

# Stopcocks for Infusion Therapy

## Evidence and Experience

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### ABSTRACT

Stopcocks have been used for decades to deliver infusion therapy in patients of all ages and in all health care settings. During the past 20 years, a growing number of studies have validated concern about the risk of the open lumen allowing intraluminal contamination. Additional studies highlight fluid flow dynamics associated with stopcocks. This integrative literature review and clinician practice survey analyzes the published evidence and reports of actual practices with stopcocks, and raises issues about practice changes that could reduce these risks.

**Key words:** catheter-related bloodstream infection, closed system, fluid flow dynamics, manifold, open system, stopcock

Increasing attention to patient safety and changing to a pay-for-performance reimbursement structure is driving scrutiny of all clinical practices. Infusion therapy and the entire infusion system is no exception. Stopcocks are a component of the infusion system that is receiving careful attention. While anesthesia and critical care staffs are most familiar with the routine use of stopcocks, they are also used throughout the health care system for special procedures and nursing interventions, such as obtaining blood samples and instilling solutions for catheter clearance.

The use of stopcocks and their contribution to catheter-related bloodstream infection (CR-BSI) has long been a concern. The 2011 *Infusion Nursing Standards of Practice* stated that stopcock use was not recommended because of the risk of infection and called for special attention to the addition of sterile caps to ensure a closed system.<sup>1(p531)</sup> The 2016 *Infusion Therapy Standards of Practice* (the *Standards*) called for similar avoidance of their use, but added that a

stopcock with an integral needleless connector (NC) should be chosen to reduce stopcock contamination.<sup>2(p572)</sup>

There are geographical differences in clinical practice with stopcocks. In many European countries, a stopcock is placed on each vascular access device (VAD) lumen for intermittent use, while in the United States the stopcock attached to a VAD hub is for temporary use during a specific procedure. A survey of nurses in neonatal units in Australia and New Zealand identified 10 units that routinely used stopcocks, while 3 units never used them.<sup>3</sup> In addition, the technology of stopcocks is improving to reduce the identified risks of contamination and flow issues.

The purpose of this work is 3-fold: (1) to explore the technology associated with stopcocks; (2) to report findings of an integrative literature review on stopcocks; and (3) to present self-reported clinical practices with stopcocks through an online survey of health care personnel.

### STOPCOCK TECHNOLOGY

Stopcocks are devices used to direct the flow of fluid through an infusion system, while allowing multiple fluids to be connected. Turning an exterior handle allows the clinician to choose the specific fluid or medication to flow at a given time. Stopcocks must meet many requirements of industry standards, such as flow rate, high- or low-pressure resistance, chemical resistance to lipid-based solutions, sterilization compatibility, dead space, and handle-rotating torque.

Stopcocks have 3 components: (1) a body, (2) a handle, and (3) a luer-locking collar that can be fixed or rotating (Figure 1). The handle has a cylindrical component, with an opening to allow for fluid flow, extending into the stopcock body. Stopcocks are available with or without a luer-locking

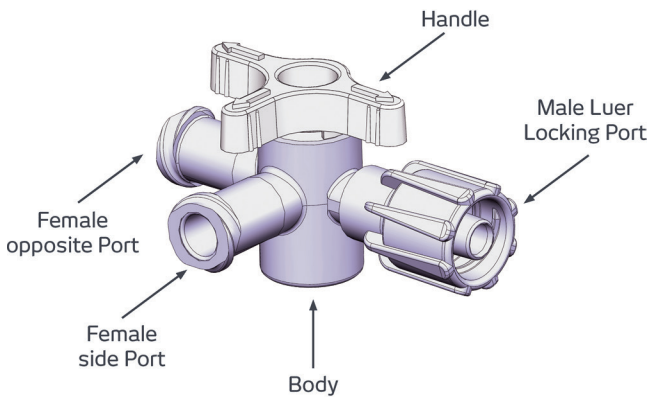
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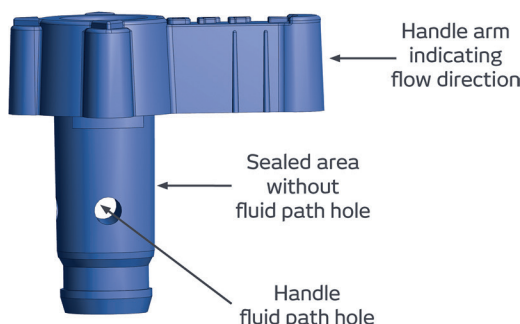


**Figure 1** Standard stopcock components. Reproduced and used with permission from Elcam Medical.

collar on the male port; however, the national standard of practice is to use a luer-locking mechanism on all connections in the infusion administration system.<sup>2</sup> Stopcocks have a male port that luer locks to the hub of the VAD, or the female end of an administration set. The opposite end and the side ports have a female port design to accept the male luer-locking connection of an administration set or syringe.

Stopcocks are also offered in a manifold design, a single device with several stopcocks assembled together in a straight line. This device is used most often by anesthesiologists and in critical care settings. Each stopcock has the same internal design, although the handles may be different colors. The different colors can be used to indicate different medications in each stopcock, although reliance on color coding as the sole indicator for choosing the lumen for medication administration can lead to errors and is not recommended.<sup>2</sup> Because fluids flow through the same channel, a manifold system may not be appropriate for infusing incompatible solutions.

Stopcocks are available as a standard design, in addition to high-flow and high-pressure designs. The size of the opening determines the maximum flow rate. By rotating the handle, the hole is positioned toward one of the flow paths, creating a multidirectional rotating valve (Figure 2). Stopcocks can be designed with 1, 2, 3, or 4 fluid flow paths, all controlled by the handle. High-flow stopcocks have the same design with a larger opening. High-pressure stopcocks are designed with more robust connectors and handles to



**Figure 2** Handle with fluid pathway hole in a standard stopcock. Reproduced and used with permission from Elcam Medical.

withstand higher pressures for interventional cardiology and radiology procedures (Table 1).

The internal diameter of intravenous (IV) administration sets includes standard bore, macrobore, and microbore. There are no standard measurements for each of these groups, and each manufacturer must provide sets that are compatible. Also uniformity in the internal diameter is not required.<sup>4</sup> A standard bore set may be approximately 3 mm, while a blood administration set is approximately 4 mm, and a microbore set is usually less than 1.5 mm.<sup>5</sup> The opening of a standard stopcock is 2.33 mm, slightly less than the 3 mm of a standard administration set. However, the stopcock will allow a maximum flow rate of about 500 mL/min and usually does not have a negative effect on flow rates in clinical practice.

Dead space is an issue with stopcocks. The lumen of the unused port will initially contain air when the stopcock is first added to the infusion system. After infusion through the side port, fluid or medication remains inside the space (Figure 3). A syringe attached to the side port of the stopcock is used to aspirate the air or flush residual fluid or medication into the primary flow pathway. A new stopcock design that has eliminated this problem allows fluid from the primary flow pathway to flow into and out of this space in a U-shaped pattern, flushing out trapped air bubbles or residual medication (eg, Ultraport ZerO, B. Braun Medical, Bethlehem, PA; Marvelous Stopcock, Elcam Medical, Hackensack, NJ) (Figure 4). Maximum flow rate in this new design is 220 mL/min with a maximum pressure tolerance of 29 pounds per square inch (psi).

Stopcocks are an open system, requiring some type of closure to reduce the entry of microorganisms into the lumen. A sterile dead-end cap is attached to the lumen when the extra ports are not connected to an administration set or syringe. Uncapped, open stopcock lumens pose a significant risk for contamination leading to CR-BSI. Stopcocks currently are available with the integration of a luer-activated NC on the stopcock body, creating a closed system.

Unique stopcock features correspond to cultural differences around the globe. For example, in the United States, stopcocks include an “off” handle to indicate the direction of flow that is closed, while European health care professionals prefer “on” so that the handle indicates the open-flow directions.

## LITERATURE REVIEW RESULTS

The search of published literature was planned to address the following questions:

1. In which clinical settings and among patients of what age are stopcocks used for the delivery of infusion therapy through any type of VAD?
2. What are the reported clinical outcomes of stopcock use for infusion therapy?

The process chosen was an integrative literature review, a method that uses empirical and theoretical publications to achieve a greater understanding of a problem or issue. This

**TABLE 1****Stopcock Characteristics**

	Standard	High Flow	High Pressure
Opening size	7 Fr, 2.33 mm	9 Fr, 3 mm	2.25 mm
Maximum flow rate	~500 mL/min	~750 mL/min	~510 mL/min
Maximum pressure	43 psi	29 psi	1200 psi
Priming volume	0.2-0.4 mL	0.32-0.57 mL	0.56 mL

Abbreviations: Fr, French; min, minute; mL, milliliter; mm, millimeter; psi, pounds per square inch.

method is specifically important for evidence-based practice because it is not limited to experimental research methods alone.<sup>6</sup> All types of evidence, as outlined in the *Standards*, were included.<sup>2(p510)</sup> Criteria for inclusion were (1) any article discussing stopcock use in specific procedures and the associated clinical setting (ie, Level V<sup>2(p510)</sup>) and (2) any clinical or laboratory research study using a stopcock on any type of VAD. All quasi-experimental and experimental research designs were included (ie, Levels I, II, III, and IV<sup>2(p510)</sup>).

Search terms included *stopcock*, *stopcock catheter intravenous*, and *stopcock catheter infusion*. The search was conducted using PubMed from the US National Library of Medicine of the National Institutes of Health, and Google Scholar to retrieve publications not listed on PubMed. The original search yielded almost 5000 articles. Further refinement by reading article abstracts eliminated all articles related to the use of stopcocks in other specialties, such as intraoperative procedures, along with management of endotracheal intubation/ventilation, nasogastric tubes, intracranial pressure monitoring, and many others. Publications from January 2000 through June 2016 were included. One hundred thirty-three articles were found and

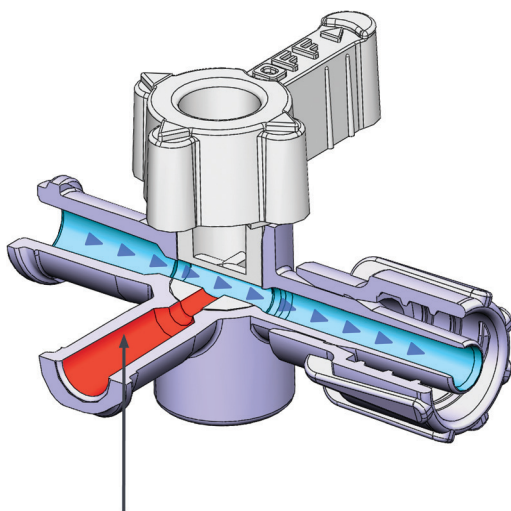
examined closely; 12 identified clinical stopcock use, and 28 were clinical or laboratory research studies.

Available publications were divided into 2 groups: (1) those that presented procedure details involving stopcock use for specific infusion-related procedures, and (2) clinical or laboratory research studies examining stopcocks for any type of infusion therapy or VAD management.

**Published Clinical Stopcock Uses**

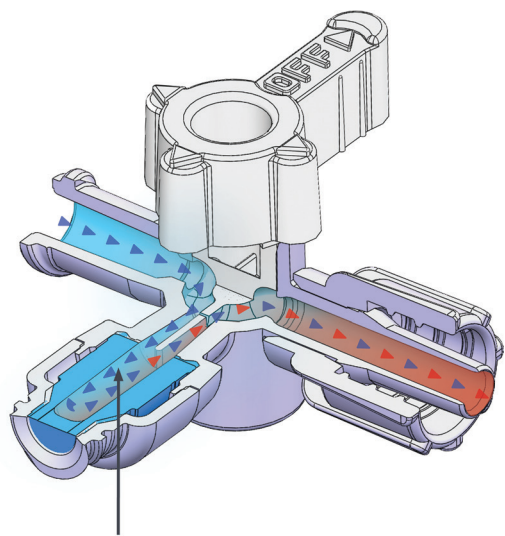
Publications involving specific procedures with stopcocks included intra-arterial blood pressure monitoring, blood sampling from central vascular access devices (CVADs), CVAD clearance procedures, and contrast-enhanced ultrasound for CVAD tip location identification.

Intra-arterial blood pressure monitoring procedures require frequent assessment to ensure complete stopcock closure and that a minimum number of stopcocks are used in the system. Air in the infusion system, use of long and flexible tubing, and multiple stopcocks can result in a serious overestimation of systolic blood pressure.<sup>7-9</sup> To prevent arterial backflow of blood into some types of infusion tubing, 1 report recommended the use of a stopcock on



Trapped fluid  
or air in side port

**Figure 3** Trapped fluid or air in side port. Reproduced and used with permission from Elcam Medical.



Constant flushing  
of the side port

**Figure 4** Constant flushing of the side port. Reproduced and used with permission from Elcam Medical.

both ends of the pressure monitoring line.<sup>10</sup> Stopcocks also are used within the system to monitor for central venous pressure, through both peripherally inserted and centrally inserted central venous catheters.<sup>11</sup>

Blood sampling from CVADs and arterial catheters may employ stopcocks. A study designed to evaluate the reliability and validity of using a bundle checklist for obtaining blood samples from pediatric oncology patients included stopcocks in its procedure. The routine use of stopcocks was determined by the opinion of 3 experts in the facility. The checklist included the use of a “closed stopcock method”; however, there was no further explanation of procedure details or the benefits of using a stopcock on the CVAD hub.<sup>12</sup> Concern for drug adsorption or adherence to the intraluminal catheter walls raises concern for obtaining accurate laboratory data when the blood sample is taken from the same lumen used for drug infusion. A study testing the “mixing” method, also known as the push-pull method, for drawing blood samples from a single-lumen CVAD used a stopcock in the protocol. However, there was no discussion of why the stopcock was needed.<sup>13</sup> On another note, hospital-acquired anemia is a significant problem associated with blood sampling. The literature was searched, and there was no mention of the use of stopcocks for obtaining blood samples from any type of VAD.

Procedures for clearing material obstructing a CVAD lumen frequently involve the use of stopcocks. The primary reason for lumen occlusion is thrombus, but drug precipitate and lipid accumulation may also cause the occlusion. The occluding material may be anywhere along the CVAD lumen, and there may be fluid between the occlusion and the hub. The goal is to remove the fluid and create negative pressure inside the catheter lumen. When the negative pressure is released, the solution in the attached syringe will be pulled into the lumen without using force on the syringe plunger. This reduces the possibility that overpressurization could cause catheter damage, and it allows the solution to reach the occluding material more readily. Stopcocks have been described for this procedure in medical-surgical nursing unit,<sup>14</sup> home care,<sup>15</sup> special procedures unit,<sup>16</sup> and oncology settings.<sup>16</sup>

Although postprocedure chest x-rays and electrocardiograms are the most common methods for identifying CVAD tip location, stopcocks now have a role. They are being used for CVAD tip location with ultrasound. The stopcock is used to create agitated saline, usually a mixture of 90% sodium chloride and 10% air. This solution is injected through the catheter with ultrasound used to identify the tip of the catheter by detecting the presence of microbubbles in the bloodstream at the CVAD tip location.<sup>17</sup> An article from the critical care literature warned about stopcock use when a stopcock is attached to a large percutaneous sheath introducer system. This article described how an uncapped stopcock accidentally opened as a result of patient movement and resulted in exsanguination of the patient through a large sheath introducer.<sup>18</sup>

Analysis of outcome data if included in these studies is not possible because of the many variations in procedures

and clinical practices. Inclusion of this Level V<sup>2(p510)</sup> evidence highlights the wide variety of clinical settings and patient populations in which stopcocks may be used.

## Clinical and Laboratory Studies

This literature search identified 15 randomized controlled trials (RCTs), 7 quasi-experimental studies, and 7 descriptive studies about stopcock use. The stopcock studies have a wide variety of differences in research methods and clinical processes used. The differences make it difficult to list them on evidence tables. The studies were divided by the issues being examined, including comparison of traditional open stopcocks to closed stopcocks due to the addition of an NC, intraoperative stopcock use, fluid flow dynamics through stopcocks, and arterial blood sampling methods. A brief narrative discussion of each study highlights methods, differences, and outcomes.

## Open Versus Closed Stopcocks

About 25 years ago, colonization of VAD hubs and its relationship to CR-BSI emerged. Studies before 2000 had reported that 22% of stopcock entry ports were contaminated after 72 hours of clinical use.<sup>19</sup>

Since 2000, 4 RCTs compared stopcock closure using a standard end cap (ie, a conventional open stopcock) versus closure using an NC on each stopcock lumen (ie, a closed system). All studies were conducted in adult critical care patients. Three of the 4 studies showed a significant reduction in contamination of the stopcock entry port at 72 hours of use with the closed system. Different methods for collecting samples for culturing external and internal surfaces were used in these 3 studies. There was also a difference in the disinfecting agents used on the NC surfaces, with 1 study using 3 disinfectants and 2 studies using 70% alcohol.<sup>19-21</sup> The fourth study reported a reduction in central line-associated bloodstream infection (CLABSI) rates, using the Centers for Disease Control and Prevention (CDC) definition of that term.<sup>2</sup> CLABSI rates decreased from 6.4 per 1000 catheter days to 2.2 per 1000 catheter days. This study also included the use of commercially prepared prefilled flush syringes in the experimental group, while the control group received flushes with sodium chloride drawn from multidose vials, adding a process not included in other studies.<sup>22</sup>

Esteve et al<sup>23</sup> compared the use of stopcocks that had the conventional end cap on each CVAD and arterial catheter hub versus an NC directly attached to the CVAD hub. Alcoholic chlorhexidine 0.5% was used for disinfecting the NC surface. The incidence of contamination and CR-BSI rates were similar between the groups, with 4.1/1000 catheter days for the stopcock group and 4.6/1000 catheter days for the NC group ( $P = .59$ ).

Two additional RCTs compared a traditional stopcock that had an end cap versus a stopcock with a split-septum NC in adult patients. The first study used 80% ethanol with 0.1% chlorhexidine for disinfecting the NC surface.<sup>24</sup> The

second study used a disinfection cap containing a chlorhexidine-impregnated sponge on the NC when not in use.<sup>25</sup> Both studies placed a 0.2-micron filter below the injection sites and reported microbial analysis of the organisms trapped in the filter. The first study showed no significant difference in contamination between the 2 groups; however, the second study using the disinfection cap on the NC showed significant reduction of organisms in the intraluminal pathway.

An RCT in low-birth-weight neonates also compared the stopcock/end cap system with a mechanical valve NC for stopcock closure inside the administration sets for infusion into both peripheral and central venous catheters. This study used the CDC definition for CLABSI and reported a rate of culture-proven bloodstream infection (BSI) in the NC/stopcock group of 3.3% and 26.7% in the stopcock/end cap group ( $P = .026$ ).<sup>26</sup>

An RCT in adult patients compared the outcomes of a closed peripheral catheter system and a traditional catheter system. The closed catheter system used a catheter with a permanently attached extension set, avoiding the connection of the extension to the catheter hub at insertion, and a split-septum NC on the distal end of the extension set. The open system used a traditional peripheral catheter, with the extension set attached at insertion and the distal end with a stopcock and end cap. A sample of removed catheters cultured the exterior side of the catheter lumen and reported on catheter-related complications. No data addressed the differences between the stopcock versus the NC and intraluminal contamination.<sup>27</sup>

A time cohort study reported using a stopcock and end cap closure on CVAD hubs for 1 year, followed by a second year using a mechanical valve NC on the CVAD hub. During both years, a bacterial filter was included in the infusion system. Blood cultures were obtained on the basis of clinical signs and symptoms of CR-BSI. The outcome analysis showed 66 positive blood cultures predominately with coagulase-negative *Staphylococcus epidermis*. There were no differences found between these systems during the 2-year period.<sup>28</sup>

Finally, a laboratory study compared injections through 4 systems, including a traditional stopcock, a stopcock with an NC, and both systems using a unique device designed to protect the system components while a syringe was being attached. Cultures included the stopcock lever, internal port lumens, and sodium chloride flushed through each system. Cultures of the internal port lumen revealed that only 24% of the sodium chloride effluent cultures were positive, although the authors thought this was an insensitive marker. Cultures taken of the stopcock lever showed the same organism in 29% of the effluent cultures, indicating manual contact and the need for attention to hand hygiene.<sup>29</sup>

## Stopcock Contamination in the Operating Room

In the operating room (OR), infusion therapy is started and maintained primarily by anesthesia personnel. Several

studies have focused specifically on the anesthesia work space, tools, and devices used, and their connection to hospital-acquired infection. This work began with a study of stopcocks used on short peripheral IV catheters in the OR. Operating suites were randomized to have the first case of the day included for a total of 61 patients. At time 0, cultures were taken from the stopcock's intraluminal surfaces and the surfaces of valves and dials on anesthesia machines. Time 1 was the completion of the case when cultures of anesthesia equipment were repeated before routine disinfection. Time 2 was a repeat culture of the intraluminal surfaces of all 3 stopcock lumens. In addition, all patients were followed for 30 postoperative days to identify hospital-acquired infections. Stopcock contamination was found in 32% of cases; 5 patients with stopcock contamination developed nosocomial pneumonia, wound, and BSIs, and 2 of the 5 died from their infection. Five patients without stopcock contamination also developed hospital-acquired conditions, but there were no deaths in this group.<sup>30</sup>

In a multiple-site study, 274 operating suites were randomly selected for the first 2 cases of each day. Samples for culture were taken from the hands of anesthesia providers before, during, and after each case. Patient cultures were taken of the nasopharynx and the axilla. The anesthesia machine was cultured from 2 surfaces before and after each case. Intraluminal surfaces of each stopcock lumen were cultured at the end of each case. Cultures showed stopcock contamination in 126 of 548 cases (23%), with contamination occurring 14 times between cases and 30 times within the same case. In the 30-day, postoperative period, each patient was followed for changes in white blood cell counts, fever, anti-infective orders, any signs and symptoms of infection, and acquisition of any bacterial cultures. In the 30-day postoperative period, 48 infections were identified in 44 patients (8%). The organism causing the infection was identified in 20 of 44 (45%) patients. In 6 of 20 (30%) patients, pulsed-field gel electrophoresis confirmed that the infecting organism was present in at least 1 intraoperative reservoir. Suboptimal surface disinfection followed by inadequate hand hygiene was confirmed to be the cause of stopcock contamination.<sup>31</sup>

Loftus et al<sup>32</sup> used a similar study design to investigate 2 new devices designed to reduce stopcock contamination. A new catheter care station was designed to disinfect the male luer connection on the IV administration set and the open and closed connection surface of the stopcock and NC. The stopcock contamination rate was 41% in the control group and 32% in the study group using the catheter care station. Hospital-acquired infection occurred in 12% of patients. The second RCT compared a conventional open stopcock versus a new closed stopcock design with a unique flow channel. This simulated study was conducted in the operating suite while a patient was present, but the stopcock systems were not attached to the patient. The anesthesia providers were asked to flush sodium chloride through a traditional open stopcock, the new closed

stopcock after disinfection with 70% alcohol, and the new closed stopcock without disinfection. The sodium chloride flush was collected for culture. The closed stopcock with disinfection had no contaminated effluent (0/152), while the closed stopcock without disinfection had 4% (7/162) culture-positive effluent samples, and the open stopcock had 3.2% (5/154) contaminated sodium chloride samples. This outcome supports the concept that device design and provider methods of handling the device are the 2 most important factors to prevent contamination, with the correct disinfection techniques being the most important factor.<sup>33</sup>

A small pilot study collected used manifolds with 3 stopcocks each on transfer to the postanesthesia care unit. The manifolds were placed in sterile containers and transported to the laboratory for culture of internal surfaces. A total of 24 manifolds with 70 stopcocks were cultured; 9 (38%) of the manifolds had growth in at least 1 stopcock, and 12 (17%) of the individual stopcocks had growth. This study led to several practice changes, including providing anesthesia providers with hand gel containers to be worn, and replacing manifolds with NCs and port protectors, also known as disinfection caps.<sup>34</sup>

An *in vitro* study collected extension sets with stopcocks used on same-day surgery patients when they were removed from the patient. Sets had been used to infuse propofol and nonpropofol anesthesia. Samples of fluid were obtained from the stopcock at 6, 24, and 48 hours after surgery for a total of 50 samples in each group; however, each stopcock was used for 1 sample collection only. Samples from stopcocks used for propofol were positive for bacterial growth in 17.3% (26/150), while nonpropofol stopcocks were positive in 18.6% (28/150). At 48 hours, bacterial counts from the stopcocks used for propofol showed significantly more growth, with an average of 472 colony-forming units (CFUs)/mL and 4 CFU/mL from the nonpropofol stopcocks. The researchers stressed the concern for bacterial growth within the dead space in patients with continuing IV infusion and suggested that the extension set with the stopcocks be changed immediately after surgery.<sup>35</sup>

## Flow Rate Concerns

Infusion of critical drugs, such as inotropes and vasopressors, or drugs requiring low-volume infusion (eg, neonates or pediatrics), requires careful consideration of the entire infusion system and its internal volume. This internal volume includes the catheter and all attached extension sets and stopcocks from the point where the drug is attached to the system to the bloodstream at the catheter tip. Another factor influencing the dynamics of fluid flow is any carrier or continuous fluids flowing simultaneously with the drug infusion.

An *in vitro* study using methylene blue demonstrated that the priming volume of large CVADs may require 25 minutes for the drug to reach the bloodstream initially

and as much as 30 minutes for the drug to stop entering the bloodstream when the infusion is stopped. Larger lumens and attaching the drug to the primary infusion system upstream will result in longer periods before the drug reaches the bloodstream. According to the researchers, the drug should be connected with a stopcock at the closest point to the patient.<sup>36</sup>

Similar *in vitro* study methods examined the various times for a critical drug to reach the bloodstream based on the stopcock position in the manifold. A drug connected at the fourth (most distal to the patient) stopcock position infusing at 3 mL/h into a carrier fluid infusing at 10 mL/h would require 17 minutes to reach a steady state of infusion. At the first stopcock position, the time required is 5 minutes. The volume of the manifold system and the flow rate of both fluid and medication will have a significant impact on the length of time required for the medication to reach the patient's bloodstream, an issue that could have substantial clinical results in some critical patients.<sup>37</sup> Lovich et al<sup>38</sup> also demonstrated similar results with changes in drug flow rate, depending on the dead space of the multistopcock manifold device. A larger dead space requires a greater period of time for the drug flow to reach a steady infusion rate.

Another *in vitro* study using dye showed that a longitudinal chain of stopcocks requires a greater priming volume, resulting in a lengthy delay of the infusion drug reaching the patient when the drug is attached to the most distal stopcock. In addition, the dye was seen to stream on the bottom of the stopcock and administration set, depending on the position of the stopcock system. Streaming of one drug infusion could mean inconsistent flow rates and an alteration in clinical response from the drug. Infusion of multiple low-flow infusions through a parallel infusion system, such as a multiple-lumen extension set, would reduce or eliminate these problems. A multiple-lumen extension set would mean each drug would flow for the same distance. This infusion method would allow each drug to reach a steady infusion in about the same time as the stopcock closest to the patient.<sup>39</sup>

Alteration in flow rate of 1 drug was demonstrated in another *in vitro* study when a second drug was added upstream on a manifold set. This occurs with microinfusion of multiple critical drugs. The flow rate for the first drug can increase with the addition of another fluid flowing from an upstream stopcock. When stopping the infusion of 1 drug, the flow of the second drug can decrease. Factors affecting the degree of the flow rate change include flow rates for each drug and the fluid carrier, the priming volume of the infusion system, and the concentration of each drug.<sup>40</sup>

## Blood Sampling Systems

Two RCTs using very similar processes compared a closed blood conservation device versus a stopcock closed with an end cap for obtaining blood samples from arterial catheters. Oto et al<sup>41</sup> studied adult critical care patients,

and Tang et al<sup>42</sup> studied pediatric patients. Both studies cultured intraluminal fluid and the extraluminal catheter tip on removal. Intraluminal fluid contamination was significantly lower in the blood conservation device in both studies. Catheter tip colonization was not statistically different in each group in both studies. Possible reasons for this difference include the fact that the dwell time for arterial catheters usually is much shorter than for venous catheters. Additionally, culture of the extraluminal wall would not reveal organisms from inside the catheter lumen.

### Miscellaneous Studies

Management of the IV administration set became the focus of a time-series study with the goal of decreasing CR-BSI in neonatal patients. CR-BSI rates during the traditional method of set management were tracked and compared with a period after significant changes had been introduced. These practice changes included complete administration set assembly with attached flush syringes; sterile technique used for changing the administration set performed daily by the same 2 nurses; limitation of entry into the system to once in a 24-hour period; and using a 2-person standardized sterile procedure for CVAD dressing changes. Although stopcocks were used in both study periods, the rate of CR-BSI dropped from 15.7 BSIs to 2.1 BSIs per 1000 catheter days, emphasizing the need for maintaining a closed system and restricting manipulation of the system.<sup>43</sup>

A survey of all adult inpatients in a 1368-bed hospital assessed the number of VADs and the number of lumens, revealing that 40% were unnecessary. These authors counted every port on a stopcock as an individual lumen, finding a mean number of 1.86 stopcock lumens per peripheral catheter and more than 3 stopcock lumens per CVAD. Reducing the number of stopcocks used would decrease the number of times the system would be manipulated, and the authors suggest that stopcock use should be assessed on a daily basis in the same manner as the VAD itself.<sup>44</sup>

An in vitro study of disinfecting methods for conventional open-lumen stopcocks and NCs showed that the rim of a stopcock could be disinfected with manual scrubbing with an alcohol pad, but not the intraluminal surfaces. A new device containing finger-like sponges wet with a disinfectant agent did not adequately disinfect the stopcock rim or intraluminal surfaces. The authors of that study suggested that the disorderly compression of the small sponges prevented them from reaching the intraluminal surfaces.<sup>45</sup>

## SURVEY OF STOPCOCK USE

To obtain feedback about clinical uses of stopcocks, an online survey of health care personnel was performed. The survey tool was created and tested on a volunteer basis on a group of nurses. The questions were adjusted as needed based on feedback from the volunteers. An invitation to complete the finished survey was sent by e-mail to 1398

health care personnel. Additional invitations were posted on 5 large online discussion groups. The survey contained 8 demographic questions and 18 questions about clinical practice. There was a total of 348 responses. Of those, 315 stated that they had responsibility for starting and managing infusion therapy on patients; the remaining 32 answered negatively and were not allowed to proceed. Analysis of each question was based on the number of responses to that specific question because some respondents did not answer certain questions.

The largest group of respondents (122/302; 40.4%) were from academic medical centers or teaching hospitals, and 81/302 (26.8%) were from community hospitals. The third-largest group of 33 (10.9%) worked in home care. *Vascular access specialty* was identified more frequently in all types of hospitals (88/159; 70%), and *infusion therapy specialty* was identified more frequently in ambulatory infusion clinics and home care (40/159; 25%). Registered nurses (84%) were the largest group of respondents, with remaining responses from nurse practitioners, clinical nurse specialists, nurse anesthetists, licensed practical/vocational nurses, radiology technologists, infection prevention staff, nursing managers and educators, and physicians. By clinical specialty, the largest groups were vascular access specialist (94/300; 31%) and infusion therapy (66/300; 22%). The "other" group was made up of multiple combination specialties, such as medical/surgical and vascular access or vascular access and interventional radiology (Table 2).

Seventy percent of respondents had more than 15 years of experience, and 40% had been working for their current employer for more than 15 years. Respondents were from 42 states and 18 countries other than the United States.

Stopcocks were used for any type of infusion therapy by 71.2% of all respondents; 97% of pediatric and critical care personnel reported using stopcocks. Sixty percent of all respondents had not received any in-service training on the use of stopcocks, and many commented that such training was unnecessary. Table 3 lists the answers of all respondents regarding infusion procedures with stopcocks. "Other" infusion procedures included therapeutic phlebotomy, apheresis, and blood exchange procedures from implanted ports; diagnostic studies requiring injection of agitated saline; and intrathecal medication administration. Pediatric and critical care respondents reported higher rates of stopcock use for all infusion therapy procedures. A single stopcock is the most common device used (67%). Multiple stopcocks attached together were reported more often by pediatric and pediatric/neonatal critical care personnel. The most common site reported for placement of the stopcock within the infusion system was direct attachment to the catheter hub (55%), with 40% adding it to the administration set. Several respondents commented that both locations were used.

After use, 90/196 (46%) responded that the administration set is detached from the stopcock and the lumen is closed, but 87/196 (44%) responded that the set is left

**TABLE 2****Responses by Clinical Specialty**

Answer Options	Response Percentage	Response Count
Medical	5.7%	17
Surgical	1.3%	4
Oncology	3.7%	11
Pediatrics	3.7%	11
Operating room	1.3%	4
Postanesthesia care unit	0.7%	2
Surgical adult intensive care	1.0%	3
Medical adult intensive care	4.7%	14
Neurological intensive care	0.0%	0
Neonatal intensive care	1.7%	5
Pediatric intensive care	5.7%	17
Infusion therapy	22.0%	66
Vascular access	31.3%	94
Radiology	2.3%	7
Emergency department	1.3%	4
Cardiology (eg, cardiac catheterization)	1.3%	4
Gastrointestinal (eg, endoscopy)	0.0%	0
Other (Please explain)	12.3%	37
<b>Answered question</b>		<b>300</b>
<b>Did not answer question</b>		<b>47</b>

**TABLE 3****Stopcock Uses for Infusion Therapy**

Do you use stopcocks for any of the following? Check all that apply.

Answer Options	Response Percentage	Response Count
IV fluids or medication administration	63.9%	129
Hemodynamic pressure monitoring on a CVAD	43.1%	87
Intra-arterial pressure monitoring on a peripheral arterial catheter	37.1%	75
Obtaining IV blood samples from a central venous catheter	39.6%	80
Obtaining IV blood samples from a peripheral venous catheter	14.9%	30
Obtaining intra-arterial blood samples	34.2%	69
Instilling a thrombolytic agent for declotting a central venous catheter	57.4%	116
Other (please explain)	11.4%	23
<b>Answered question</b>		<b>202</b>
<b>Did not answer question</b>		<b>145</b>

Abbreviations: CVAD, central vascular access device; IV, intravenous.

92% are not using stopcocks with a bonded NC. The most common reason for NC disconnection was that the NC was not correctly luer locked to the stopcock, and diversion of attention to other patient needs was a close second in responses. Most respondents (79%) had not used a stopcock with a permanently fixed or bonded NC. Scrubbing with an alcohol pad for 15 seconds is most commonly used to disinfect an NC attached to a stopcock, and 90% reported allowing time for the solution to dry.

Responses from the United States were compared with those from other countries. Although the survey did not target personnel from other countries, there were responses from 18 countries other than the United States. Although the numbers are not adequate to perform statistical analysis, differences were seen in the responses about removal of a stopcock or manifold (Table 4). Responses from the United States indicated a greater rate of removal when the stopcock is no longer needed, as well as immediately after a specific procedure. Responses from outside the United States indicated that stopcocks are left attached to the catheter hub and are only changed at specific intervals.

This survey was biased toward the specialty of infusion and vascular access personnel, although every attempt was made to reach personnel from all specialties. Numerous studies have addressed the infection risk associated with stopcocks, especially in the OR. Practices in the perianesthesia setting could not be evaluated in this survey because only 2% of respondents were from that setting. Failure to close a stopcock or finding stopcocks without an end cap were reported at high rates, also adding to the infection risk.

attached to the stopcock. Seventy-seven percent of pediatric and neonatal critical care respondents reported leaving the administration set attached to the stopcock lumen. Many commented that the decision to leave the administration set attached depended on the purpose of the stopcock.

Disinfection of the stopcock before use is most frequently accomplished by scrubbing the stopcock lumen (50/113; 44%), and 15 seconds was reported as the most common length of the scrub time. An additional 36 (32%) respondents indicated that the open lumen is wiped with a disinfectant pad, and 13 (11%) stated that the entire surface of the stopcock is wiped with a disinfectant pad. Fourteen (12%) responded that disinfection was not possible because the stopcock is an open lumen. A total of 113 responded to this question; 234 did not respond. Although the reason for this is unclear, the respondents may not have understood the question or may not have had a common or standardized practice.

Almost 60% responded that they had found stopcock lumens left open. Almost 75% reported using an NC for closure of a stopcock lumen; however, 42% reported seeing an NC inadvertently disconnected from the stopcock. Ninety-five percent of pediatric and neonatal critical care respondents reported closing a stopcock with an NC, although



**TABLE 4****Stopcock/Manifold Removal**

Answer Options	Responses in United States, n (%)	Responses Outside United States, n (%)
Immediately removed from the infusion system when no longer required for the therapy being infused (eg, discontinuing infusion of multiple drugs such as vasopressors)	45 (29.4)	9 (29)
Only used for certain procedures and removed immediately after the procedure is complete (eg, declotting or taking blood sample)	53 (34.6)	2 (6.5)
Left attached directly to the catheter hub and changed at a specific interval—ie, 72 hours, 96 hours, etc.	15 (9.8)	10 (32.3)
Changed when the administration set is changed	36 (23.5)	10 (32.3)
Other (please explain)	4 (2.6)	0 (0)
<b>Answered question</b>	<b>153</b>	<b>31</b>
<b>Did not answer question</b>	<b>95</b>	<b>19</b>

The literature review also reported flow rate concerns, which is a problem mainly among neonatal and pediatric patients. Only 11% of survey respondents were from these settings. Special procedures settings, such as radiology, cardiology, and endoscopy, were also underrepresented.

Stopcocks are used for a wide variety of infusion practices; however, additional research on these practices is needed. For instance, collection of venous and arterial samples from peripheral and central VADs is frequently performed according to the survey responses, yet the literature review found only 2 RCTs about this practice, with many questions left unanswered.

## DISCUSSION

This integrative literature review revealed stopcock use in all patient ages and in virtually all health care settings, including inpatient, outpatient, and alternative sites.

Technology changes in stopcock design create a closed system and eliminate the dead space, or space inside the device but not in the usual fluid pathway. One *ex vivo* study<sup>33</sup> demonstrated a reduction in intraluminal contamination, compelling the need for more research on the effect of the closed system on the incidence of CR-BSI or the surveillance rates for CLABSI. Elimination of the stopcock dead space could also reduce the risk of CRBSI, especially when used to infuse propofol that is associated with a significant increase in pathogen growth over time.

As seen in published articles and in the survey of health care personnel, stopcock use for drawing blood samples is a common practice, yet the only available research compares stopcocks versus a closed blood sampling system. Two RCTs<sup>41,42</sup> demonstrated greater intraluminal contamination with traditional open stopcocks than the special closed blood sampling system, identifying the need for research comparing a closed lumen stopcock versus these closed blood sampling systems.

Use of stopcocks for catheter clearance procedures allows for an easy method to aspirate intraluminal fluid and create negative pressure inside the catheter lumen. The same process can be performed with a clamp on the catheter's extension leg and multiple syringes. "How-to" nursing articles include the use of both procedures, but no studies comparing the outcomes of these methods have been found.

The predominant themes in stopcock research are stopcock contamination and its impact on CR-BSI and fluid flow dynamics through multiple stopcock systems. A wide variety of methodologies were used in these studies, preventing the aggregation of study data.

Contamination and subsequent CR-BSI risk were highlighted in many studies comparing open and closed stopcock lumens and lumen contamination within the OR setting. Seven of 8 RCTs, a simulated *ex vivo* study, and a time cohort study demonstrated a significant trend toward reduced intraluminal contamination when the stopcock is closed with an NC. Yet most health care personnel report not using a bonded NC on the stopcock.

In the OR, contamination of anesthesia machines and inadequate hand hygiene have been shown to be the cause of stopcock contamination. Postoperative follow-up of these surgical patients also has confirmed that hospital-acquired infections result from this intraoperative contamination. One study using pulsed-field gel electrophoresis demonstrated the infecting organisms were the same organisms identified in cultures taken from stopcocks during surgery. Propofol, a lipid-based drug associated with organism growth, produces growth of organisms in the dead space of stopcocks used in surgery, causing the authors to recommend that stopcocks used in the OR be removed or replaced immediately after surgery. As recommended by the CDC<sup>46</sup> and the Infusion Nurses Society,<sup>2</sup> the primary and secondary IV administration set should be changed at 96 hours. Significant levels of organisms growing in the stopcock dead space over this prolonged period could easily produce infection in vulnerable surgical patients.

Fluid flow dynamics with small volume and low flow rates are an issue for neonatal and pediatric patients; however, this problem could affect patients of any age. Vasopressors, inotropes, and drugs used to control cardiac arrhythmias require low flow rates. The point of attachment to the stopcock manifold can make a difference in a patient's response to these drugs because of the length of time required to reach the bloodstream. Temporarily increasing the flow rate of the primary or carrier fluid is not the answer because the patient may not be able to tolerate this temporary increase in fluid volume, and errors occur if the clinician forgets to return the fluid flow to the prescribed rate.

Clinical implications from this work would include several practice changes. Studies of hand hygiene and stopcock contamination were conducted in the OR. However, the need for adequate hand hygiene before manipulation of the infusion system is paramount in all settings. Following anesthesia with propofol, changing the IV administration set would reduce the risk associated with organisms growing in the dead space of stopcocks or any injection site. Studies conducted in ORs indicate that IV set contamination has an influence on all infection rates during the inpatient period. Specialty areas, such as perianesthesia and special procedures settings, require collaboration between personnel. Infusion nurse specialists can lead efforts to communicate with anesthesia, OR nursing staff, critical care staff, and infection prevention personnel. Because of the extreme importance of infection prevention, ensuring standardization of stopcock practices throughout the entire facility is necessary. Further reduction of stopcock contamination could be achieved with the use of a stopcock design that allows for continual flushing of residual medications. Finally, maintaining a closed system by using a stopcock with bonded NCs would reduce the significant risk of intraluminal contamination that leads to CR-BSI.

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