**Minireview Article**

# Abstract:A review of the intraluminal fluid pathway to prevent catheter related bloodstream infections and occlusions

The most common complications associated with vascular access devices are catheter related bloodstream infections (CR-BSI), which occur in acute care patients every minute, and occlusions. This review will address major issues associated with patient care and research associated with vascular access and intravenous connectors including descriptions of different types of connectors, care and maintenance issues such as septum disinfection and flushing, education of students and practitioners, a new framework for research, and relevant questions for healthcare practitioners to ask during patient assessment. This review includes two overall strategies to prevent CRBSI's and occlusions;1) prevent the active and passive migration of microorganisms into the fluid pathway and 2) prevent microorganism adhesion to the catheter surface. The connector,which is placed on the end of a catheter, is the gatekeeper to the intraluminal fluid pathway and its design directly impacts the success of strategies to prevent complications. Best practice requires that practitioners have specific knowledge of connector technology as well as patient factors for caring for vascular access devices. There is a large gap in the scientific literature and in policies and procedures related to evidenced based decision making associated with care and maintenance of needleless intravenous connectors. A review on connectors is necessary to meld research and practice together for best patient practices, so the occurrences of CRBSI's and occlusions can be mitigated and eliminated.

Key words: CRBSI, sepsis, connectors, nursing care, vascular access, occlusions

# A Review of theIntraluminal Fluid Pathway to Prevent Catheter Related Bloodstream Infections and Occlusions

## Background

A patient obtains a catheter related bloodstream infection every minute[1]and this can lead to a diagnosis of sepsis which is the most costly hospital acquired infection withup to a 50% mortality rate.[2]Catheter occlusions result in loss of vascular access, loss of time for treatments and increased length of stay. Any of these negative outcomes causes a poorer quality of life for the patient. The importance of understanding current research on connectors and its association with their care, maintenance and educational needs is imperative to professional best care practices.

The intravenous catheter, whether centrally or peripherally placed, is an extension of the venous system to the outside environment. As a result, a hole in the skin referred to as the insertion site (extraluminal) and the hole in the catheter (intraluminal) are entry points for bacteria, yeast and fungus. The role of nursing practice in caring forthe intraluminal pathway is to prevent treatment-related complications so that every vascular access device (VAD) remains safely in place and complication free for the durationthe VAD is needed (brief or prolonged). The two most common complications associated with the intraluminal pathway are CR-BSI[3] and occlusion.

Best practices for extraluminal care[4,5]are reported to only prevent 40% of bloodstream infections[6]. Therefore, 60% of CR-BSIs have causes that are intraluminal in nature. Intraluminal CR-BSIs occur when organisms, in particular bacteria, migrate into the fluid pathway and adhere to the pathway wall. Once attached, the bacteria form a colony and develop a protective cover referred to as biofilm. When biofilm is formed it is difficult to eradicate the colony and infection can occur and proliferate. The cost of CR-BSIs has been calculated to be approximately $33,000-$35,000 (£20,915-22,183) per episode making it a relevant cost issue[7,8,9]. Four major pathogens (*Staphylococcus epidermidis*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Escherichia coli*) are responsible for 60% of CR-BSIs at a total cost of $225 (£ 143) million per year and 200,000 intensive care unit days/year [10]. Occlusions are common[11]and under reported and about half are directly related to thrombus formation[12]. Occlusion is also related to fluid pathway design with the best design to minimize occlusions being a connector that is short, small, has a straight fluid pathway and minimal reflux on connection and disconnection.Intraluminal reflux related thrombi rates are reported as 5%-25%[13] and connector use is associated with varying amounts of reflux and thereforethe connector is directly related to intraluminal thrombi[14].Fibrin deposition on the intraluminal surfaces of the intravenous (IV) connector fluid pathway and catheter has been shown to also increase the risk of coagulase-negative staphylococci infection[15]. Therefore, through several mechanisms thrombosis has been shown to enhance the risk of infection[16]. Interestingly prevention of occlusions may rely heavily on patient assessment and this has not been recognized by healthcare practitioners.

**IV Connectors Overview**

The IV connector is referred to by many different names such as “hep-locks”, “male adaptors”, “Luer-locks”, “split septums” and “INTs” to name a few. Needleless connectors were developed in the 1990’s as a means of preventing needle sticks and decreasing the potential for human immunodeficiency virus transmission. During the last decade research findings have questioned the role of IV connectors by category and as contributors to CR-BSI[17,18]. In 2010, nine design features were outlined as variables that impacted CR-BSI including: septum surface, septum seal, fluid pathway, dead space, internal mechanism, clamping sequence, visibility, blood reflux and flushing solution[19].

All IV connectors available today have four elements in common: an external housing, a septum which is the entry point of the connector, a fluid pathway, and a mechanism for returning the septum to its original closed position with disconnection. Dead space, which exists in most connectors, refers to areas within the fluid pathway that cannot be cleared when flushing. The designs of these four elements vary greatly from connector to connector.

There are three major types of needleless intravenous connectors based on reflux known as negative, positive, and neutral fluid displacement[20]. Connector designs evolved over a decade with changes made to improve usability and to minimize occlusion associated with their use. The first type is negative mechanical valves (NMV). Reflux occurs with disconnection. Total or partial occlusion[12,14] is associated with NMV reflux. In addition NMVs have been associated with CR-BSI[21]. The second type is positive pressure mechanical valves (PPMV) and with this type reflux occurs with connection. Positive connectors have been associated with increased bloodstream infections[22,23].These are under FDA (USA) investigation for possibly causing deaths[24]. The last and most recent type is neutral. Withneutralconnectors there is no reflux with either connection ordisconnection.Several studies reveal that specific connectors are associated with an increased risk of blood stream infections[21,22,25,26] including positive-pressure connectors[17,27].

It is not one design feature that is important in connector design and their associated outcomes, but the combination of all the design features outlined by Dr. Jarvis[19]that will impact complication reductions and eliminations.

**Care & Maintenance of Connectors**

Strategies to prevent intraluminal complications must be two-pronged; 1) prevent the active and passive migration of microorganisms into the intraluminal fluid pathway, and 2) prevent catheter wall adhesion. This approach will prevent bacterial colonization and biofilm formation.

Nursing has only two actions for intraluminal care within their domain of practice: swabbing the connector septum for disinfection and flushing the fluid pathway to remove residue after use.

**Septum Disinfection of Connectors**

Septum disinfection is the first action necessary to prevent bacterial migration. Today, 70% alcohol alone or Chlorhexidine (CHG) alcohol are the two most commondisinfection agents selectedby institutions in the United States. Alcohol biocide activity occurs while wet. It dehydrates the cell surface causing cell destruction. CHG must enter the cell and disrupt the cell contents to cause cell death. So while alcohol is active when wet, CHG must dry to be effective.CHG's greatest benefit is persistence when applied to the skin. There is minimal research associated with its benefits when applied to inanimate objects. Appropriate septum disinfection is a significant part of care. Even with conventional disinfection with 70% alcohol one study of NMVs revealed 67% transmit microorganisms ranging from 442 to 25,000 colony-forming units[28] and it is known that greater than 15 colony-forming units can lead to sepsis[29].Another studyrevealed a range of colony forming units for different connectors, post 70% alcohol swab using downward pressure and 3 rotations, to range from zero to over 13,500 for 4 different bacteria lending data to the knowledge base that connectors are a significant variable in the development of infections[30].

The IV connector must be swabbed before each access. Thisprotocol results in three or four(if using heparin as a final flush) separate swabbing procedures with each IV push medication or blood draw. It is common for connectors to be accessed repeatedly during a patient care shift. In the US, there has been an increase in swabbing times to 15- 30 seconds in an attempt to improve disinfection. This action has placed the entire burden on the nurse and may not be clinically realistic. Connector design has not been considered even though research has confirmed that complete disinfection of some IV connectors septum's surfaces is difficult and in fact may not be achievable at high rates in the clinical setting[28, 31]. To increase septum disinfection success, the septum should be made of hydrophobic material and be smooth without irregularities to prevent bacteria from sticking. The septum seal should be tight when not activated so that there are no areas that lie outside disinfectant contact. When relying on research to set the swabbing practice, it is important to remember that generalization of research findings to connectors not included in the study is problematic. Long, complicated swabbing practices are cumbersome and difficult to consistently perform in the clinical setting.

Selecting a connector that can be swabbed easily with > 99% bacterial kill will improve compliance. Ask manufacturersof connectors for independent research in this area and if they have none be weary of using the product. If the manufacturer tells you to follow your hospital policy on scrubbing the hub do NOT accept this as valid as it is not research based and is actually an admission that the manufacturers have no research on their product. This lack of research and evidence does not support evidence based nursing practice and can be detrimental to patient outcomes.Research on one product,Invision-Plus® (RyMed Technologies, Inc., TN, USA), validated through aninvitro study by Nelson laboratories (Salt Lake City, UT) showed that3-5 twists of swabbing with 70% alcohol pad, like squeezing an orange, removes 100% of bacteria[32].

**Flushing of Connectors**

Fibrin deposition on the intraluminal surfaces of the fluid pathway increases the risk of coagulase-negative staphylococci infection[15] and occlusions. Thrombosis has been shown to enhance the risk of infection[16] and makes flushing difficult or impossible.In order for flushing to be successful, the fluid pathway must be straight. This is because fluid follows the path of least resistance. This means that anything outside this pathway will not come in contact with the flushing solution. These areas outside the pathway continue to have blood and medication residueproviding an environment forbacterial growth. Edminston[34] inoculated connector intraluminal fluid pathways and reported that increased intraluminal fluid pathway volume corresponds to higher organism growth rates. With a larger internal volume there was increased area outside the fluid pathway. A small unobstructed, straight fluid pathway provides an area where 100% of the pathway surface comes into contact with the flush. An invitro study showed that a connector designed with a very small priming volume (0.027 mL)and using as little as 1 mL saline flush 99.96% and with 4 mL saline that 100% of microscopic hemoglobin was removed[35].

It is practice in some institutions in the US to use a push-pause flushing method. This practice became very popular because it was hypothesized that fluid turbulence enhances the“scrubbing” action of the flush. No research is available to support this practice. Donlan[35], a leader in biofilm science, reported in 2002 that turbulent flow actually enhances bacterial adhesion and that a steady flush minimizes adhesion. No research exists that focuses flushing on patient need yet many patients are at high risk for occlusion (see below).

Table 1: Patients At High Risk For Vascular Access Occlusion

| |
|---|
| Acute Spinal Cord Injury |
| Advanced Age |
| Bone Marrow Transplant |
| Brain Tumor |
| Catheters Placed via the Left Subclavian Vein |
| Catheter Tip Location in Subclavian Vein |
| Chronic Obstructive Pulmonary Disease |
| Dehydration |
| Diabetes |
| High Platelet Levels |
| History of Deep Vein Thrombosis |
| Lung Cancer |
| Major Trauma Gynecologic Malignancies |
| Malposition of the Catheter |
| Oral Contraceptive Use |
| Pregnancy |
| Renal Failure |
| Sickle Cell Anemia |
| Trauma Patients |

Performing the identical flushing procedures with all patients may result in uneven outcomes and research is needed in this area. Using a final heparin flush is also problematic. Heparin is a protein derived from pigs. This protein becomes food for bacterial colonies.Also heparin is associated with a serious complication known as heparin induced thrombocytopenia (HIT). Numerous medications are incompatible with heparin and must be completely flushed before heparin is instilled making compliance in care more difficult. Because of certain connector pathway designs, residue remains in the dead space adding to bacterial growth and biofilm formation environments. Hence, we do not recommend the use of heparin as common practice.

Negative and positive connectors have reflux associated with usage. Since reflux occurs either with disconnection (NNV) or connection (PPV) mitigating reflux depends on the nurses' ability to identify the connector by type and then apply the correct clamping sequence[20]either before disconnection clamping (NNV) or after disconnection(PPV). Additionally, when using the Y-port on anyIV administration tubing a clamping sequence cannot be used and reflux cannot be mitigated. Many institutions stock more than one type of connector necessitating the nurse to visually identify the connector type and then select the correct clamping sequence. The package label usually does not identify the connector type or whichclamping sequence to use.Thismakes the nurse's job more difficult. Using the wrong sequence means that occlusion is more prevalent when using a negative pressure system[36,37]with reflux occurring with disconnection. Occlusion incidence is much less using one neutral connector[38]. Selecting one IV connector to be used exclusively enhances education and ultimately improves procedure compliance[17]. New research has reported that for flushing ports the nurse needs to make sure that the needle bevel is in an upward/top direction before flushing. This placement improves the fluid flow path, enhancing cleaning[39]. Knowledge about connector design and associated best flushing practices will help in overcoming CRBSIs and occlusions.

**EDUCATION**

The prevention of CR-BSIs[40] and occlusionsare possible but requires education of healthcare providers on cause, care and maintenance actions related to the specific IV connector, and continual recent research evaluation with associated implementation of policy and practice changes. Research reveals that 78% of acute care nurses are uninformed about different connector types and their specific, yet opposing, care[41]. Forty three percent of nurses could not name 2 complications associated with IV connectors (e.g.: infection, occlusion, thrombosis) and 64% are involved with 4 to 5 hours of IV therapy care and maintenance per 12 hour nursing shift, making IV therapy an important clinical issue and educational necessity[41]. However, there are neither courses nor enough lectures in most nursing programs on IV therapy, though information related to science and research has resulted in several books being published in the area of IV therapy. The ability of nurses to collect cues related to IV connector problems begins with education on information that is basic, understandable, differentiating and complete to aid in clinical reasoning. Patient assessment, knowledge of technology and specific nursing care are required to best protect the intraluminal fluid pathway of VADs[1,42-45].Without knowledge and appropriate nursing interventions intraluminal protection becomes compromised and there can be an increase in CR-BSI, occlusions, thrombi and potential associated deaths.

**Framework for Research**

For nursing and medical research associated with VADs the Healthcare AndTechnology Synergy (HATS) framework (Figure 1) is appropriate. This framework[46] represents a synergy between three major variables (patient, product, practice) with each one affecting the others and being affected by the others. All of the variables can have an impact on healthcare outcomes. This framework adds a more holistic and comprehensive approach to comparative effectiveness and evidence based practice research and when translating findings to bedside care. Using connectors as an example the patient variables to be considered, though not an exhaustive list, include age, diagnosis, comorbidities, therapeutic regimens, projected length of stay, physical assessment, mental health status, transcultural beliefs, finances, and length of treatment including current needs and recurring needs. Product variables may include the following; intravenous connectors categorized on the basis of reflux as well as bacterial and biofilm growth as previously discussed, connector septum design including septum seal tightness, fluid pathway design, type of VAD, insertion site,and number of catheter lumens.Practice variables may include connector septum disinfection practice, dressing management, clamping sequence,flushing practiceincluding solution(s) and time frequency (eg: 10 mL normal saline every 6 hours), the education and skill levels of the nurse specific to vascular access, availability of specialized vascular access teams,and nurse-patient staffing ratios. Research in some of these areas have already been implemented, presented and/or published[41, 42, 47-52].

**Patient IV Connector Assessment**

- What type of connector does my patient have? Is it negative, positive orneutral?
- Do I have the materials, skills and knowledge to correctly implement scrubbing the hub and flushing?
- Do I have the knowledge to implement appropriate disconnection?
- How often should I change the connector? This time frame should be specifically stated by the manufacturer as "follow your usual hospital policy" is meaningless to nursing care.
- Does my patient have a three way stop cock? The use of stop cocks increased bloodstream infections when compared to disinfectable needlefree-connectors[53].

**Summary**

- Connector design and category impact occlusion and CR-BSI rates
- Connector design impacts nursing disinfection and flushing practice success
- Best practice requires that health care professionals have specific knowledge of connector technology aswell as patient factors for caring for vascular access devices.
- The more desirable design features a connector has included in its final product the more user friendly the connectorwill be and the less complications you will encounter.
- Without specific knowledge regardingconnector technology there is an increase in the potential for sepsis, catheter occlusion and death.
- When the connector surface is not properly disinfected, flushed, and/or disconnected thenbacteria can enter the intraluminal fluid pathway, adhere to the internal surface, colonizeand develop biofilm increasing the risk for patient infection and sepsis.
- Healthcare providers should demand that manufactured connector devices be developed with fail-safe engineering advances aimed at further mitigation of risk of infection in the complex hospital environment and devices that include ease of use by the nurse. The addition of alcohol caps is another step for nurses to implement and one that should not be necessarywith a properly designed connector. Additional steps also increase human error.

- Instituting the “Healthcare And Technology Synergy (HATS)” framework that includes “Patient, Practice, Product”, into intravenous practice settings and within research is paramount to a better understanding of intraluminalvascular access infections.
- The frequent usage and care of connectors in all healthcare settings makes connectors significantvariables for practice and comparative effectiveness and outcomesresearch.
- There are large gaps in the scientific literature, policies and procedures in regards to unbiased evidenced based decision making, care and maintenance related to needleless connectors.

**CONCLUSIONS**

An increased knowledge of connector design and evidence based practice can prevent CRBSI’s and occlusions through preventing the active and passive migration of microorganisms into the fluid pathway and preventing microorganism adhesion to the catheter surface. The connector, as the gatekeeper to the intraluminal fluid pathway,plays a significant and vital role in the prevention of patient complications, including death. CRBSIs are related to septum design and fluid pathway design of connectors and occlusions are related to fluid pathway design of connectors. The best designed connector should have all design features[19] not just zero reflux. Best practice requires utilization of research in the development and implementation of policy and procedures associated with needleless intravenous connector care and maintenance. Also, the potential of value enhanced purchasing can best be accomplished through inclusion of evidence. Through a combination of research and education there could be a very significant decrease in ‘one every minute’ CRBSI’s and vascular access catheter occlusions.

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Figure 1: Healthcare And Technology Synergy (HATS) Framework