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Improving Aseptic Technique During the Treatment of Pediatric Septic Shock

A Comparison of 2 Rapid Fluid Delivery Methods

Hillary Spangler, MD ● Mark Piehl, MD, MPH ● Andrew Lane, MS, BS ● Galen Robertson, MSME, BSME

ABSTRACT

Rapid fluid resuscitation is used to treat pediatric septic shock. However, achieving fluid delivery goals while maintaining aseptic technique can be challenging. Two methods of fluid resuscitation—the commonly used push-pull technique (PPT) and a new fluid infusion technique using the LifeFlow device (410 Medical, Inc; Durham, NC)—were compared in a simulated patient model. PPT was associated with multiple aseptic technique violations related to contamination of the syringe barrel. This study confirms the risk of PPT-associated syringe contamination and suggests that this risk could be mitigated with the use of a protected syringe system, such as LifeFlow.

Key words: aseptic technique, fluid resuscitation, infection control, LifeFlow, patient safety, push-pull technique, quality improvement, sepsis, syringes

American College of Critical Care Medicine (ACCM) guidelines recommend early and rapid fluid resuscitation as a key element of care in pediatric septic shock.[1] Adherence to fluid delivery guidelines has been shown to reduce mortality, organ dysfunction, and length of stay and to be a key driver of other components of sepsis bundles.[2-4] Unfortunately, fluid targets recommended in the Society of Critical Care Medicine/Pediatric Advanced Life Support guidelines and hospital sepsis protocols often are not achieved as a result of technical barriers to fluid delivery, including slow infusion rate and cumbersome methods.[2,5,6]

A common method of rapid fluid delivery in children is the push-pull technique (PPT), in which a syringe and a 3-way stopcock are used repeatedly to deliver 10-mL to 60-mL doses of fluid, until the desired resuscitation volume is achieved.[6-8] The PPT assembly is not purchased prepackaged; rather, it is assembled by a nurse using off-the-shelf components readily available in the hospital. The PPT offers a higher infusion rate than traditional alternatives such as an infusion pump or pressure bag, and in certain situations it can enable users to meet fluid resuscitation guidelines. Disadvantages of the PPT include complexity of set-up, the potential for user fatigue, difficulty tracking larger fluid volumes, and user

Author Affiliations: *Departments of Internal Medicine and Pediatrics, University of North Carolina (UNC) Health Care, Chapel Hill, North Carolina (Dr Spangler); 410 Medical, Inc, Durham, North Carolina (Dr Piehl, Mr Lane, and Mr Robertson); University of North Carolina School of Medicine, Department of Pediatrics, Chapel Hill, North Carolina (Dr Piehl); and WakeMed Health and Hospitals, Raleigh, North Carolina (Dr Piehl).*

Hillary Spangler, MD, *is a resident physician in the Departments of Internal Medicine and Pediatrics at University of North Carolina (UNC) Health Care. She received her medical training at UNC Chapel Hill. A pediatric sepsis survivor, Dr Spangler's clinical and research interests involve sepsis and quality improvement. She is also an active participant in UNC's Code Sepsis Initiative.* **Mark Piehl, MD, MPH,** *is a pediatric intensivist at WakeMed in Raleigh, North Carolina, and is a clinical associate professor in the Department of Pediatrics at the UNC School of Medicine. He received his MD and MPH degrees from UNC and is now chief medical officer of 410 Medical, Inc.* **Andrew Lane, MS, BS,** *is a mechanical engineer at 410 Medical, Inc. He has done research in ergonomics and human factors of medical devices, critical care, and robotics. He obtained a BS in biomedical engineering from UNC Chapel Hill and an MS in mechanical engineering from North Carolina State University.* **Galen Robertson, MSME, BSME,** *is a mechanical engineer and the chief operating officer at 410 Medical, Inc. He has been involved in research involving ergonomics and human factors of medical devices in critical care, general surgery, and robotics. He earned his BSME and MSME degrees from Georgia Institute of Technology in Atlanta.*

Dr Spangler has no conflicts of interest to disclose. Dr Piehl, Mr Lane, and Mr Robertson are employed by 410 Medical, the manufacturer of LifeFlow.

Corresponding Author: *Hillary Spangler, MD, University of North Carolina Hospitals, Internal Medicine-Pediatrics, 118 Knox Way, Chapel Hill, NC 27517 (hbspangler8@gmail.com).*

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errors, such as inadvertently withdrawing blood from the patient.[8] Another disadvantage is the risk of syringe contamination because the plunger is repeatedly exposed to the provider's hands and surrounding environment. Several studies have documented that bacteria are readily transferred from contaminated gloves into the fluid being infused.[9-11] Because the risk of contamination appears to be directly correlated with the number of strokes of the syringe plunger, PPT may be particularly likely to increase the risk of hospital-acquired infection. No study has rigorously documented how often users contact the syringe plunger while performing PPT.

LifeFlow (410 Medical, Inc; Durham, NC) is a manually operated device designed to deliver measured fluid boluses more rapidly and efficiently by using repeated and automatic filling of a 10-mL syringe enclosed within a single-use handle. While LifeFlow accomplishes faster flow compared with PPT or other common techniques, it also offers the advantage of fully protecting the sterile syringe plunger during use, potentially eliminating the nosocomial infection risk associated with repeated use of standard syringes.[12]

This study was conducted to compare aseptic technique compliance with 2 methods of rapid fluid resuscitation (PPT and LifeFlow) in a simulated pediatric patient with septic shock. Although there are several different techniques available for the infusion of fluids, LifeFlow was selected as the comparator for PPT because it is the only alternative fluid resuscitation technique that potentially offers a higher infusion rate and decreased contamination risk. The authors hypothesized that there would be fewer aseptic technique violations when using LifeFlow compared with PPT.

METHODS

Aseptic Technique Simulation

Because this single-center study was considered a quality improvement initiative, it was determined to be exempt from review by the local institutional review board. Study participants were pediatric critical care nurses with 8 to 36 years of experience who were asked to complete a standardized fluid resuscitation procedure at the Center for Innovative Learning at WakeMed in Raleigh, North Carolina. Nurses were asked to deliver a rapid infusion of 500 mL of saline using each of 2 methods: 1) PPT with a 20-mL syringe, and 2) the LifeFlow rapid infusion device. Participants were familiar with both methods before the study, and no additional training or instruction was provided. Fluid was infused through a 22-gauge catheter into the simulated 25-kg patient.

The PPT setup consisted of a 76-inch administration set (Baxter; Deerfield, IL), connected to a 4-way stopcock (B. Braun; Melsungen, Germany) with a 20-mL syringe (BD; Franklin Lakes, NJ) and 7-inch extension tubing (ICU Medical; San Clemente, CA). When the PPT system was assembled (Figure 1A), a bag of sterile saline was spiked and the distal end was connected to a 22-gauge catheter placed in the simulated patient. The LifeFlow Rapid Infusion System setup included a sterile administration set and handle (Figure 1B). The LifeFlow device was assembled according to the manufacturer's instructions.

All participants gave written consent and were informed that fluid resuscitation methods were being observed and video recorded. Nurses were specifically instructed to use aseptic technique for each given method; gloves and alcohol wipes were provided. Participants were asked to infuse the fluid as quickly as possible using the 2 methods and were not aware that observers would be assessing their compliance with proper aseptic technique.

Two independent observers with training in aseptic technique observed the simulation for each method and separately recorded the number of aseptic technique violations observed for each participant. Four categories of aseptic technique violations were tabulated: 1) failure to properly clean the needleless connector with an alcohol

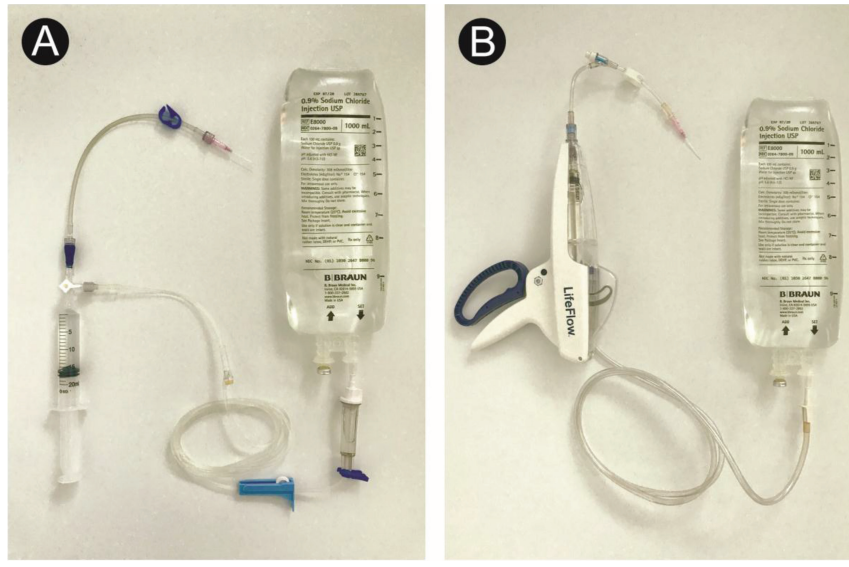

Figure 1 PPT and LifeFlow setup: A) PPT setup and B) Lifeflow setup. *Abbreviation: PPT, push-pull technique.* Courtesy of 410 Medical, Durham, NC.

wipe before connecting the administration set (*alcohol wipes*); 2) contamination of the sterile administration set by contacting a nonsterile surface (*tubing*); 3) hand contact with the sterile portion of the syringe plunger (*plunger contact*); and 4) any other violation of aseptic technique (*other*). If observers differed in the number of recorded aseptic violations, the numbers were averaged. The Fisher exact test was used to compare the number of users with aseptic technique violations by group, and the Mann-Whitney *U* test was used to compare the median number of aseptic technique violations by group. Statistical significance was set at $\alpha < .05$.

Benchtop Demonstration of Syringe Contamination

After completing the simulation, a second benchtop experiment was conducted to visualize the effects of potential aseptic technique violations during PPT syringe use. Photographs were taken under ultraviolet (UV) light during various stages of the 500-mL bolus (Figure 2). All images were taken through a UV filter to visualize only the fluorescent and not the UV light. Wearing clean gloves, an investigator applied a small drop of water with fluorescein (fluorescein sodium salt; GTI Laboratories Supplies, Houston, TX) to the tip of the gloved index finger a single

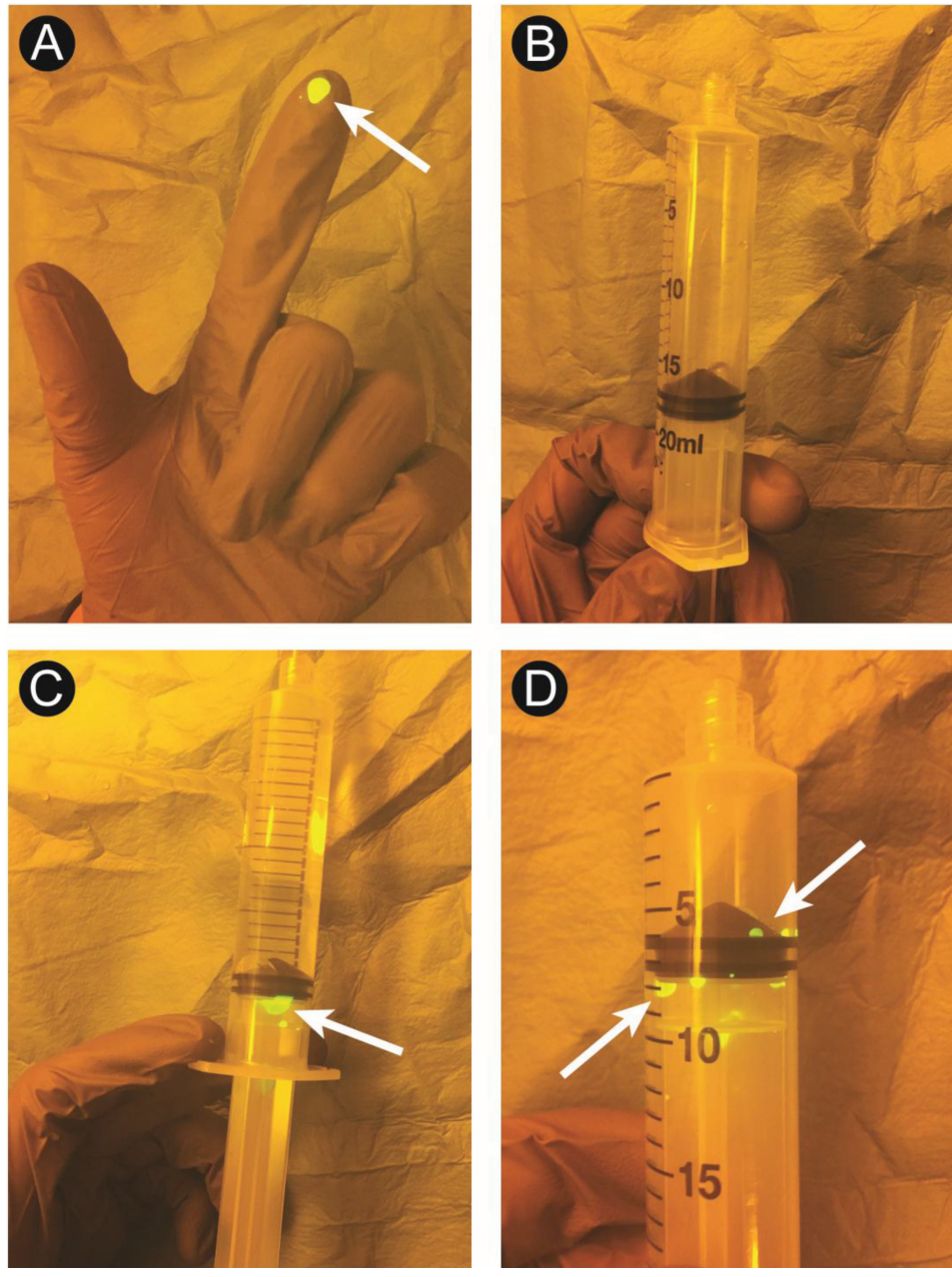

Figure 2 Simulated demonstration of potential syringe contamination during push-pull technique. Photographs were taken under UV light during various stages of the 500-mL bolus. All images were taken through a UV filter to visualize only the fluorescence and not the UV light: A) Initial placement of simulated contamination on glove. B) Syringe shown before use. C) Contamination from contact with plunger during initial stroke. D) Contamination observed on both sides of plunger after simulated 500-mL infusion. *Abbreviation: UV, ultraviolet.* Courtesy of 410 Medical, Durham, NC.

TABLE 1

Frequency Count of Aseptic Technique Violations During Simulated Fluid Resuscitation

Rapid Fluid Delivery Method	Participant	Violation Type and Frequency			
		Alcohol Wipes	Administration Set	Plunger	Other
Lifeflow	1	0	0	0	0
	2	0	0	0	0
	3	1	0	0	0
	4	0	0	0	0
Push-pull technique	1	0	0	25.0	0
	2	0	0	25.0	0
	3	0	0	16.5	0
	4	0	0	25.0	0

time (Figure 2A). The investigator then placed the index finger on a rib of the syringe plunger, as observed in the simulation (Figure 2B). After placing the droplet, the 20-mL syringe was cycled 25 times to simulate a single 500-mL bolus. The syringe was filled with water and then emptied immediately before the start of the test, so that small water droplets remained within the sterile portion of the syringe barrel. This was done to allow visualization of the fluorescein, if it were to travel across the plunger.

RESULTS

Aseptic Technique Simulation

During the PPT trials, there were on average 23 aseptic violations (median of 25) per study participant (n = 4) during the 500-mL infusion. All recorded violations for PPT were hand contact with the sterile portion of the plunger (*plunger contact*) (Table 1). Although it was not specifically quantified, it appeared that most of the contact occurred as the plunger was being retracted to refill the syringe.

In contrast, only 1 aseptic violation was observed by a single participant during the 500-mL infusion using LifeFlow. This violation resulted from failure to disinfect the tubing connection with an alcohol wipe before connecting to the catheter (*tubing*).

Evaluating only syringe plunger contamination, every user (n = 4) had repeated plunger violations using PPT; there were no instances of syringe contamination with the same users when they used LifeFlow ($P = .029$). The median number of violations for each user of LifeFlow was 0 versus 25 with PPT ($P = .029$) (Table 2).

Benchtop Demonstration of Syringe Contamination

In the benchtop experiment that followed the simulation, fluorescein was observed to pass across the plunger in enough quantity to be visible in water droplets on the inside of the syringe (Figures 2C and 2D). This benchtop experiment visually demonstrates that small particles of contamination can pass across the plunger during fluid delivery, as has been demonstrated in previous studies.[9]

DISCUSSION

All participants using PPT in the study inadvertently and repeatedly violated aseptic technique by contacting the sterile portion of the syringe plunger (see Figure 3 for areas of a syringe that should remain sterile and areas for potential contamination), highlighting the significant potential infection risk related to this frequently used practice. Interestingly,

TABLE 2

Summary of Syringe Aseptic Technique Violations During Simulated Fluid Resuscitation

Users	LifeFlow	Push-Pull Technique	*P* Value
Median number of aseptic technique violations per user (inner quartile range)	0 (0, 0)	25 (18.6, 25)	.029
Number of users with syringe aseptic technique violations	0	4	.029

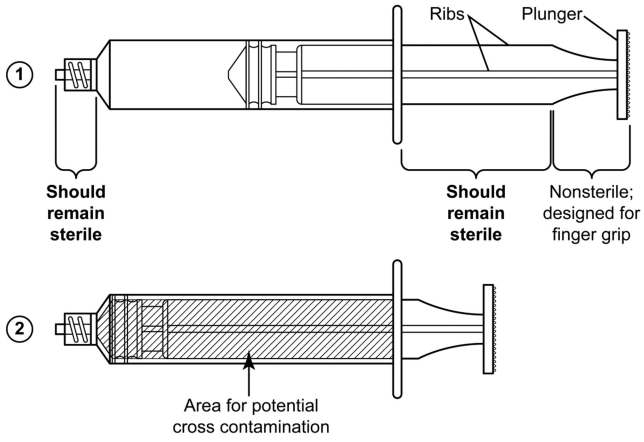

Figure 3 Syringe aseptic technique. Courtesy of 410 Medical, Durham, NC.

in several often-cited articles focusing on PPT as an optimal approach for fluid resuscitation, the same plunger rib contact violation observed repeatedly in this study can be seen in published images describing the technique.[6-8,13] Additionally, in how-to videos readily available on YouTube, this method of aseptic violation can be seen in at least 2 demonstration videos with combined views of 5000.[14,15]

The Centers for Disease Control and Prevention estimate that 250 000 catheter-related infections occur annually.[16] Catheter-associated infections account for approximately 10% of all hospital-acquired infections, resulting in significant morbidity and a mortality rate as high as 25%.[17,18] Given the known risk of introducing bacteria into a sterile syringe through contamination of the plunger, this study demonstrates that the PPT technique can represent a significant potential source of introducing infection. Although providers typically wear gloves while infusing fluid by means of PPT, the gloves are nonsterile, and previous studies have shown that contamination exists on more than 80% of gloves before they are removed from the box.[19,20]

Additional contamination may occur during fluid administration as providers contact the patient, bedsheets, monitors, and other items in the room while wearing gloves. This may be of particular concern for the patients who are at high risk for septic shock, including immunocompromised patients and those with chronic illnesses and/or indwelling catheters. Recent studies have shown that the use of manufacturer-prefilled syringes for flushing implantable vascular access devices reduces the risk of syringe contamination and bloodstream infection.[21,22] The use of a protected syringe, such as the LifeFlow system, would likely result in a similar infection reduction by preventing additional nonsterile contact with the plunger of the syringe.

CONCLUSION

Compared with PPT, LifeFlow is more effective at maintaining aseptic technique during rapid resuscitation, which has important implications for the treatment of pediatric sepsis. Additional studies investigating syringe contamination and the risk of infection for PPT are warranted.

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