. M. R. (2019). Peripheral venous catheter-related bloodstream infection: A new quality indicator? Journal of Hospital Infection, 101(2), 175-176.

Bell, T., & O'Grady, N. P. (2017). Prevention of Central Line–Associated Bloodstream Infections. *Infectious Disease Clinics of North America*, *31*(3), 551–559. https://doi.org/10.1016/j.idc.2017.05.007

Blood Stream Infections related to Hemodialysis Catheter Use - ProQuest. (n.d.). https://www.proquest.com/dissertations-theses/blood-stream-infections-related-hemodialysis/docview/2682474343/se-2

Bryers, J. D. (2008). Medical biofilms. *Biotechnology and Bioengineering*, *100*(1), 1–18. https://doi.org/10.1002/bit.21838

Buetti, N., Abbas, M., Pittet, D., Chraiti, M. N., Sauvan, V., De Kraker, M. E. A., Boisson, M., Teixeira, D., Zingg, W., & Harbarth, S. (2022). Lower risk of peripheral venous catheter-related bloodstream infection by hand insertion. *Antimicrobial Resistance & Infection Control*, *11*(1). https://doi.org/10.1186/s13756-022-01117-8

Burmølle, M., Ren, D., Bjarnsholt, T., & Sørensen, S. J. (2014). Interactions in multispecies biofilms: do they actually matter? *Trends in Microbiology*, *22*(2), 84–91. https://doi.org/10.1016/j.tim.2013.12.004

Chaves, F., Garnacho-Montero, J., del Pozo, J. L., Bouza, E., Capdevila, J. A., de Cueto, M., Domínguez, M. N., Esteban, J., Fernández-Hidalgo, N., Fernández

Sampedro, M., Fortún, J., Guembe, M., Lorente, L., Paño, J. R., Ramírez, P., Salavert, M., Sánchez, M., & Vallés, J. (2018). Executive summary: Diagnosis and Treatment of Catheter-Related Bloodstream Infection: Clinical Guidelines of the Spanish Society of Clinical Microbiology and Infectious Diseases (SEIMC) and the Spanish Society of Intensive Care Medicine and Coronary Units (SEMICYUC). *Enfermedades Infecciosas Y Microbiología Clínica*, *36*(2), 112–119. https://doi.org/10.1016/j.eimc.2017.10.019

Chaves, F., Garnacho-Montero, J., del Pozo, J. L., Bouza, E., Capdevila, J. A., de Cueto, M., Domínguez, M. N., Esteban, J., Fernández-Hidalgo, N., Fernández Sampedro, M., Fortún, J., Guembe, M., Lorente, L., Paño, J. R., Ramírez, P., Salavert, M., Sánchez, M., & Vallés, J. (2018). Executive summary: Diagnosis and Treatment of Catheter-Related Bloodstream Infection: Clinical Guidelines of the Spanish Society of Clinical Microbiology and Infectious Diseases (SEIMC) and the Spanish Society of Intensive Care Medicine and Coronary Units (SEMICYUC). *Enfermedades Infecciosas Y Microbiología Clínica*, *36*(2), 112–119. https://doi.org/10.1016/j.eimc.2017.10.019

Chen, R. (2015). Risk Factors for Early Onset of Catheter-Related Bloodstream Infection in an Intensive Care Unit in China: A Retrospective Study. *Medical Science Monitor*, *21*, 550–556. https://doi.org/10.12659/msm.892121

Chen, X., & Liang, M. (2022). A Meta-Analysis of Incidence of Catheter-Related Bloodstream Infection with Midline Catheters and Peripherally Inserted Central Catheters. *Journal of Healthcare Engineering*, *2022*, 1–8. https://doi.org/10.1155/2022/6383777

Chittick, P., & Sherertz, R. (2010). Recognition and prevention of nosocomial vascular device and related bloodstream infections in the intensive care unit. Critical Care Medicine, 38, S363-S372. doi:10.1097?CCM.obo13e3181e6cdca

Devries, M. (2016). Bloodstream infections from peripheral lines: An underrated risk. American Nurse Today, 11(1), 13–20

Diseases and Organisms in Healthcare Settings | HAI | CDC. (n.d.). http://www.cdc.gov/HAI/organisms/organisms.html#a

Drugeon, B., Guenezan, J., Pichon, M., Devos, A., Fouassin, X., Neveu, A., Boinot, L., Pratt, V., & Mimoz, O. (2023). Incidence, complications, and costs of peripheral venous catheter-related bacteraemia: a retrospective, single-centre study. *Journal of Hospital Infection*, *135*, 67–73. https://doi.org/10.1016/j.jhin.2023.02.012

Duncan, M., & Warden, P. (2017). A Bundled Approach to Decrease Primary Bloodstream Infections Related to Peripheral Intravenous Catheters. *American Journal of Infection Control*, *45*(6), S74. https://doi.org/10.1016/j.ajic.2017.04.107

Duzgol, M., Boncuoglu, E., Kiymet, E., Akaslan Kara, A., Erdem, M., Odaman Al, I., Demirag, B., Zihni, C., Hilkay Karapinar, T., Oymak, Y., Mese, T., Bayram, N., & Devrim, I. (2021). Evaluation for Metastatic Candida Focus and Mortality at Candida-associated Catheter-related Bloodstream Infections at the Pediatric Hematology-oncology Patients. *Journal of Pediatric Hematology/Oncology*, *44*(3), e643–e648. https://doi.org/10.1097/mph.0000000000002197

Doski, V. (2023). Potential Change in Central Line-Associated Bloodstream Infections (CLABSIs) at UC San Diego Health Hospitals After Adoption of SecurAcath for Peripherally Inserted Central Catheters (PICCs) (Order No. 30309435). Available from ProQuest Dissertations & Theses Global. (2833873189). https://www.proquest.com/dissertations-theses/potential-change-central-line-associated/docview/2833873189/se-2

Evans, N. S., & Ratchford, E. V. (2018). Catheter-related venous thrombosis. *Vascular Medicine*, *23*(4), 411–413. https://doi.org/10.1177/1358863x18779695

Fisher, M., Golestaneh, L., Allon, M., Abreo, K., & Mokrzycki, M. H. (2019, December 5). Prevention of Bloodstream Infections in Patients Undergoing Hemodialysis. *Clinical Journal of the American Society of Nephrology*, *15*(1), 132–151. https://doi.org/10.2215/cjn.06820619

Gahlot, R., Gahlot, R., Nigam, C., Kumar, V., Yadav, G., Anupurba, S., Nigam, C., Kumar, V., Yadav, G., & Anupurba, S. (2014). Catheter-related bloodstream infections. *International Journal of Critical Illness and Injury Science*, *4*(2), 162. https://doi.org/10.4103/2229-5151.134184

Gahlot, R., Nigam, C., Kumar, V., Yadav, G., & Anupurba, S. (2020). Catheter-related bloodstream infections. International Journal of General Medicine, 13, 35-47.

Goede, M. R., & Coopersmith, C. M. (2009, April). Catheter-Related Bloodstream Infection. *Surgical Clinics of North America*, *89*(2), 463–474. https://doi.org/10.1016/j.suc.2008.09.003

Gorski, L. A., Hadaway, L., Hagle, M. E., McGoldrick, M., Orr, M., & Doellman, D. (2021). Infusion therapy standards of practice, 8th edition. Journal of Infusion Nursing, 44(1S), S1-S224.

Goodman, P. (2022). Blood Stream Infections related to Hemodialysis Catheter Use (Order No. 29253064). Available from ProQuest Dissertations & Theses Global. (2682474343). https://www.proquest.com/dissertations-theses/blood-stream-infections-related-hemodialysis/docview/2682474343/se-2

home-page - Near East University Hospital. (2023). Near East University Hospital. https://neareasthospital.com/?lang=en

Htay, H., & Johnson, D. W. (2019). Catheter Type, Placement, and Insertion Techniques for Preventing Catheter-Related Infections in Maintenance Peritoneal Dialysis Patients: Summary of a Cochrane Review. *American Journal of Kidney Diseases*, *74*(5), 703–705. https://doi.org/10.1053/j.ajkd.2019.07.005

Ishizuka, M., Nagata, H., Takagi, K., & Kubota, K. (2013). Needleless Closed System Does Not Reduce Central Venous Catheter-Related Bloodstream Infection: A Retrospective Study. *International Surgery*, *98*(1), 88–93. https://doi.org/10.9738/cc132.1

Ista, E., van der Hoven, B., Kornelisse, R. F., van der Starre, C., Vos, M. C., Boersma, E., & Helder, O. K. (2016). Effectiveness of insertion and maintenance bundles to prevent central-line-associated bloodstream infections in critically ill patients of all ages: a systematic review and meta-analysis. The Lancet Infectious Diseases, 16(6), 724-734.

Johnson, K., & Grossman, A. (2013). Implementation and Maintenance of Practice Guidelines to Decrease Central Line Associated Bloodstream Infections by Minimizing Line Manipulation. *Biology of Blood and Marrow Transplantation*, *19*(2), S172. https://doi.org/10.1016/j.bbmt.2012.11.150

Kaye, K. S., Patel, D. A., Stephens, J. M., Khachatryan, A., Patel, A., & Johnson, K., (2021). Rising United States hospital admissions for acute bacterial skin and skin structure infections: recent trends and economic impact. PLoS One, 16(1), e0244851.

Kehagias, E., & Tsetis, D. (2019). The "Arm-to-Chest Tunneling" technique: A modified technique for arm placement of implantable ports or central catheters. *The Journal of Vascular Access*, *20*(6), 771–777. https://doi.org/10.1177/1129729819826039

Kehagias, E., Galanakis, N., & Tsetis, D. (2023). Central venous catheters: Which, when and how. *The British Journal of Radiology*, *96*(1151). https://doi.org/10.1259/bjr.20220894

Koh, D. B., Lee, S. S., Kim, S., Choi, Y. H., & Jeong, D. C. (2019). Risk factors and outcomes of catheter-related bloodstream infection in critically ill patients: A retrospective study. Medicine, 98(46), e17999.

Liu, G., Ma, W., Liu, H., Tang, L., & Tan, Y. (2022). Risk factors associated with catheter-related venous thrombosis: a meta-analysis. *Public Health*, *205*, 45–54. https://doi.org/10.1016/j.puhe.2022.01.018

Lott, J. P., Iwashyna, T. J., Christie, J. D., Asch, D. A., Kramer, A. A., & Kahn, J. M. (2009). Critical Illness Outcomes in Specialty versus General Intensive Care Units. *American Journal of Respiratory and Critical Care Medicine*, *179*(8), 676–683. https://doi.org/10.1164/rccm.200808-1281oc

Lu, H., Hou, Y., Chen, J., Guo, Y., Lang, L., Zheng, X., Xin, X., Lv, Y., & Yang, Q. (2020). Risk of catheter-related bloodstream infection associated with midline catheters compared with peripherally inserted central catheters: A meta-analysis. *Nursing Open*, *8*(3), 1292–1300. https://doi.org/10.1002/nop2.746

Lv, L., & Zhang, J. (2019). The incidence and risk of infusion phlebitis with peripheral intravenous catheters: A meta-analysis. *The Journal of Vascular Access*, *21*(3), 342–349. https://doi.org/10.1177/1129729819877323

Maki, D. G., Kluger, D. M., & Crnich, C. J. (2006). The Risk of Bloodstream Infection in Adults With Different Intravascular Devices: A Systematic Review of 200

Published Prospective Studies. *Mayo Clinic Proceedings*, *81*(9), 1159–1171. https://doi.org/10.4065/81.9.1159

María, L. T., Alejandro, G. S., & María Jesús, P. G. (2021). Central venous catheter insertion: Review of recent evidence. *Best Practice & Research Clinical Anaesthesiology*, *35*(1), 135–140. https://doi.org/10.1016/j.bpa.2020.12.009

Marik, P. E., Flemmer, M., & Harrison, W. (2012). The risk of catheter-related bloodstream infection with femoral venous catheters as compared to subclavian and internal jugular venous catheters. *Critical Care Medicine*, *40*(8), 2479–2485. https://doi.org/10.1097/ccm.0b013e318255d9bc

Marsh, N., Webster, J., Ullman, A. J., Mihala, G., Cooke, M., Chopra, V., & Rickard, C. M. (2020). Peripheral intravenous catheter non-infectious complications in adults: A systematic review and meta-analysis. *Journal of Advanced Nursing*, *76*(12), 3346–3362. https://doi.org/10.1111/jan.14565

Masuyama, T., Yasuda, H., Sanui, M., & Lefor, A. (2021). Effect of skin antiseptic solutions on the incidence of catheter-related bloodstream infection: a systematic review and network meta-analysis. *Journal of Hospital Infection*, *110*, 156–164. https://doi.org/10.1016/j.jhin.2021.01.017

Matthews, R., Gavin, N. C., Marsh, N., Marquart-Wilson, L., & Keogh, S. (2023, November). Peripheral intravenous catheter material and design to reduce device failure: A systematic review and meta-analysis. *Infection, Disease & Health*, *28*(4), 298–307. https://doi.org/10.1016/j.idh.2023.05.005

McCauley, P. M. (2010). Evidence-based clinical guidelines and their impact on prevention of catheter related blood stream infections (Order No. 3421844). Available from ProQuest Dissertations & Theses Global. (752061948). https://www.proquest.com/dissertations-theses/evidence-based-clinical-guidelines-their-impact/docview/752061948/se-2

McConnell, S. A., Gubbins, P. O., & Anaissie, E. J. (2003). Do Antimicrobial-Impregnated Central Venous Catheters Prevent Catheter-Related Bloodstream Infection? *Clinical Infectious Diseases*, *37*(1), 65–72. https://doi.org/10.1086/375227

Mimoz, O., Villeminey, S., Ragot, S., Dahyot-Fizelier, C., Laksiri, L., Petitpas, F., & Debaene, B. (2007). Chlorhexidine-Based Antiseptic Solution vs Alcohol-Based Povidone-Iodine for Central Venous Catheter Care. *Archives of Internal Medicine*, *167*(19), 2066. https://doi.org/10.1001/archinte.167.19.2066

Moriyama, K., Ando, T., Kotani, M., Tokumine, J., Nakazawa, H., Motoyasu, A., & Yorozu, T. (2022). Risk factors associated with increased incidences of catheter-related bloodstream infection. *Medicine*, *101*(42), e31160. https://doi.org/10.1097/md.0000000000031160

Near East University Hospital - Wikipedia. (2023). https://en.wikipedia.org/wiki/Near_East_University_Hospital

Peace, D. M. (2011). Central line associated bloodstream infections in South Carolina: A correlational study of bed capacity, surveillance techniques, and therapeutic processes (Order No. 3449355). Available from ProQuest Dissertations & Theses Global. (862722249). https://www.proquest.com/dissertations-theses/central-line-associated-bloodstream-infections/docview/862722249/se-2

Peng, S., & Lu, Y. (2013). Clinical epidemiology of central venous catheter–related bloodstream infections in an intensive care unit in China. *Journal of Critical Care*, *28*(3), 277–283. https://doi.org/10.1016/j.jcrc.2012.09.007

Phua, A. I. H., Hon, K. Y., Holt, A., O'Callaghan, M., & Bihari, S. (2019). Candida catheter-related bloodstream infection in patients on home parenteral nutrition - Rates, risk factors, outcomes, and management. *Clinical Nutrition ESPEN*, *31*, 1–9. https://doi.org/10.1016/j.clnesp.2019.03.007

Pinto, M., Borges, V., Nascimento, M., Martins, F., Pessanha, M., Faria, I., Rodrigues, J., Matias, R., Gomes, J., & Jordao, L. (2022). Insights on catheter-related bloodstream infections: a prospective observational study on the catheter colonization and multidrug resistance. *Journal of Hospital Infection*, *123*, 43–51. https://doi.org/10.1016/j.jhin.2022.01.025

Pitiriga, V., Bakalis, J., Kampos, E., Kanellopoulos, P., Saroglou, G., & Tsakris, A. (2022). Duration of central venous catheter placement and central line-associated bloodstream infections after the adoption of prevention bundles: a two-year retrospective study. *Antimicrobial Resistance & Infection Control*, *11*(1). https://doi.org/10.1186/s13756-022-01131-w

Pitiriga, V., Kanellopoulos, P., Bakalis, I., Kampos, E., Sagris, I., Saroglou, G., & Tsakris, A. (2020). Central venous catheter-related bloodstream infection and colonization: the impact of insertion site and distribution of multidrug-resistant pathogens. *Antimicrobial Resistance & Infection Control*, *9*(1). https://doi.org/10.1186/s13756-020-00851-1

Pronovost, P., Needham, D., Berenholtz, S., Sinopoli, D., Chu, H., Cosgrove, S., Sexton, B., Hyzy, R., Welsh, R., Roth, G., Bander, J., Kepros, J., & Goeschel, C. (2006). An Intervention to Decrease Catheter-Related Bloodstream Infections in the ICU. *New England Journal of Medicine*, *355*(26), 2725–2732. https://doi.org/10.1056/nejmoa061115

Ranji, S. R. (2007). *Closing the Quality Gap: A Critical Analysis of Quality Improvement Strategies (Vol. 6: Prevention of Healthcare–Associated Infections)*. NCBI Bookshelf. http://www.ncbi.nlm.nih.gov/bookshelf/br.fcgi?book=techrev9v6

Ray-Barruel, G., Xu, H., Marsh, N., Cooke, M., & Rickard, C. M. (2019). Effectiveness of insertion and maintenance bundles in preventing peripheral intravenous catheter-related complications and bloodstream infection in hospital patients: A systematic review. *Infection, Disease & Health*, *24*(3), 152–168. https://doi.org/10.1016/j.idh.2019.03.001

Ruffin, K. C. S. (2013). Bloodstream Infections from Preexisting Intravenous Catheters Present on Hospital Admission (Order No. 3599592). Available from ProQuest Dissertations & Theses Global. (1461769537). https://www.proquest.com/dissertations-theses/bloodstream-infections-preexisting-intravenous/docview/1461769537/se-2

Ruiz-Giardin, J. M., Ochoa Chamorro, I., Velázquez Ríos, L., Jaqueti Aroca, J., García Arata, M. I., SanMartín López, J. V., & Guerrero Santillán, M. (2019). Blood stream infections associated with central and peripheral venous catheters. *BMC Infectious Diseases*, *19*(1). https://doi.org/10.1186/s12879-019-4505-2

Ruiz-Ruigómez, M., & Aguado, J. M. (2021). Duration of antibiotic therapy in central venous catheter-related bloodstream infection due to Gram-negative bacilli. *Current Opinion in Infectious Diseases*, *34*(6), 681–685. https://doi.org/10.1097/qco.0000000000000763

Sato, A., Nakamura, I., Fujita, H., Tsukimori, A., Kobayashi, T., Fukushima, S., Fujii, T., & Matsumoto, T. (2017). Peripheral venous catheter-related bloodstream infection is associated with severe complications and potential death: a retrospective observational study. *BMC Infectious Diseases*, *17*(1). https://doi.org/10.1186/s12879-017-2536-0

Schritt, J., & Voß, J. P. (2023). Colonization, appropriation, commensuration: Three modes of translation. *The Sociological Review*. https://doi.org/10.1177/00380261231201475

Selby, L. M., Rupp, M. E., & Cawcutt, K. A. (2021). Prevention of Central-Line Associated Bloodstream Infections. *Infectious Disease Clinics of North America*, *35*(4), 841–856. https://doi.org/10.1016/j.idc.2021.07.004

Singer, M., Deutschman, C. S., Seymour, C. W., Shankar-Hari, M., Annane, D., Bauer, M., Bellomo, R., Bernard, G. R., Chiche, J. D., Coopersmith, C. M., Hotchkiss, R. S., Levy, M. M., Marshall, J. C., Martin, G. S., Opal, S. M., Rubenfeld, G. D., van der Poll, T., Vincent, J. L., & Angus, D. C. (2016). The Third International Consensus Definitions for Sepsis and Septic Shock (Sepsis-3). *JAMA*, *315*(8), 801. https://doi.org/10.1001/jama.2016.0287

Sumrall, D. B. (2022). Reducing Peripheral Line-Associated Bloodstream Infection Rates through Introduction of a Bundle and Staff Education (Order No. 29397465). Available from ProQuest Dissertations & Theses Global. (2731049856). https://www.proquest.com/dissertations-theses/reducing-peripheral-line-associated-bloodstream/docview/2731049856/se-2

Urtecho, M., Torres Roldan, V. D., Nayfeh, T., Espinoza Suarez, N. R., Ranganath, N., Sampathkumar, P., Chopra, V., Safdar, N., Prokop, L. J., & O'Horo, J. C. (2023). Comparing Complication Rates of Midline Catheter vs Peripherally Inserted Central Catheter. A Systematic Review and Meta-analysis. *Open Forum Infectious Diseases*, *10*(2). https://doi.org/10.1093/ofid/ofad024 van Vught, L. A., Klein Klouwenberg, P. M. C., Spitoni, C., Scicluna, B. P., Wiewel, M. A., Horn, J., Schultz, M. J., Nürnberg, P., Bonten, M. J. M., Cremer, O. L., & van der Poll, T. (2016). Incidence, Risk Factors, and Attributable Mortality of Secondary Infections in the Intensive Care Unit After Admission for Sepsis. *JAMA*, *315*(14), 1469. https://doi.org/10.1001/jama.2016.2691

Wallis, M. C., McGrail, M., Webster, J., Marsh, N., Gowardman, J., Playford, E. G., & Rickard, C. M. (2014). Risk Factors for Peripheral Intravenous Catheter Failure: A Multivariate Analysis of Data from a Randomized Controlled Trial. *Infection Control & Hospital Epidemiology*, *35*(1), 63–68. https://doi.org/10.1086/674398

Wang, Y., Xiang, Q., Wu, J., Xiao, N., & Chen, J. (2022). Obesity and the risk of catheter-related bloodstream infection: a systematic review and meta-analysis. *Antimicrobial Resistance & Infection Control*, *11*(1). https://doi.org/10.1186/s13756-022-01166-z

Walker, R. L. (2018). Reducing CLABSI Rate among ICU Patients (Order No. 10982351). Available from ProQuest Dissertations & Theses Global. (2149672349). https://www.proquest.com/dissertations-theses/reducing-clabsi-rate-among-icu-patients/docview/2149672349/se-2

Whitfield, A. G. (2019). Reducing Central Line-associated Bloodstream Infections (Order No. 22620595). Available from ProQuest Dissertations & Theses Global. (2296357250). https://www.proquest.com/dissertations-theses/reducing-central-line-associated-bloodstream/docview/2296357250/se-2

Yan, P. R., Chi, H., Chiu, N. C., Huang, C. Y., Huang, D. T. N., Chang, L., Kung, Y. H., Huang, F. Y., Hsu, C. H., Chang, J. H., Chang, H. Y., & Jim, W. T. (2022). Reducing catheter related bloodstream infection risk of infant with a prophylactic antibiotic therapy before removing peripherally inserted central catheter: A retrospective study. *Journal of Microbiology, Immunology and Infection*, *55*(6), 1318–1325. https://doi.org/10.1016/j.jmii.2021.09.016

Zhang, H. H., Cortés-Penfield, N. W., Mandayam, S., Niu, J., Atmar, R. L., Wu, E., Chen, D., Zamani, R., & Shah, M. K. (2018). Dialysis Catheter–related Bloodstream Infections in Patients Receiving Hemodialysis on an Emergencyonly Basis: A Retrospective Cohort Analysis. *Clinical Infectious Diseases*, *68*(6), 1011–1016. https://doi.org/10.1093/cid/ciy555

Zhang, Y., Wang, Y., Sheng, Z., Wang, Q., Shi, D., Xu, S., Ai, Y., Chen, E., & Xu, Y. (2023). Incidence Rate, Pathogens and Economic Burden of Catheter-Related Bloodstream Infection: A Single-Center, Retrospective Case-Control Study. *Infection and Drug Resistance*, *Volume 16*, 3551–3560. https://doi.org/10.2147/idr.s406681

Zhong, Y., Zhou, L., Liu, X., Deng, L., Wu, R., Xia, Z., Mo, G., Zhang, L., Liu, Z., & Tang, J. (2021). Incidence, Risk Factors, and Attributable Mortality of Catheter-Related Bloodstream Infections in the Intensive Care Unit After Suspected Catheters Infection: A Retrospective 10-year Cohort Study. *Infectious Diseases and Therapy*, *10*(2), 985–999. https://doi.org/10.1007/s40121-021-00429-3

Zingg, W., Barton, A., Bitmead, J., Eggimann, P., Pujol, M., Simon, A., & Tatzel, J. (2023). Best practice in the use of peripheral venous catheters: A scoping review and expert consensus. *Infection Prevention in Practice*, *5*(2), 100271. https://doi.org/10.1016/j.infpip.2023.100271