ISSN: 2754-6667

Journal of Critical Care & Emergency Medicine

SCIENTIFIC Research and Community

Research Article

Open Access

When Time is of the Essence: Comparing Infusion Rates by Gravity, "Push-Pull" Technique and Pressure Bag Delivery

Fatima Ezzahra Amasloukh[1], Goh Ying Hong[2] and Fatimah Lateef[3]*

[1]7th Year Medical Student, Faculty of Medicine and Pharmacy of Casablanca, University Hassan II, Casablanca, Morocco

[2]Senior Executive, SingHealth Duke NUS Institute of Medical Simulation (SIMS), Singapore

[3]Senior Consultant, Dept of Emergency Medicine, Singapore General Hospital, Core Faculty, Emergency Medicine Residency, Sing Health, Professor, Duke NUS Graduate Medical School, Yong Loo Lin School of Medicine, National University of Singapore and Lee Kong Chian Medical School, Nanyang Technological University, Director, SingHealth Duke NUS Institute of Medical Simulation (SIMS), Faculty, Duke NUS Global Health Institute, Singapore

ABSTRACT

Background: Rapid infusion is a fundamental component of resuscitation in trauma, conditions such as shock, perioperative bleeding and sepsis. The ability to deliver fluids and blood products swiftly and safely often determines the outcome of critical cases. Rapid fluid administration will help to restore volume, augment cardiac output and reverse shock. It represents one of the early interventions that can help reduce mortality and morbidity. In most emergency situations, peripheral intravenous (IV) access provides the fastest and most practical route for initial resuscitation when central access or automated rapid infusers are not yet available. However, infusion rate through a peripheral line is affected by multiple mechanical and physical factors, such as bag height, tubing length, cannula gauge, external pressure, and fluid viscosity.

Objective: To compare the flow rates via three peripheral infusion techniques gravity flow, pressure-bag assistance, and push–pull syringe method, using both normal saline and simulated blood at two pole heights (1.85 m and 1.50 m).

Methods: Thirty-six bench-simulation trials were conducted in a controlled laboratory using an 18-gauge cannula, standard transfusion tubing, and a mannequin arm. Each combination of method, pole height, and fluid type was tested in triplicate (250 mL per run). Mean infusion times (seconds) and flow rates (mL/min) were recorded.

Results: Pressure-bag infusion produced the highest flow rate (**118 ± 27 mL/min**), significantly outperforming gravity (**36 ± 7 mL/min**) and push–pull syringe techniques (**31 ± 2 mL/min**) ($p < 0.001$). Raising the pole from 1.50 m to 1.85 m increased flow by 14–25%, depending on method. Saline infused faster than simulated blood (mean +23 mL/min, $p < 0.05$). The fastest combination was **Pressure Bag + High Pole + Saline (139.7 mL/min)**, and the slowest was **Gravity + Low Pole + Blood (26.7 mL/min)**.

Conclusion: External pressure and greater hydrostatic height substantially enhance infusion speed. Pressure-bag assistance offers a simple, effective solution when rapid infusion is required, particularly in emergency or low-resource settings.

***Corresponding author**

Fatimah Lateef, Senior Consultant, Dept of Emergency Medicine, Singapore General Hospital, Core Faculty, Emergency Medicine Residency, Sing Health, Professor, Duke NUS Graduate Medical School, Yong Loo Lin School of Medicine, National University of Singapore and Lee Kong Chian Medical School, Nanyang Technological University, Director, SingHealth Duke NUS Institute of Medical Simulation (SIMS), Faculty, Duke NUS Global Health Institute, Singapore.

Received: December 17, 2025; **Accepted:** December 24, 2025; **Published:** December 31, 2025

Keywords: Rapid Infusion, 'Pressure Bag' Infusion, Gravity Infusion, Simulation, Flow Rate, Viscosity, "Push-Pull" Technique

Introduction

Rapid infusion is a fundamental component of resuscitation in trauma, conditions such as shock, perioperative bleeding and sepsis. The ability to deliver fluids and blood products swiftly and safely often determines the outcome of critical cases [1-3]. Rapid fluid administration will help to restore volume, augment cardiac output and reverse shock. It represents one of the early interventions that can help reduce mortality and morbidity [4-6]. In most emergency situations, peripheral intravenous (IV) access provides the fastest and most practical route for initial resuscitation when central access or automated rapid infusers are not yet available [7-9]. However, infusion rate through a peripheral line is affected by multiple mechanical and physical factors, such as bag height, tubing length, cannula gauge, external pressure, and fluid viscosity [9-11].

Three main methods are commonly employed for peripheral infusion: **gravity infusion, pressure-bag assistance, and the push–pull syringe technique**. Gravity infusion relies solely on hydrostatic pressure created by elevating the fluid source above the patient. Pressure-bag infusion adds external compression,

thereby increasing the pressure gradient driving fluid through the system. The push–pull syringe method uses manual aspiration and injection through a three-way stopcock and is particularly useful in pediatric or low-resource settings. Although all three methods are routinely practiced, few studies have directly compared their performance under controlled laboratory conditions [12-16].

There are also other considerations when setting up infusions: [9,12,13,15].

- The setting up time
- The time taken to gather and assemble all the equipment needed
- Familiarity with the equipment/ set-up and
- Optimal functionality of the equipment

When considering infusion flow rates, the following factors are also often overlooked: [10,12,17-19].

- Resistance of the infusion lines
- Resistance of the catheter/ cannula (resistance will increase with increasing length/ resistance will also increase to the 4th power with decrease in radius of the catheter/ cannula)
- Viscosity of the fluid being delivered (eg. crystalloids, colloids, blood)
- Orientation of the catheter/ cannula as well as the presence of any kinks, bends or air bubbles
- Vessel wall damage/ Inflammation and phlebitis around the area of insertion (linked to inflammatory mediator release), and
- The percentage of the vessel lumen occupied by the catheter/ cannula From a physics perspective, two factors; hydrostatic head and fluid viscosity, are expected to influence flow rate substantially [19,20]. The other factors may have minor contributions and can be corrected by good practices when inserting catheters/ cannulae.

Blood, being more viscous (≈4–6 cP/ centiPoise) than saline (≈1 cP), encounters greater resistance within the IV tubing. In slow flow rate conditions, the viscosity will tend to increase. Raising the fluid bag's height increases the hydrostatic pressure, thus accelerating flow [18,21]. Despite these known principles, quantitative comparative data are scarce. Understanding these relationships can guide clinicians in optimizing infusion techniques, when seconds matter.

Simulation-based research offers a reproducible, low-risk platform to examine such mechanical parameters systematically. It enables investigators to isolate individual variable such as height, pressure, and viscosity while maintaining realistic clinical conditions [22-24].

Objective

The objectives of this study is to compare the flow rate performance of infusion by gravity, pressure-bag, and push–pull syringe techniques, at two pole heights (1.85 m and 1.50 m) using saline and simulated blood [25,26].

Hypothesis

Pressure-bag infusion would achieve the fastest flow rates, while saline would flow more rapidly than blood due to lower viscosity. Also, the higher pole height will facilitate flow rates.

Methodology

Study Design

An **experimental, comparative bench study** was performed in a clinical simulation laboratory to assess how infusion method, fluid type, and IV pole height influence infusion rates. The setup simulated peripheral infusion using standard equipment in a controlled environment. (Photos 1-4) No human participants were involved in the conduct of the experiment.

Equipment and Materials

The following represents the basic list of equipment for the conduct of the experiment:

Item	Specification / Description
IV cannula	18-gauge standard peripheral catheter
Infusion tubing	Standard blood transfusion set with drip chamber
IV pole	Adjustable (high = 1.85 m, low = 1.50 m from ground level)
Pressure bag	Manual infusion cuff, inflated to 300 mmHg
Syringe & stopcock	60 mL syringe with three-way stopcock
Simulated blood	0.9 % saline with red dye (viscosity ≈ 4 cP) (25, 26)
Normal saline	0.9 % sodium chloride (viscosity ≈ 1 cP)
Mannequin arm	Standard training arm with IV access port
Stopwatch	Digital precision timer (0.01 s accuracy)

Each trial used **250 mL** of normal saline or simulated blood, infused through the same cannula and tubing by a single operator to minimize variability. The simulated blood we used was True Clot, a blood simulated concentrate which comes as a pre-mixed liquid. It is safe and nonhazardous and can be washed off with soap and water. Alternatively, 'fake' blood can be made by mixing water with corn syrup in the appropriate ratio to achieve the right viscosity [25,26].

Experimental Variables

Two sets of variables were involved in the study:

Independent Variables

- Infusion method (Gravity / Pressure Bag / Push–Pull Syringe)
- Pole height (1.85 m high / 1.50 m low)
- Solution type (Normal saline / Simulated blood)

Dependent Variables

- Total infusion time (seconds)
- Flow rate (mL/min)

Experimental Procedure

Each combination of infusion method, pole height, and solution type was tested **in triplicate**, making up **36 trials** in total.

Gravity Infusion (Photo 1)

- The IV bag was suspended at either 1.85 m or 1.50 m.
- The roller clamp was fully opened.
- Timing began as the first drop entered the drip chamber and ended once 250 mL had infused completely.

Pressure-Bag Infusion

- The IV bag was placed within a pressure cuff inflated to 300 mmHg.
- The clamp was opened, and time was recorded using the same method.
- Each fluid type and height combination was tested three times.

Push–Pull Syringe Technique (Photo 2)

- A 60 mL syringe connected via a three-way stopcock was used to draw and push the fluid manually.
- The process continued until 250 mL was fully delivered.
- The same operator maintained consistent rhythm and force across all trials.

Outcome Measures

The Outcome Measures of the Experiment Included:

- **Primary Outcome:** Total infusion time (s).
- **Secondary Outcome:** Flow rate (mL/min), calculated as:

The flow rate was calculated as: (250/Time in seconds)/60
Observational data was also recorded for any complications (air entry, occlusion, leakage).

Data Analysis

In this study, descriptive statistics were expressed as **mean ± standard deviation (SD)** for each condition. A **three-way ANOVA** test evaluated the effects of infusion method, pole height, and fluid type, as well as their interactions [27]. When significant differences were detected, **Bonferroni-adjusted t-tests** identified specific group contrasts [28]. Statistical significance was defined as $p < 0.05$ and data analysis was performed using **Jamovi v3.0** software [29].

Ethical Considerations

The study, conducted in the simulation laboratory, used only simulation equipment and did not involve human or animal subjects; therefore, **ethical approval was not required.** All testing followed institutional safety as well as laboratory standards.

Results

A total of **36 trials** were performed under standardized laboratory conditions. Each configuration (3 methods × 2 pole heights × 2 fluids) was repeated three times. The mean infusion times and calculated flow rates are presented below.

Method	Pole Height	Solution	MeanTime(s)	Flow (mLmin)
Gravity	1.85 m	Saline	300.7	44.1
Gravity	1.50 m	Saline	434.3	34.6
Gravity	1.85 m	Blood	364.3	41.2
Gravity	1.50 m	Blood	563.0	26.7
Pressure Bag	1.85 m	Saline	107.7	139.7
Pressure Bag	1.50 m	Saline	120.7	124.0
Pressure Bag	1.85 m	Blood	142.0	105.5
Pressure Bag	1.50 m	Blood	204.0	73.5
Push–Pull Syringe	1.85 m	Saline	437.0	34.3
Push–Pull Syringe	1.50 m	Saline	460.0	32.6
Push–Pull Syringe	1.85 m	Blood	514.0	29.2
Push–Pull Syringe	1.50 m	Blood	524.0	28.7

Pressure-bag Infusion Achieved the Highest Mean Flow (118 ± 27 mL/min), significantly greater than both gravity (36 ± 7 mL/min) and push–pull syringe methods (31 ± 2 mL/min) ($p < 0.001$). Raising the pole increased flow by up to 25%, most notably for gravity infusion. Saline consistently flowed faster than simulated blood ($p < 0.05$), in view of the lower viscosity. No leakage or occlusion was observed.

Discussion

Rapid infusion of fluid/ blood products is to restore intravascular volume, correct hypotension from a variety of causes, improve organ perfusion and reduce likelihood of cardiovascular collapse from under-filling. Setting up infusions after getting vascular access is one of the fundamental steps in the resuscitation of patients. However, barriers do exist. These would include difficult or challenging venous access, inadequate or inappropriate resources, lack of skills on the part of the operator and slow infusion methods. All these can limit effective resuscitation [2,3,7,8,30].

In the resuscitation literature, 'rapid infusion' is often recommended [1,2,31,32]. How rapid is 'rapid' ? There is no strong consensus opinion pertaining to this, nor the optimal rate of infusion. Also, does 'rapid infusion' means large volume of fluid delivery ?. At times, an initial small volume of fluid is able to contribute towards initial stabilization, which can then be followed by progressive titratable volume [6,31]. However, in conditions of ongoing losses and severe haemorrage, large volumes will be required [1,2,25].

There are some guide and recommendations available for fluid resuscitation in shock. For Example:

- 1000 mls over 10-20 minutes (Critical Care and Emergency Medicine text) [33].
- 500 mls in under 30 mins for shock (European Society for Intensive Care Medicine) [34].
- 4 ml/kg over 10 mins (International Fluid Academy) [35].
- 2 litres of crystalloids for trauma patients in shock (ATLS) [36].

These seem to be relatively flexible, not strongly evidence-based recommendations and thus, may not be strictly adhered to in practice.

Our study demonstrates that **Pressure-bag–Assisted Transfusion Markedly Enhances Peripheral Flow**, outperforming both gravity and manual syringe methods. The improvement results from an increased pressure gradient maintained throughout the infusion, consistent with Poiseuille's law and prior clinical observations.

Poiseuille's law states: [17,37,38]

$$\text{Flow} = \frac{\pi \text{ X Pressure X Radius}^4}{8 \text{ X Viscosity X Length of Tubing}}$$

It essentially means that the laminar flow of fluid in a tubing is proportional to the pressure difference and the radius of the tubing to the 4th power. It is also inversely proportional to the length of the tubing and the viscosity of the fluid [17,38] The tubing here refers to the infusion tubing used in clinical settings. The radius is represented by the gauge size of the catheter or cannula [37,38].

Pole height significantly affected both gravity and pressure-bag performance. Increasing the height from 1.50 m to 1.85 m improved flow by 12–44%, confirming that hydrostatic head directly influences velocity or the flow rate. Even simple adjustments such as raising the IV pole can therefore meaningfully accelerate infusion rates in emergency contexts.

The viscosity effect was also evident, as simulated blood had slower flow than saline across all configurations. Whole blood's higher viscosity (4–6 cP vs 1 cP) increases internal friction and resistance within the tubing. This mechanical limitation underscores the need to anticipate delays when transfusing packed cells, particularly through small-gauge cannulas [15,18,20,21].

Our findings align with prior reports showing that pressure infusers can achieve 3–4 times the flow rate of gravity alone infusion [15,21,39]. The inclusion of the push–pull syringe method adds comparative value for low-resource or pediatric contexts where mechanical devices may not be available. Although slower, the method remains feasible and controlled [16,21].

Infusion by Gravity

This is the commonest infusion technique and is highly dependent on the catheter luminal diameter, tubing length as well as the extremity/ arm position/ posture. This is where Poiseuille's law (see above) applies. Larger bore and shorter length cannula will increase rate of fluid flow [38]. With reference to Fig 1 and Table 1, choice of cannula size is important when administering fluid, drugs or blood products. Factors such as: [9,14,21]

- Duration cannula will be used (eg. hours versus days)
- Condition being managed eg. resuscitation versus routine fluid maintenance
- Rapidity of delivery or the flow rate required
- Concentration of solution being delivered eg. hypertonic solution should have a larger bore cannula via a larger vein such as one in the ante-cubital fossa
- Use of blood products, where a larger gauge cannula is recommended
- The commonly used cannula sizes, the average flow rate and common uses are referred to in Table 1. It is also important to take note that the use of needleless Luer connectors with the cannula does add additional resistance and thus, decrease the flow rate further [40,41].

Pressure Bag Infusion

The use of pressure cuff or bag is to increase the speed of infusion. However, this method may require continuous re-inflation of the cuff to maintain flow since the applied pressure quickly diminishes as fluid volume decreases. The pressure cuff is usually inflated to 300 mmHg. With this method, the amount of time required for set-up of the IV access, maintaining constant pressure and performing bag changes during resuscitation, must not be underestimated [5,10,35].

Manual Syringe Infusion ("Push-Pull Technique)

This method is often used on urgent conditions, especially when rapid infusers or large bore cannula are not available. Typically, a syringe is connected via a three-way stopcock, which enables fluid to be repeatedly withdrawn from a fluid reservoir and then administered to the patient. This method does require one to be alert and attentive. It is a two-handed operation and distraction and fatigue can set in. There is also a small risk of nosocomial infection through repeated contamination of the exposed syringe plunger [14-16,42] . (Photo 2)

Other Considerations

Infusion pumps are now more commonly available. The maximum flow rate is usually 1000 ml/hr. This would be too slow for acute correction of hypotension or resuscitation. The availability of these pumps can result in "hands-off" fluid infusion where during the salvage phase of resuscitation, the pump is left running automatically and "forgotten". This may lead to a small risk of fluid overload or over-delivery of fluid, especially in susceptible patients [10,19,43]. Rapid infusion devices can also cause subcutaneous extravasation and catheter/ cannula dislodgment. Larger cannula may cause vessel wall damage, if not carefully inserted. Infusion of blood products though cannula can also have effect such as hyperkalemia from hemolysis, especially with smaller gauge cannula [38].

Educational Value

The study exemplifies how simulation can serve as a bridge between theoretical fluid dynamics and practical infusion technique. Controlled laboratory conditions allowed reproducible testing without risking actual patients, whilst reinforcing key physiological principles [22,24].

Limitations

It is important to be aware that laboratory models cannot fully replicate venous compliance, patient movement, or thermodynamic factors. Only one cannula size was used and one operator conducted all the tests. However, internal consistency and clear differences between conditions strengthen the validity of the results.

Our study did not incorporate peripheral intravascular pressure; however, this was relatively constant in view that the same cannula and same mannikin arm was used for all the experiments [44]. Neither did we incorporate the friction forces within the tubing in our calculations. For a more comprehensive flow analysis, Bernoulli's equation may also be considered in future studies [45]. The effect of temperature on fluidity is also another variable to consider [46].

Future Directions

Further research should examine larger-bore cannulas, pressure variations beyond 300 mmHg, and integration with blood-warming systems available today. Multi-center simulation studies using standardized infusion templates could also enhance reproducibility and global training impact.

Conclusion

Pressure-bag assistance significantly increases infusion speed through a peripheral 18G cannula compared to gravity or push–pull methods. Raising the pole height from 1.50 m to 1.85 m and using less viscous fluids further improve flow. These findings support simple, practical measures, such as applying pressure, elevating the bag, and anticipating viscosity as vital steps to optimizing infusion efficiency in emergencies.

Simulation provided a controlled and clinically relevant platform for systematically evaluating these mechanical factors without patient risk. The consistency observed across all trial conditions supports the validity of the findings and highlights the value of simulation for both research and procedural training [22-24].

In emergency or low-resource environments where access to automated infusion systems may be limited, the practical measures examined in this study offer effective, readily implementable strategies to improve transfusion efficiency. Further research should explore wider pressure ranges, larger catheter diameters, and integration with warming or rapid infusion systems. Expanding this model through structured multicenter simulation frameworks, may facilitate broader adoption and guide training in evidence-based transfusion practice.

Photo 1: Conduct of the Simulated Experiment in the Laboratory using Normal Saline and Simulated Blood.

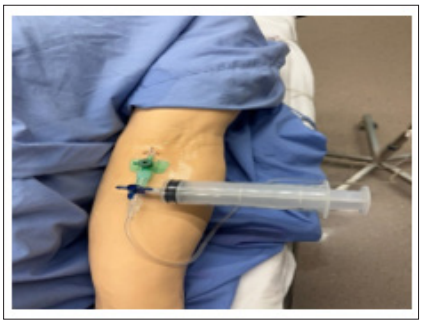

Photo 2: Infusion of Saline Via the "Push-Pull" Technique

Photo 3: Infusion of Simulated Blood Via the "Push-Pull" Technique

Photo 4: The Equipment used for the Experiment: Including Simulated Blood and Pressure Bag.

Figure 1: Cannulae Size and Flow Rates

Table 1: Commonly Used IV Canula Sizes and Flow Rates

Cannula Size (Gauge)	Flow Rate in ml/min (byManufacturer)	OuterDiamater(mm)	Common Uses
24G	22	0.7	Neonates, fragile veins, low flow rate needed
22G	35	0.9	Elderly, paediatric patients, slower in-fusion
20G	60	1.1	Routine mainte-nance fluid, medica-tion delivery
18G	105	1.3	Blood transfusion, fluid esuscitation
16G	196	1.7	Surgery, rapid vol-ume replacement

References

1. Cannon JW (2018) Hemorrhagic shock. N Engl J Med 378: 370-379.
2. Kaur P, Basu S, Kaur G, Kaur R (2011) Transfusion protocol in trauma. Journal of Emergencies Trauma and Shock 4: 103-108.
3. Dalinger RP, Levy MM, Rhodes A, Annane D, Gerlach H, et al. (2013) Survising sepsis campaign: International guidelines for management of severe sepsis and septic shock. Crit Care Med 41: 580-637.
4. Spaite DW, Hu C, Bobrow BJ, Chikani V, Sherrill D, et al. (2017) Mortality and prehospital blood pressure in patients with major traumatic brain injury: implications for the hypotension threshold. JAMA Surg 152: 360-368.
5. Malbrain MLNG, Van Regenmortel N, Saugel B, De Tavernier B, Van Gaal PJ, et al. (2018) Principles of lfluid management and stewardshipin septic shock: Its time to consider the four Ds and the 4 phases of fluid therapy. Ann Intensive care 8: 66.
6. Vincent JL (2019) Fluid management in the critically ill. Kidney Int 96: 52-57.
7. Meyer DE, Vincent LE, Fox EE, Keeffe OT, Inaba K, et al. (2017) Every minute counts: time to delivery of inital massive transfusion cooler and its impact on mortality. J Trauma Acute care Surg 83: 19-24.
8. Leisman DE, Doerfler ME, Sneider SM, Masick DK, A D'Amore J, et al. (2018) Predictors, prevalance and outcomes of early crystalloid responsiveness amongst initially hypotensive patients with sepsis and septic shock. Crit Care Med 46: 189-198.
9. Cook LS (2007) Choosing the right IV catheter. Home Healthcare Nurse 25: 523-533.
10. Zingg W, Pitt D (2009) Peripheral venous catheter: an under-evaluated problem. Int J Antimicrob Agents 34: 538-542.
11. Atanda D, West J, Stables T, Johnson C, Merrifield R, et al. (2023) Flow rate accuracy of infusion devices within healthcare settings: a systematic review. Ther Adv Drug Saf 14: 20420986231188602.
12. Yamaguchi K, Doi T, Muguruma T, Nakajima K, Nakamura K, et al. (2022) A simulation study of high flow versus normal flow 3-way stop-cock for rapid fluid administration in emergency situations: a randomized crossover design. Australian Crit Care 35: 66-71.
13. McQueen MJ (2009) Manual push–pull transfusion technique in pediatric resuscitation. Pediatr Emerg Care 25: 183-187.
14. Grossberg AJ, Fowl DA, Merritt BT, Nackley MG, Savona CL, et al. (2024) Comparing the push-pull technique to pressure bag for administration of blood products: a prospective non blinded observational simulation-based study (CoPP toP Study) Journal of Emergencies, Trauma and Shock 17: 208-211.
15. Cohn SM, DuBose J, Kansas E, et al. (2001) Effective flow rates in gravity-fed IV systems. J Trauma 51: 1039-1043.
16. Singh A, Patel N, Roy S, et al. (2014) Manual syringe-assisted transfusion technique in pediatric resuscitation: efficacy and safety analysis. Pediatr Emerg Care 30: 95-100.
17. Reddick AD, Ronald J, Morrison WG (2011) IV fluid resuscitation: Was Poiseuille right ? Emergency Med J 28: 201-202.
18. Ko E, Song YJ, Choe K, Park Y, Yang S, et al. (2022) The effects of IV fluid viscosity on the accuracy of IV infusion flow regulators. J Korean Med Sci 37: e71.
19. Park YG, Kim JY, Yang DW, Lee S, Park P, et al. (2025) Accuracy of Gravity-Based Automatic Infusion System for Chemoport Intravenous Infusion. Med Devices (Auckl) 18: 271-280.
20. Kim N, Lee H, Han J (2024) Comparison of fluid flow rates, fluid height and catheter size in normal and hypotensive blood pressure scenarios. Healthcare 12: 2445.
21. Royer TJ, Kee C, Gagnon D, et al. (2012) Maximum flow rates achievable through peripherally inserted central and peripheral IV catheters: impact of fluid viscosity and pressure. J Vasc Access 13: 271-277.
22. Motola I, Devine LA, Chung HS, Sullivan JE, Issenberg SB (2013) Simulation in healthcare education: a best-evidence practical guide. Med Teach 35: e1511-e1530.
23. Lateef F (2010) Simulation based learning: Just like the real thing. Journal of Emergencies, trauma and Shock 3: 348-352.
24. Lateef F (2025) Informal and Non-Formal Faculty Development in Emergency Medicine: What Does It Take to Uplift Recognition. J Case Rep Rev Med 1: 1-7.
25. True Clot. Simulated Blood Concentrate. Available at https://trueclot.com.
26. (2015) Science Buddies. Fake Blood made scientific, Available at: https://www.scientificamerican.com/article/fake-blood-made-scientific/.
27. How to perform a 3-way ANNOVA. Laerd Statistics. Available at: https://statistics.laerd.com.
28. Hayes Adams. Bonferroni Adjusted t-test. What is Bonferroni cottrvyion test and how is it used/. Available at: https://www.investopedia.com.
29. Janovi version3.0 For Windows. Available at: https://www.janovi.org.
30. Elad D, Zaretsky U, Heller O (1994) Hydrodynamic evaluation of intravenous infusion systems. Ann Emerg Med 23: 1284-1289.
31. Elmer J, Brown F, Martin-Gill C, Guyette X F (2020) Prevalence and predictors of post intubation hypotension in prehospital trauma care. Prehosp Emerg Care 24: 461-469.
32. Hoeller JG, Bech CN, Henriksen DP, Mikkelsen S, Pedersen C, et al. (2015) Non traumatic hypotension and shock in the ED and prehospital setting, prevalence, etiology and mortality: a systematic review. PLoS One 10: e0119331.
33. Tintinnali JE, Stapczynski JS, Mah OJ, Meckler DG, Stapczynski JS, et al. (2019) Tintinnali EM: A comprehensive Study Guide: 9th Ed. New York: McGraw Hill Education/Medical p2192.
34. Cecconi M, DeBacker DAntonelli M, Beale R, Bakker J, et al. (2014) Consensus on circulatory shock and haemodynamic monitoring: taskforce of the European Society of Intensive Care Med. Intensive Care Med 40: 1795-1815.
35. Malbrain MLNG, Langer T, Annane D, Gattinoni L, Elbers P, et al. (2020) IV fluid therapy in the perioperative and critical care settings: executive summary of The IUnternational Fluid Academyu. Ann Intensive Care 10 :64.
36. (2018) College of Surgeons. ATLS®: Advanced Trauma Life Support® Manual. 10th ed. Chicago, IL. https://cirugia.facmed.unam.mx/wp-content/uploads/2018/07/Advanced-Trauma-Life-Support.pdf.
37. Pfitzner J (1976) Poiseuille and his law. Anaesthesia 31: 273-275
38. David J, Berner D, Schiavi A et al. (2020) Factors that influence flow through intravascular catheters: The clinical relevance of Poiseuille Law. Transfusion 60: 1410-1417.
39. Nifong TP, McDevitt TJ (2011) The effect of catheter to vein ratio on blood flow rates in a simulated model of peripherally inserted CVC. Chest 140: 48-53
40. Niel-Weise BS, Daha TJ, van der Broek PJ (2006) Is there evidence for recomending needleless closed catheter access options in guidelines? A systematic review of randomized controlled trials. J Hosp Infect 62: 406-413.

41. Rosenthal VD (2020) Clinical impact of needle-free connector design: a systematic review of the literature. J Vasc Access: 1129729820904904.
42. Nakae H, Omokawa S, Asanuma Y, Igarashi T, Tajimi K, et al. (2006) Study of safe usage of high flow three- way stopcocks in a blood circuit. Ther Apher Dial 10: 436-440.
43. Butler FK JR, Holcomb JB, Shackleford SA (2018) Advance resuscitative care in tactical combat casualty care: TCCC Guidelines change. J Spec Oper Med 18: 37-55.
44. Khoyratty SI, Gajendragadkar PK, Polisetty K, Ward S, Skinner T, et al. (2016) Flow rate through IV access devices: an invitro study. J Clin Anesth 391: 101-105.
45. Qin RQ, Duan CY (2017) The principle and applications of bernoulli's Equation. J Physics Conf Series 916: 012038.
46. DeFreitas Fonseca M, Andrade CM Jr, De mello MJE (2011) Effects of temperature on fluidity of irrigation fluid. Br J Anaesth 106: 51-56.