# Heparin or 0.9% sodium chloride to maintain central venous catheter patency: A randomized trial

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***Objective:*** **To compare heparin (3 mL, 10 units/mL) and 0.9% sodium chloride (NaCl, 10 mL) flush solutions with respect to central venous catheter lumen patency.**

***Design:*** **Single-center, randomized, open label trial.**

***Setting:*** **Medical intensive care unit and Surgical/Burn/Trauma intensive care unit at Barnes-Jewish Hospital, St. Louis, MO.**

***Patients:*** **Three hundred forty-one patients with multilumen central venous catheters. Patients with at least one lumen with a minimum of two flushes were included in the analysis.**

***Interventions:*** **Patients were randomly assigned within 12 hrs of central venous catheter insertion to receive either heparin or 0.9% sodium chloride flush.**

***Measurements and Main Results:*** **The primary outcome was lumen nonpatency. Secondary outcomes included the rates of loss of blood return, inability to infuse or flush through the lumen (flush failure), heparin-induced thrombocytopenia, and catheter-related blood stream infection. Assessment for patency was performed every 8 hrs in lumens without continuous infusions for the duration of catheter placement or discharge from intensive care unit. Three hundred twenty-six central venous catheters were studied yielding 709 lumens for analysis. The nonpatency rate was 3.8% in the heparin group (n = 314) and 6.3% in the 0.9% sodium chloride group (n = 395) (relative risk 1.66, 95% confidence interval 0.86–3.22, $p = .136$). The Kaplan-Meier analysis for time to first patency loss was not significantly different (log rank = 0.093) between groups. The rates of loss of blood return and flush failure were similar between the heparin and 0.9% sodium chloride groups. Pressure-injectable central venous catheters had significantly greater rates of nonpatency (10.6% vs. 4.3%, $p = .001$) and loss of blood return (37.0% vs. 18.8%, $p < .001$) compared to nonpressure-injectable catheters. The frequencies of heparin-induced thrombocytopenia and catheter-related blood stream infection were similar between groups.**

***Conclusion:*** **0.9% sodium chloride and heparin flushing solutions have similar rates of lumen nonpatency. Given potential safety concerns with the use of heparin, 0.9% sodium chloride may be the preferred flushing solution for short-term use central venous catheter maintenance. (Crit Care Med 2012; 40:1820–1826)**

**Key Words: catheterization; central venous; flushing; heparin; sodium chloride; vascular patency**

Central venous catheters (CVCs) are used widely in critical care to administer a variety of blood products, intravenous (IV) fluids and medications, to monitor hemodynamic indices, to obtain blood samples, and for pacing or dialysis. A variety of short-term (≤3–4 wks dwell time) and long-term (months to years dwell time) peripherally or centrally inserted catheters are used. Venous catheters generally develop a fibrin sheath as a result of the body's physiologic response to the vein injury and the foreign catheter (1). Evolution of a clot both in size and shape can lead to catheter obstruction. Biofilm, a collection of microorganisms from catheter insertion and catheter manipulations, also develops intraluminal and on the catheter surface, leading to potential catheter-related bloodstream infection (CR-BSI) (2).

Flushing a catheter lumen utilized for intermittent infusions is important. After an intermittent infusion or flush, blood reflux within the catheter increases the risk of thrombus formation (2). Thrombus frequently leads to loss of functionality of that lumen and possibly an increased risk of CR-BSI. Loss of catheter functionality due to thrombosis can require costly thrombolytic therapy or catheter removal and replacement, which are not without risks (3).

Interventions to prevent catheter thrombosis occlusion and maintain function of CVCs vary from unit to unit and institution to institution. Heparin is the standard flush recommended in many CVC maintenance guidelines (4–6); however, direct comparisons to 0.9% sodium chloride (NaCl) lack scientific rigor (3). Comparisons of 0.9% NaCl and heparin for peripheral IV line maintenance have demonstrated similar rates of thrombosis, and as a result the use of 0.9% NaCl has become the widely accepted standard of practice (7, 8). Given the physical differences (e.g., longer length, multiple lumens) as well as longer dwell times, it is inappropriate to extrapolate the findings from peripheral IVs to CVCs.

National surveys have demonstrated a change in practice over the past 15 yrs despite the lack of research. A survey conducted in 1995 found 97% of nurses surveyed (n = 92) across 24 states used heparin flush for CVC maintenance (9). In 2009, we conducted a survey of 632 members of the American Association of Critical Care Nurses in which two-thirds of respondents used 0.9% NaCl alone and one-third used heparin in a wide variety of concentrations and volumes (10). This apparent change in practice has occurred despite national guidelines recommending heparin and without supporting evidence (4–6). The switch to 0.9% NaCl

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flush may be due in part to concern for heparin related toxicities including bleeding and heparin-induced thrombocytopenia (HIT), a complication of heparin therapy with potential for significant consequences including life- or limb-threatening thrombosis (11). Case studies have identified heparin flushes as a cause of both HIT and bleeding complications (12, 13).

The primary objective of this study was to compare two flush solutions, heparin and 0.9% NaCl, on catheter lumen patency in adults with short-term use CVCs.

## MATERIALS AND METHODS

*Patients*. The study was conducted within the medical intensive care unit (ICU) and surgical/burn/trauma ICU at an academic medical center, Barnes-Jewish Hospital/Washington University Medical Center (1,200 beds) in St. Louis, MO, from April 2009 to May 2010. The ICUs are closed units employing multidisciplinary rounds directed by a physician board certified in critical care. The study was approved by the Washington University School of Medicine Human Studies Committee. Written consent was obtained from the patients or their proxies; telephone consent was approved after the first 7 months of the study due to the high number of patients missed during the 12-hr inclusion criteria time limit.

To be enrolled in the study, patients had to have a newly inserted (≤12 hrs) multilumen CVC performed by personnel at the institution and all lumens had to be patent. Patients with multilumen dialysis or pheresis catheters, peripherally inserted central catheters (PICC), long-term use catheters, pulmonary artery catheters, implanted ports, large bore single lumen sheath catheters, and multilumen catheters threaded through large bore sheath catheters were excluded. Initially, patients with double lumen catheters were also approached for inclusion but after the first several catheters demonstrated no available lumens, this type of catheter was also excluded. Additional exclusion criteria included a known heparin allergy, a diagnosis of HIT, bleeding risk identified by attending physician, age <18 yrs, and pregnancy.

Randomization was performed according to the Consolidated Standards for the Reporting of Trials (CONSORT) guidelines. A random allocation sequence was created using a computerized random number generator in Microsoft Excel. Simple randomization was done such that consecutively numbered cards with the flush assignment according to the randomization schedule written on the back of each card. The allocation sequence was concealed until the card was retrieved upon obtaining patient consent.

*Study Treatment and Procedures*. When consent was obtained within 12 hrs of CVC insertion, patients received either heparin (3 mL, 10 units/mL) or 0.9% NaCl (10 mL) flushes every 8 hrs (Table 1). There was no control for flush solutions received prior to enrollment and although the standard practice was saline flush, the use of heparin cannot be excluded. The assigned flush solution was entered into the electronic medication administration record and a sign with flush assignment was posted at the bedside. Needleless access devices were standardized to a luer activated device (SmartSite, Alaris, Care Fusion Corporation, San Diego, CA) for all study patients. This device requires clamping prior to flush syringe removal. Daily at 8:00 AM, one of the nurse investigators conducted a patency assessment for all lumens without a continuous or pressurized infusion. Daily at 4:00 PM and 12:00 AM, the patient's bedside nurse performed the patency assessments and documented results on a data collection sheet located at the patient's bedside. Therefore, three patency assessments per lumen assessment day were possible. These assessments were performed daily until the CVC was removed or until 1 day after the patient was transferred out of the ICU, whichever came first.

**Table 1.** Flushing procedure for each group

| 0.9% NaCl Flush Solution Group | Heparin Lock Flush Solution, United States Pharmacopeial 10 units/mL Group |
|---|---|
| Active lumen: 10 mL 0.9% NaCl, followed by intermittent infusion, followed by 10 mL 0.9% NaCl | Active lumen: 10 mL 0.9% NaCl, followed by intermittent infusion, followed by 10 mL 0.9% NaCl, followed by 3 mL heparin lock flush solution (10 units/mL) |
| Inactive lumen: 10 mL 0.9% NaCl every 8 hrs | Inactive lumen: 10 mL 0.9% NaCl, followed by 3 mL heparin lock flush solution (10 units/mL) every 8 hrs |

All bedside nurses were educated on study purpose, protocol, data collection, and the importance of adhering to regular flushing intervals, proper flushing/clamping sequence, and application of troubleshooting techniques when loss of patency was suspected. Prior to study initiation, the use of colored water in a demonstration-return demonstration technique was used to validate competency of correct flushing and clamping technique. Validation of proper flushing technique was not repeated throughout the study; however, we strived to incorporate this as standard work. Study information was provided during orientation for all new nurses during the data collection period. In addition, study investigators had daily contact with nurses throughout the study duration to provide reminders and study updates as well as verify nurses' understanding.

When a CVC lumen met criteria for nonpatency (as defined below), the nurse contacted the physician to decide whether or not restoration of lumen function would be attempted using Cathflo Activase (alteplase, Genentech, San Francisco, CA). When an order for alteplase was obtained, it was administered with a pulsatile technique and the volume instilled was based on dwell volume of the specific catheter lumen. After 30 mins, blood withdrawal was attempted. If unable to withdraw blood, the alteplase was allowed to dwell another 120 mins. If the lumen remained occluded, a second dose of alteplase was administered and the same process was followed. If blood return was obtained, 4–5 mL of blood was removed and wasted. The lumen was then irrigated with 10 mL of 0.9% NaCl followed by a heparin flush if the patient was in the heparin group.

During the study period, four different catheters were inserted for short-term use. Catheters included in the study were as follows: Arrow Triple lumen catheter 7F 20 cm (Teleflex, Limerick, PA); Arrow quad lumen catheter 8F 20 cm; Arrow pressure-injectable triple lumen power catheter 7F, 20 cm; Cook Spectrum minocycline/rifampin antibiotic impregnated pressure-injectable triple lumen power catheter 7F, 20 cm (CookMedical, Bloomington, IN); PreSep Central Venous Oximetry Catheter triple lumen 8.5F, 20 cm (Edwards Life Sciences LLC, Irvine, CA). The type of catheter inserted was selected by the inserter with consideration of need for number of lumens, antimicrobial properties, core venous oximetry, or pressure injector capability.

*Study Outcomes and Definitions*. The primary outcome of the study was rate of lumen nonpatency, defined as inability to both withdraw blood and flush through a lumen. Arrival at this end point occurred only after completion of the following interventions with the patency assessment: 1) if the lumen could not be flushed, the patient was repositioned and flush reattempted; 2) if still unable to flush, the needleless access device was changed and flush was reattempted. If the nurse could neither obtain blood return nor flush the lumen after these maneuvers, the lumen met criteria for nonpatency. Loss of blood return was defined as the inability to withdraw blood while maintaining the ability to infuse or flush through a lumen. Flush failure was defined as the inability to infuse or flush through a lumen prior to application of the aforementioned troubleshooting techniques.

As secondary outcomes, the frequencies of loss of blood return and flush failure were also assessed individually. Additional secondary end points were the rates of CR-BSI and HIT. HIT was considered confirmed when an enzyme-linked immunosorbent assay heparin-PF4 antibody assay was positive in the setting of a clinical picture consistent with HIT. Results of the following evaluations for venous thromboembolism were also recorded: Doppler ultrasonography of the

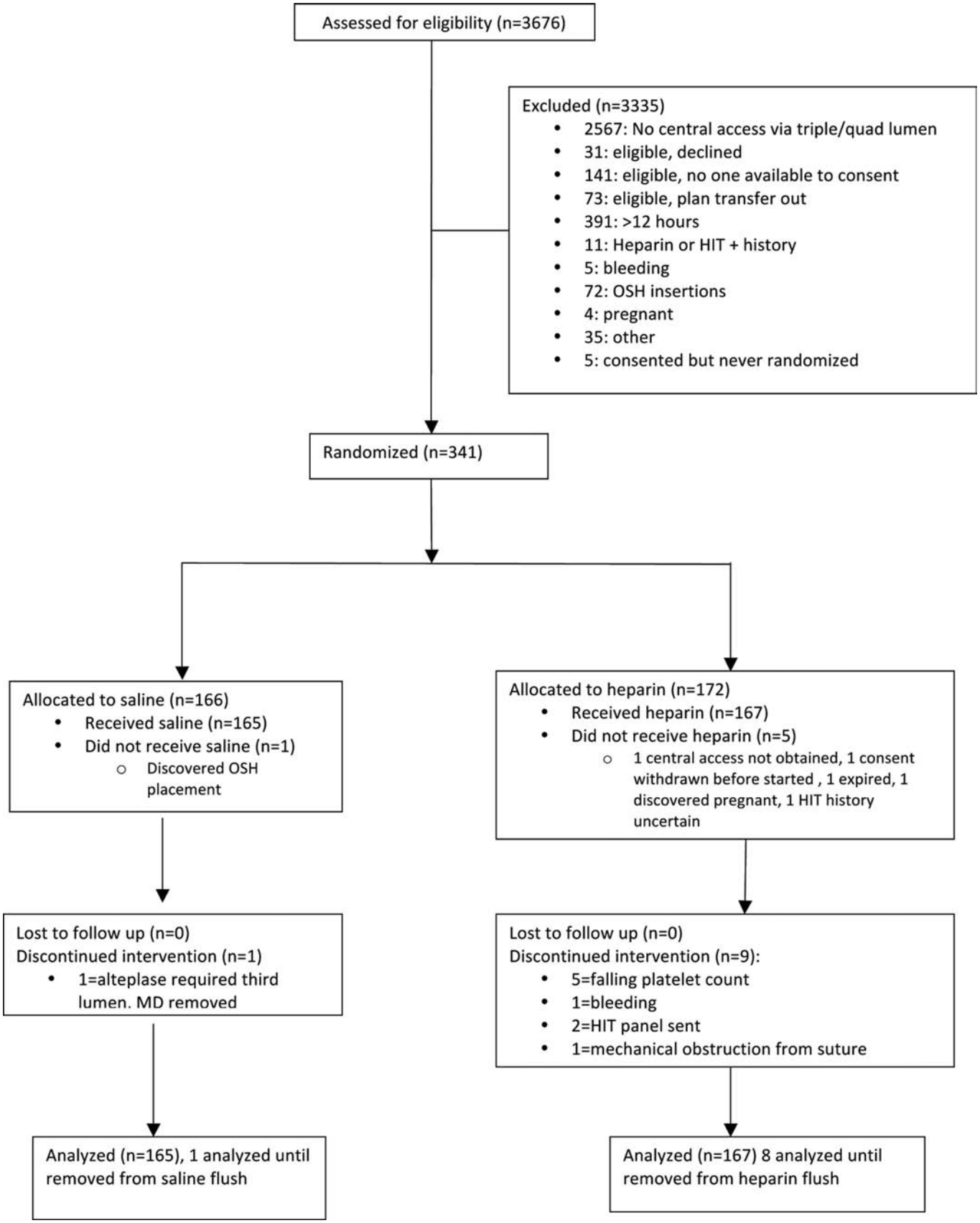


**Figure 1.** Patient enrollment, randomization, treatment, and disposition. *HIT*, heparin-induced thrombocytopenia; *OSH*, outside hospital; *MD*, medical doctor.

upper and/or lower extremities, computed tomography of the chest, or pulmonary ventilation-perfusion scanning. Administration of prophylactic and systemic anticoagulation was recorded daily. Catheter days were recorded for the entire catheter dwell time. Lumen assessment days included only the ICU time period and the following morning assessment if the patient transferred with the study catheter in place.

*Statistical Analysis*. Assumptions for the sample-size calculation were based on previous studies that compared heparin and 0.9% NaCl for arterial line patency. With catheter lengths >2 inches, catheters had an 89% patency rate at 72 hrs with saline flush (14). In addition, orders for alteplase compared to central line days in both units were assessed to determine overall occlusion rate for 6 months prior to the study with a combination of saline and heparin flush solutions in use for CVCs. Assuming a 10% lumen nonpatency rate in the 0.9% NaCl group, it was calculated that 684 lumens used for intermittent infusions would be needed to detect a 5% absolute difference in lumen patency in the heparin group compared with the 0.9% NaCl group, with 80% statistical power and a two-sided $\alpha$ value of 0.05. All outcome analyses were performed according to intention-to-treat principle. Data for patients who withdrew (Fig. 1) were censored at the time of the last study contact.

Differences between groups were assessed using the Student's *t* est, Mann-Whitney *U* test, the chi-square test, or the Fisher's exact test, as appropriate. All reported *p* values are two-sided and have not been adjusted for multiple comparisons. Kaplan-Meier curves were plotted to assess the time from enrollment to major and minor occlusion. All statistical analyses were performed using SPSS version 16.0 (SPSS, Chicago, IL).

## RESULTS

*Baseline Characteristics*. Over a 13-month time period, 3,676 patients were screened for eligibility, of which 341 patients were consented and randomized (Fig. 1). Centrally placed catheters not included in the study accounted for 919 patients excluded while 529 patients had a PICC. One thousand one hundred and nineteen patients had peripheral IVs only.

Among the randomized patients, 295 had at least 1 lumen with a minimum of two flushes and were therefore included in the analysis. This resulted in 326 catheters with 709 assessable lumens, 395 lumens in the 0.9% NaCl group and 314 lumens in the heparin group. Baseline demographics (Table 2) and catheter and lumen characteristics (Table 3) were similar between the two flush groups. Catheter days ranged from 1–27 days. Lumen assessment days ranged from 1–22 days with a range of 2–40 patency assessments. A total of 4.5% of patency assessments were not documented. There was no significant difference in missed assessments between flushing groups ($p = .213$). In the 34 nonpatent lumens, assessment immediately prior to nonpatent assessment was missed in 11 lumens. Six of the nonpatent lumens with a missed assessment were due to the patient being off the floor.

**Table 2.** Baseline characteristics

| Characteristic | 0.9% NaCl | Heparin | *p* |
|---|---|---|---|
| Patients | 150 | 145 | |
| Age (yrs) | 58.3 ± 17.5 | 59.1 ± 15.2 | .683 |
| Male | 83 (55.3%) | 68 (46.9%) | .147 |
| Race | | | |
| Caucasian | 105 (70.0%) | 101 (69.7%) | .552 |
| African American | 43 (28.7%) | 40 (27.6%) | |
| Other | 2 (1.3%) | 4 (2.7%) | |
| Intensive care unit | | | |
| Medical | 92 (61.3%) | 75 (51.7%) | .096 |
| Surgical | 58 (38.7%) | 70 (48.3%) | |
| Reason for intensive care unit admission | | | |
| Surgical, trauma | 12 (8.0%) | 12 (8.3%) | .913 |
| Surgical, nontrauma | 28 (18.7%) | 35 (24.1%) | .252 |
| Sepsis | 51 (34.0%) | 46 (31.7%) | .677 |
| Respiratory failure | 19 (12.7%) | 19 (13.1%) | .911 |
| Gastrointestinal bleed | 12 (8.0%) | 10 (6.9%) | .718 |
| Other[a] | 28 (18.7%) | 23 (15.9%) | .524 |
| Anticoagulation with heparin | | | |
| Prophylaxis | 77 (51.3%) | 73 (50.3%) | .865 |
| Therapeutic | 18 (12.0%) | 16 (11.0%) | .795 |
| Both | 13 (8.7%) | 16 (11.0%) | .495 |
| None | 68 (45.3%) | 72 (49.7%) | |
| Antiplatelet medication[b] | 46 (30.7%) | 42 (29.0%) | .750 |

[a]Arrhythmia (n = 1), burn injury (n = 1), cardiopulmonary arrest (n = 4), heart failure (n = 1), hypertensive emergency (n = 1), hypotension, nonsepsis (n = 5), intoxication (n = 7), kidney/pancreas transplant (n = 5), liver failure (n = 6), liver transplant (n = 4), metabolic disarray (n = 9), pancreatitis (n = 7); [b]antiplatelet medications included aspirin and clopidogrel.

*Outcomes*. The crude catheter nonpatency rate was 3.8% in the heparin group and 6.3% in the 0.9% NaCl group (RR 1.66, 95% confidence interval 0.86–3.22, $p = .136$, Table 4). The Kaplan-Meier analysis assessing probability of patency over 14 days was not significantly different (log rank = .093, Fig. 2) between groups nor was time to first loss of blood return (log rank = .051). The crude rate of loss of blood return was 22.3% in the heparin group and 27.8% in the 0.9% NaCl group (RR 1.25, 95% confidence interval 0.97–1.62, $p = .091$, Table 4). Pressure-injectable CVCs (Cook [Bloomington, IN] and Arrow [Limerick, PA] power) were found to have significantly greater rates of nonpatency (10.6% vs. 4.3%, p = .001) and loss of blood return (37.0% vs. 18.8%, p < .001) compared to nonpressure injectable catheters (Edwards [Irvine, CA] and Arrow).

Eight flush failures were resolved with troubleshooting techniques and thus did not represent a nonpatent lumen. For two patients in the heparin group who had CVCs meeting lumen nonpatency criteria, the physician elected to remove the catheter instead of administering a thrombolytic. Alteplase was used in all other lumens meeting nonpatency criteria. Patency including both blood return and ability to flush was reestablished with thrombolytic instillation in all cases.

*Safety*. An enzyme-linked immunosorbent assay heparin-PF4 antibody assay was ordered based on the suspicion for HIT in 10.7% of patients in the 0.9% NaCl group and in 16.6% of patients in the heparin group. All patients evaluated for HIT were receiving concomitant heparin either as a therapeutic or prophylactic dose. Enzyme-linked immunosorbent assay heparin-PF4 antibody assays were positive in two patients, both in the 0.9% NaCl group. Venous thromboembolism was identified in 10.7% of the 0.9% NaCl group and 13.1% of the heparin group. Eight patients were removed from the heparin group due to concerns for bleeding or HIT.

Four CR-BSIs occurred in the 0.9% NaCl group (3.1 per 1,000 catheter days [95% confidence interval 0.8–7.9]), compared with the heparin group (0 per 1,000

Table 3. Catheter and lumen characteristics

| Characteristic | 0.9% NaCl | Heparin |
|---|---|---|
| Catheters, no. | 170 | 156 |
| Catheter brand | | |
| Arrow | 95 (55.9%) | 83 (53.2%) |
| Arrow pressure injectable | 9 (5.3%) | 5 (3.2%) |
| Edwards | 14 (8.2%) | 8 (5.1%) |
| Cook pressure injectable | 52 (30.6%) | 60 (38.5%) |
| Catheter type | | |
| Triple lumen | 163 (95.9%) | 154 (98.7%) |
| Quad lumen | 7 (4.1%) | 2 (1.3%) |
| Catheter location | | |
| Femoral | 11 (6.5%) | 11 (7.1%) |
| Internal jugular | 112 (65.9%) | 85 (54.5%) |
| Subclavian | 47 (27.6%) | 60 (38.5%) |
| Catheter days | | |
| Total | 1300 | 1253 |
| Median | 7 | 7.5 |
| Mean | 7.6 ± 4.3 | 8.0 ± 4.0 |
| Lumens, no. | 395 | 314 |
| Lumen location | | |
| Proximal | 130 (32.9%) | 113 (36.0%) |
| Medial | 140 (35.4%) | 112 (35.7%) |
| Medial #2 (Quad lumen) | 6 (1.5%) | 2 (0.6%) |
| Distal | 119 (30.1%) | 87 (27.7%) |
| Lumen use | | |
| Intermittent infusion | 76 (19.2%) | 57 (18.2%) |
| Mixed – continuous/intermittent | 259 (65.6%) | 210 (66.8%) |
| Mixed – pressure/intermittent | 60 (15.2%) | 47 (15.0%) |
| Lumen assessment days | | |
| Total | 2472 | 2079 |
| Median | 5 | 6 |
| Mean | 6.3 ± 3.8 | 6.6 ± 3.7 |
| Flush attempts | | |
| Total | 2880 | 2362 |
| Median/lumen | 5 | 6 |
| Mean/lumen | 7.3 | 7.5 |
| Flush failures | | |
| Total | 35 (1.2%) | 20 (0.9%) |
| Median/lumen | 0 | 0 |
| Mean/lumen | 0.08 | 0.06 |
| Per 1000 lumen days | 14.2 | 10.1 |
| Withdrawal attempts | | |
| Total | 2880 | 2362 |
| Median/lumen | 5 | 6 |
| Mean/lumen | 7.3 | 7.5 |
| Withdrawal failures | | |
| Total | 369 (12.8%) | 308 (13.1%) |
| Median/lumen | 0 | 0 |
| Mean/lumen | 0.93 | 0.98 |
| Per 1000 lumen days | 149.3 | 148.4 |

Table 4. Primary outcomes

| Characteristic | 0.9% Sodium Chloride n = 395 lumens | Heparin n = 314 lumens | RR (95% Confidence Interval) | *p* |
|---|---|---|---|---|
| Nonpatency cap change followed by loss of blood return + flush failure | 25 (6.3% of lumens) | 12 (3.8% of lumens) | 1.66 (0.86–3.22) | .136 |
| Loss of blood return | 110 (27.8%) | 70 (22.3%) | 1.25 (0.97–1.62) | .091 |
| Alteplase | 25 (6.3%) | 9 (2.8%) | 2.19 (1.00–5.01) | .049 |

catheter days [95% confidence interval 0.0–2.9]); $p = .125$. All CR-BSI's were identified in patients with the nonantibiotic impregnated catheters.

## DISCUSSION

This study demonstrated no difference between heparin and 0.9% NaCl flushes on maintaining patency of short-term CVCs in adults. The results also demonstrated that simple nursing interventions such as position change and needleless access device change can sometimes correct loss of patency, thus eliminating the need for a thrombolytic or catheter removal.

Conflicting results were found in a randomized comparison of heparin (5000 IU/mL), Vitamin C (200 mg/mL), or 0.9% NaCl flush solutions used in the distal lumen only of 99 short-term, centrally placed triple lumen catheters (15). The distal lumen was used strictly for study purposes. Attempts to aspirate blood were performed every 2 days. If blood could not be withdrawn, the catheter was considered nonpatent. The authors observed a significant difference in catheter patency between the three groups ($p<.03$, log-rank test) and concluded that heparin was superior for maintaining catheter patency. One major difference in this study was the flushing frequency of every 48 hrs as compared to every 8 hrs, and may partly account for the different findings. Additionally, the previous study did not describe the flushing technique with regard to needleless access device or lumen cap. Finally, nonpatency was defined differently in the two studies.

A recent retrospective study compared the use of 0.9% NaCl (10 mL) flushes during a 2-month period to a 16-month period of heparin (10 units/mL, 5 mL) flushes for all short- and long-term use CVCs (16). This study reported significantly increased use of alteplase and a greater number of PICC replacements during the 2 months of 0.9% NaCl use. Information on catheters that required alteplase was not available and the reason for PICC replacement was not reported. The retrospective nature of the study and inclusion of all CVC types may limit the comparison of results with our study.

Systematic reviews of various CVCs, nontunneled, tunneled, implanted, and peripherally placed have demonstrated insufficient evidence for superiority of flushing with heparin compared to 0.9% NaCl, but with the caveat that the literature backing the statement is generally of low quality (3, 17, 18). Likewise, a Cochrane review that analyzed heparin-bonded catheters with nonheparin-bonded catheters found no significant difference in patency (19).

The impact of access devices on catheter patency has been researched in small studies with inconclusive results

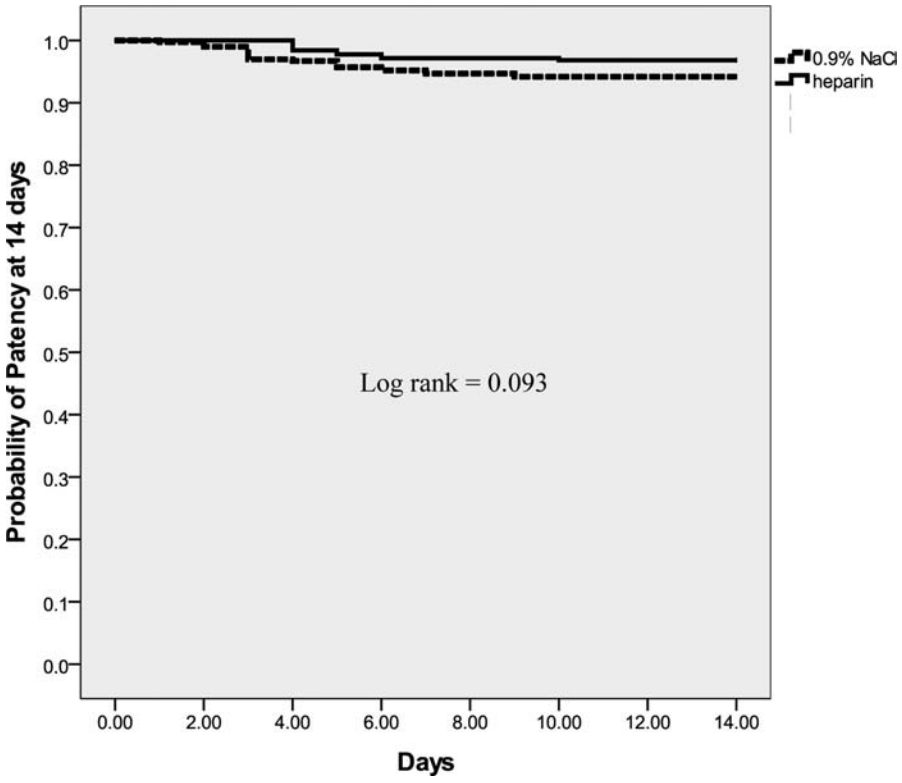


Figure 2. Probability of patency.

(2, 3). In this study, we chose to utilize only one needleless access device to minimize the potential for this to act as a confounding variable. Regardless of the access device used, the key aspect is knowledge of proper use. Proper flushing and clamping sequence is crucial to reduce blood reflux into the lumen to minimize the risk of clot formation and occlusion (2).

Based on the results of our study, the type of catheter may be an important variable in the loss of lumen patency. On account of multiple nurses observing a difference in ease and frequency of obtaining blood return between pressure-injectable and nonpressure-injectable catheters, a post hoc analysis was performed. Pressure-injectable catheters were associated with significantly higher rates of both lumen nonpatency and loss of blood return. While this finding is interesting to note, we consider it to be hypothesis generating given it was a subgroup analysis performed post hoc.

Several limitations of our study should be noted. First, the study investigators and bedside nurses were not blinded to the study interventions and thus the potential for bias cannot be eliminated. In the absence of prior studies establishing the rate of lumen nonpatency for short-term CVCs receiving saline flushes every 8 hrs, we based our sample size calculation on an estimated 10% occlusion rate, similar to that reported in a study of saline and heparin flushes for arterial line patency. The rate of lumen nonpatency in the 0.9% NaCl group was 6.3%, and therefore statistical power was reduced and we cannot rule out a small difference between groups. Another limitation is that 4.5% of flushes were not documented. It was impossible to determine if assessment was performed and just not documented with the missing flushes. It is feasible that a missed assessment led to lumen nonpatency, but establishment of a clear relationship is not possible. Lastly, initial validation of correct flushing technique was conducted upon study initiation and with all new nurses; however, no formal revalidation of proper flushing throughout the study was conducted. It is possible that proper technique was not used for all flushes and could have led to nonpatency; therefore, it is a limitation of the study.

A strength of our study is generalizability of the results because of the inclusion of both medicine and surgical patients and the high number of nurses in the two units (>140) implementing the study protocol. Given the low rate of nonpatency observed, it appears that practice standardization of proper flushing/clamping sequence performed every 8 hrs and inclusion of orders for catheter flushes on the medication administration record are worthwhile interventions to help maintain catheter patency.

## CONCLUSIONS

In conclusion, this study demonstrated no significant difference between heparin and 0.9% NaCl flushes with regards to catheter patency in adult patients with short-term use CVCs. Although measures of safety were similar between groups in this study, saline flushes may be preferred to reduce exposure to heparin and its potential complications. Regular intervals of flushing, proper flushing/clamping sequence, and troubleshooting techniques are likely the most important interventions to maintain catheter patency. Replication of this study at a different site is needed to confirm the findings. Furthermore, studies are needed with other CVC types including PICCs and long-term catheters.

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