LifeFlow®

Rethinking Pediatric Fluid Resuscitation

Addressing the Limitations of Current Rapid Fluid Delivery Techniques

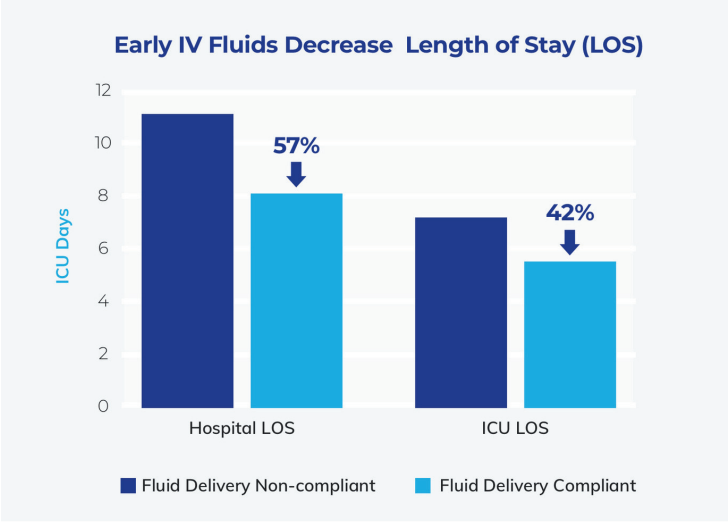
Executive Summary

Rapid fluid resuscitation is essential in the care of critically ill pediatric patients, especially those experiencing hypovolemic shock.[1] However, common methods of fluid delivery, such as the push-pull technique, often fall short of achieving timely and effective resuscitation as outlined by the recommended guidelines. This whitepaper thoroughly examines five primary infusion methods, highlighting their advantages and disadvantages, and discusses the LifeFlow Infuser, a compact, user-friendly solution that addresses the challenges faced by traditional methods. LifeFlow achieves the fastest fluid delivery, minimizes contamination risks, and maintains a high flow rate with small-gauge intravenous catheters.

Background

Rapid fluid resuscitation is an essential component of care for critically ill pediatric patients. Hypovolemic shock remains the most common type of shock in pediatric patients and carries life-threatening consequences if not treated immediately.[1] The mortality rate of pediatric patients presenting with shock is three times higher than those not in shock—regardless of whether their hypovolemia is due to trauma or another etiology like vomiting or diarrhea.[1] Pediatric patients can remain in a state of compensated shock much longer than adults.[2] However, due to their smaller overall blood volume, decompensated shock can quickly follow and lead to organ failure, tissue ischemia, and death.

Figure 1.



Percent decrease in LOS adjusting for PIM2 score at presentation and other co-morbidities.
Source: Paul, Raina, et al. "Adherence to PALS sepsis guidelines and hospital length of stay." Pediatrics (2012): peds-2012.

American College of Critical Care Medicine (ACCM) and Pediatric Advanced Life Support (PALS) guidelines note that *"early recognition and rapid intervention are critical to halting the progression from compensated shock to hypotensive shock to cardiopulmonary failure and cardiac arrest."*[3] However, early and effective fluid delivery is often not achieved when using the most common traditional methods of rapid infusion, including the push-pull method.[4]

ACCM and PALS guidelines specify that 20 ml/kg of crystalloid fluid should be administered within five minutes of septic shock or hypotension symptoms being identified, and up to 60 ml/kg of fluid can be administered within the first 15 minutes of care.[1] Both sets of guidelines advise administering 20 ml/kg fluid boluses until tissue perfusion is restored, followed by assessment after each bolus to monitor for signs of fluid overload.[1]

Numerous studies have documented that fluid resuscitation provided according to these guidelines improves mortality rates, shortens the length of stay, and decreases costs[5-17] (Figure 1). However, the literature also reveals that we are often unable to achieve the criteria outlined in PALS and ACCM guidelines due to the limitations of common fluid delivery methods.[17-21]

Review of Rapid Fluid Delivery Methods

Five primary infusion methods are commonly used in the pediatric hospital setting to rapidly deliver fluid and blood products—infusion pump, pressure bag, rapid infuser, LifeFlow, and syringe (push-pull). Each comes with practical concerns for efficiency and contamination. The following table highlights the important advantages and disadvantages of each of these methods (Table 1).

Infusion Method	Advantages	Disadvantages
LifeFlow	• Able to rapidly deliver bolus within recommended guidelines[22] • Delivers precise fluid volumes in 10mL increments • Highest flow rate with small-gauge catheters[23] • Minimizes infection risk and provider fatigue[24] • Easy set-up and one-handed operation	• Infusion requires physical effort
Pressure Bag	• Faster fluid delivery than infusion pump or gravity drip • No technology or expensive equipment required	• Difficult to give precise amounts of fluid and measure administered volume • Requires constant attention to maintain flow and mitigate risk of air administration • Significant set-up time • Poor flow rate in small-gauge catheters[23] • Infusion requires physical effort
Rapid Infuser	• Fastest method of fluid delivery once set up • Can be used with a warmer to manage hypothermia • Precise delivery of fluid volume	• Equipment is expensive and may not be accessible • Difficult to set up and requires staff with specific training • Requires dedicated staff member to run the rapid infuser • May function poorly with small-gauge catheters[23]
Syringe (Push-Pull)	• Able to rapidly deliver bolus within recommended guidelines[22] • Precise delivery of fluid volume • Works effectively with small-gauge catheters[23]	• Infusion requires physical effort • Introduces risk for contamination and infection[25] • Causes provider fatigue, which may decrease infusion rate[24] • Significant set-up time
Infusion Pump	• Precise delivery of set fluid volume • "Hands-off" infusion • Simple, routine set-up	• Maximum flow rate of 999 mL/hr • Unable to deliver bolus within recommended guidelines for patients weighing greater than 4.2kg[22] • Requires staff training to operate

Table 1. Advantages and Disadvantages of Common IV Rapid Infusion Methods

Push-Pull Method

When using the push-pull method to deliver a fluid bolus, a syringe is attached to the fluid bag using a three-way stopcock, allowing the staff member to pull fluids from the bag into the syringe and then push the fluids into the patient's intravenous (IV) line without disconnecting the syringe. Even without disconnecting, the push-pull method still presents a serious risk of contamination.

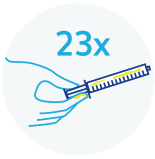
One study observing syringes inoculated with Bacillus bacteria found that two or more strokes of the plunger transported contaminants into the syringe's sterile chamber.[26]

Figure 3.

This poses a dangerous infection risk for the patient. Another study found evidence directly correlating the number of syringe aspirations with the degree of contamination.[24] To deliver a 900mL bolus (following 20 mL/kg guidelines for a 15kg patient), 30 push-pull cycles of a 30mL syringe are required. A 50kg patient receiving a 3000mL bolus requires 100 push-pull cycles. This pattern not only leads to provider fatigue and delayed fluid administration but also increases the risk of infection with each cycle[24](Figure 2).

Each year, more than 250,000 catheter-related bloodstream infections (CRBSIs) are estimated to occur in the U.S. alone.[27] These infections lead to significant morbidity and mortality, as well as increased healthcare costs.[28] But in an emergency when fluids are needed immediately, providers are more likely to touch the syringe plunger—whether due to fatigue, rushing, or for leverage to administer the fluids more quickly (Figure 3). Though inadvertent, each contact with the plunger presents a real risk for infection.

Each manual syringe stroke can introduce bacteria into the syringe barrel.[24,26,29]



When using push-pull, **providers often violate aseptic technique** – up to 23 times in one study.[25]

Syringes used multiple times on the same patient have been observed to have a **26.5% contamination rate**.[30]

Figure 2.

LifeFlow

The LifeFlow Rapid Infuser is a hand-operated device that solves challenges presented by traditional infusion methods to enable faster fluid delivery to critically ill patients. Its use is particularly impactful in pediatrics since it allows providers to deliver precise fluid volumes in 10mL increments and maintains a high flow rate in catheters of all sizes. LifeFlow takes just minutes to set up and minimizes contamination risks since providers do not need to touch the syringe during the infusion.

A recent study comparing the push-pull technique to LifeFlow found that providers in a simulated patient care environment touched the syringe plunger (plunger violations) an average of 22.8 times while administering the fluid bolus.[25] Providers using the LifeFlow handheld infuser had zero plunger violations (Figure 4).

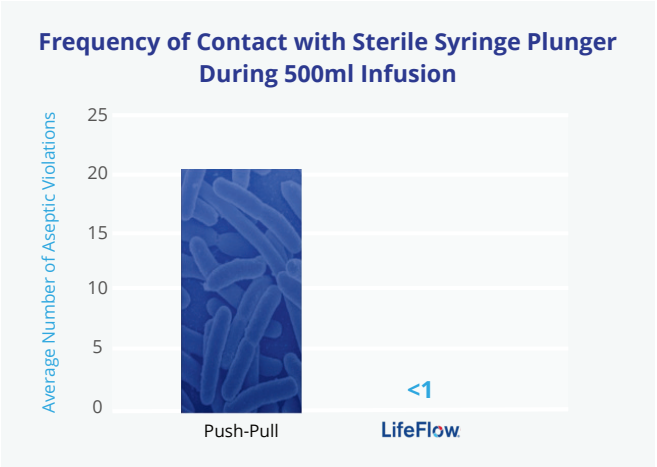


Figure 4.

Case Study

When Minutes Matter: Treating Pediatric Hypovolemic Shock, Part 1

An 8-month-old, 6 kg male with a history of premature birth presented to the ED with a two-week history of diarrhea and decreased oral intake. He had recently completed a course of antibiotics for otitis media. He had been to another local ED 3 days prior where his bloodwork was reassuring, with no indication of infection, but his mother had refused a catheterized urinalysis during that visit, so his urine was not tested. The infant had also been to his pediatrician within the last two weeks for the diarrhea. His pediatrician suspected that a milk protein allergy was causing his GI symptoms and had recently changed the infant's formula.

On the current presentation to the ED, this infant had a fever of 102.5 rectal, heart rate of 183, respiratory rate of 48, and O2 saturation of 98%. His skin was pink and his capillary refill was brisk. No blood pressure could be obtained in triage due to the infant's crying. His mother reported that over the last 24 hours he had been sleepier and fussier than usual and had fewer wet diapers than usual. His mother agreed to a catheterized urinalysis this time, which came back positive for a UTI. The infant received antipyretics, a total of 20 mls/kg normal saline bolus IV, and a dose of IV antibiotics in the ED, then was admitted to the pediatric floor for observation.

Soon after his transfer to the pediatric floor, the infant's nurse noted that the infant had dusky hands and feet, was mottled from head to toe, had delayed capillary refill, and had rigors. At that point, the infant's temperature was 101.3 rectal, his heart rate was in the 220s, and his respiratory rate was in the 70s. The infant was becoming irritable and difficult to console. His nurse was unable to obtain a blood pressure, likely due to poor perfusion and irritability. It was not clear whether the deterioration was related to sepsis or hypovolemia, but the infant was clearly deteriorating into decompensated shock; a PICU transfer was anticipated. In contrast to his ED presentation a few hours earlier, this time the infant was mottled and had delayed capillary refill.

The infant immediately received antipyretics and a total of two, 20 ml/kg rapid normal saline boluses within 5 minutes via the LifeFlow rapid infuser, including set-up time, with immediate improvement in his perfusion, his tachycardia and his tachypnea. *In contrast, the same volume administered at the highest speed by an IV pump would have taken almost 20 minutes including set-up time.* Immediately after the 40 ml/kg boluses, the infant had a temperature of 102 rectal, heart rate of 184, respiratory rate of 58, blood pressure of 99/59, and pulse ox of 99% on room air. Within minutes, the infant calmed and then tolerated oral fluids for the first time in several hours. He was able to avoid a PICU admission and remain on the pediatric unit until he was discharged home the next day. His blood culture was negative, and he went home on oral antibiotics for the UTI.

Conclusion

Research shows that the best outcomes for critically ill pediatric patients occur when shock and hypotension are managed early and effectively.[1] Rapid fluid resuscitation is key to preventing decompensated shock and life-threatening complications in pediatric patients presenting with hypovolemic shock. Traditional rapid infusion methods used in pediatrics often fail to meet established guidelines for time to bolus administration and introduce risks related to contamination and imprecise fluid administration.

LifeFlow is compact, inexpensive, and easy to use. The novel handheld device allows providers to accurately deliver a fluid bolus in a much shorter timeframe than traditional methods while maintaining a contaminant-free environment, answering the challenges of rapid infusion in pediatrics.

WANT TO LEARN MORE?

Watch a short video that demonstrates how easily a syringe can be contaminated.

https://410medical.com/applications/pediatric/

REFERENCES:

1. Pasman, E. (2019). Shock in Pediatrics. Retrieved at: https://emedicine.medscape.com/article/1833578-overview#a7
2. Emergency Nurses Association (2019). Emergency Nursing Pediatric Course Provider Manual Fifth Edition. Jones & Bartlett Learning. Des Plaines, IL.
3. Chameides L, Samson RA, Schexnayder S, Hazinski MF, eds. Pediatric Advanced Life Support Provider Manual. Dallas, TX: American Heart Association; 2016.
4. Piehl, M., Park, C.W. When Minutes Matter: Rapid Infusion in Emergency Care. Curr Emerg Hosp Med Rep 9, 116–125 (2021). https://doi.org/10.1007/s40138-021-00237-6
5. Akcan Arikan A, Williams EA, Graf JM, Kennedy CE, Patel B, Cruz AT. Resuscitation Bundle in Pediatric Shock Decreases Acute Kidney Injury and Improves Outcomes. J Pediatr. 2015;167:1301-1305 e1301.
6. Harvey G, Foster G, Manan A, Thabane L, Parker MJ. Factors affecting pediatric isotonic fluid resuscitation efficiency: a randomized controlled trial evaluating the impact of syringe size. BMC Emerg Med. 2013;13:14.
7. Balamuth F, Weiss SL, Fitzgerald JC, Hayes K, Centkowski S, Chilutti M, Grundmeier RW, Lavelle J, Alpern ER. Protocolized Treatment Is Associated With Decreased Organ Dysfunction in Pediatric Severe Sepsis. Pediatr Crit Care Med. 2016;17:817-822.
8. Carcillo JA, Davis AL, Zaritsky A. Role of early fluid resuscitation in pediatric septic shock. JAMA. 1991;266:1242-1245.
9. Carcillo JA, Kuch BA, Han YY, Day S, Greenwald BM, McCloskey KA, Pearson-Shaver AL, Orr RA. Mortality and functional morbidity after use of PALS/APLS by community physicians. Pediatrics. 2009;124:500-508.
10. Han YY, Carcillo JA, Dragotta MA, Bills DM, Watson RS, Westerman ME, Orr RA. Early reversal of pediatric-neonatal septic shock by community physicians is associated with improved outcome. Pediatrics. 2003;112:793-799.
11. Lane RD, Funai T, Reeder R, Larsen GY. High Reliability Pediatric Septic Shock Quality Improvement Initiative and Decreasing Mortality. Pediatrics. 2016;138.
12. Larsen GY, Mecham N, Greenberg R. An emergency department septic shock protocol and care guideline for children initiated at triage. Pediatrics. 2011;127:e1585-1592.
13. Leisman D, Wie B, Doerfler M, Bianculli A, Ward MF, Akerman M, D'Angelo JK, Zemmel D'Amore JA. Association of Fluid Resuscitation Initiation Within 30 Minutes of Severe Sepsis and Septic Shock Recognition With Reduced Mortality and Length of Stay. Ann Emerg Med. 2016;68:298-311.
14. Long E, Sabato S, Babl FE. Endotracheal intubation in the pediatric emergency department. Paediatr Anaesth. 2014;24:1204-1211.
15. Moresco BL, Woosley C, Sauter M, Bhalala U. Poor Compliance with Sepsis Guidelines in a Tertiary Care Children's Hospital Emergency Room. Front Pediatr. 2018;6:53.
16. Oliveira CF, Nogueira de Sa FR, Oliveira DS, Gottschald AF, Moura JD, Shibata AR, Troster EJ, Vaz FA, Carcillo JA. Time- and fluid-sensitive resuscitation for hemodynamic support of children in septic shock: barriers to the implementation of the American College of Critical Care Medicine/Pediatric Advanced Life Support Guidelines in a pediatric intensive care unit in a developing world. Pediatr Emerg Care. 2008;24:810-815.
17. Paul R, Neuman MI, Monuteaux MC, Melendez E. Adherence to PALS Sepsis Guidelines and Hospital Length of Stay. Pediatrics. 2012;130:e273-280.
18. Toshniwal G, Ahmed Z, Sengstock D. Simulated fluid resuscitation for toddlers and young children: effect of syringe size and hand fatigue. Paediatr Anaesth. 2015;25:288-293.
19. Auerbach M, Whitfill T, Gawel M, Kessler D, Walsh B, Gangadharan S, Hamilton MF, Schultz B, Nishisaki A, Tay KY, Lavoie M, Katznelson J, Dudas R, Baird J, Nadkarni V, Brown L. Differences in the Quality of Pediatric Resuscitative Care Across a Spectrum of Emergency Departments. JAMA Pediatr. 2016;170:987-994.
20. Inwald DP, Tasker RC, Peters MJ, Nadel S, Paediatric Intensive Care Society Study G. Emergency management of children with severe sepsis in the United Kingdom: the results of the Paediatric Intensive Care Society sepsis audit. Arch Dis Child. 2009;94:348-353.
21. Kessler DO, Walsh B, Whitfill T, Dudas RA, Gangadharan S, Gawel M, Brown L, Auerbach M, investigators II. Disparities in Adherence to Pediatric Sepsis Guidelines across a Spectrum of Emergency Departments: A Multicenter, Cross-Sectional Observational In
22. Stoner MJ, Goodman DG, Cohen DM, Fernandez SA, Hall MW. Rapid fluid resuscitation in pediatrics: testing the American College of Critical Care Medicine guideline. Ann Emerg Med. 2007;50:601-607.
23. Robertson, G., Lane, A., Piehl, M., Whitfill, T., & Spangler, H. (2018). Comparison of a Novel Rapid Fluid Delivery Device to Traditional Methods.
24. Olivier LC, Kendoff D, Wolfhard U, Nast-Kolb D, Nazif Yazici M, Esche Modified syringe design prevents plunger-related contamination–results of contamination and flow-rate tests. J Hosp Infect. 2003;53:140-143.
25. Spangler H, Lane A, Piehl M, Robertson G. Improving septic technique during the treatment of pediatric septic shock: A comparison of two rapid fluid delivery methods. Journal of Infusion Nursing. 2018: Accepted for publication: In Press.
26. Blogg CE, Ramsay MA, Jarvis JD. Infection hazard from syringes. Br J Anaesth. 1974;46:260-262.
27. O'Grady NP, Alexander M, Burns LA, Dellinger EP, Garland J, Heard SO, Lipsett PA, Masur H, Mermel LA, Pearson ML, Raad, II, Randolph AG, Rupp ME, Saint S, Healthcare Infection Control Practices Advisory C. Summary of recommendations: Guidelines for the Prevention of Intravascular Catheter-related Infections. Clin Infect Dis. 2011;52:1087-1099.
28. Maki DG, Kluger DM, Crnich CJ. The risk of bloodstream infection in adults with different intravascular devices: a systematic review of 200 published prospective studies. Mayo Clin Proc. 2006;81:1159-1171.
29. Chatrath M, et al. Intraoperative Contamination of Fluids by Anesthesia Providers. Presented at the 2012 Society of Pediatric Anesthesia.
30. Heid, Florian, et al. "Microbial contamination of anesthetic syringes in relation to different handling habits." American journal of infection control 44.3 (2016): e15-e17