ORIGINAL ARTICLE

Vasopressor Administration via Peripheral Intravenous Access for Emergency Department Stabilization in Septic Shock Patients

Scott Kilian[1], Aaron Surrey[2], Weston McCarron[3], Kristen Mueller[4], Brian Todd Wessman[5]

Abstract

Background: Septic shock is commonly treated in the emergency department (ED) with vasopressors. Prior data have shown that vasopressor administration through a peripheral intravenous line (PIV) is feasible.

Objectives: To characterize vasopressor administration for patients presenting to an academic ED in septic shock.

Materials and methods: Retrospective observational cohort study evaluating initial vasopressor administration for septic shock. ED patients from June 2018 to May 2019 were screened. Exclusion criteria included other shock states, hospital transfers, or heart failure history. Patient demographics, vasopressor data, and length of stay (LOS) were collected. Cases were grouped by initiation site: PIV, ED placed central line (ED-CVL), or tunneled port/indwelling central line (Prior-CVL).

Results: Of the 136 patients identified, 69 were included. Vasopressors were initiated via PIV in 49%, ED-CVL in 25%, and prior-CVL in 26%. The time to initiation was 214.8 minutes in PIV and 294.7 minutes in ED-CVL ($p = 0.240$). Norepinephrine predominated all groups. No extravasation or ischemic complications were identified with PIV vasopressor administration. Twenty-eight-day mortality was 20.6% for PIV, 17.6% for ED-CVL, and 61.1% for prior-CVL. Of 28-day survivors, ICU LOS was 4.44 for PIV and 4.86 for ED-CVL ($p = 0.687$), while vasopressor days were 2.26 for PIV and 3.14 for ED-CVL ($p = 0.050$).

Conclusion: Vasopressors are being administered via PIVs for ED septic shock patients. Norepinephrine comprised the majority of initial PIV vasopressor administration. There were no documented episodes of extravasation or ischemia. Further studies should look at the duration of PIV administration with potential avoidance of central venous cannulation altogether in appropriate patients.

Keywords: Central venous line, Extravasation, Norepinephrine, Peripheral vasopressors, Septic shock.

Indian Journal of Critical Care Medicine (2022): 10.5005/jp-journals-10071-24243

Highlight

Patients with septic shock require stabilization with fluid resuscitation, vasopressors, source control, and antimicrobials. Septic shock is a common disease presentation to the ED. In this study, we highlight the safety and efficacy of peripheral vasopressor administration to facilitate rapid hemodynamic stabilization of septic patients in the ED.

Introduction

Sepsis, a life-threatening syndrome of organ dysfunction due to dysregulated host response, is a leading cause of morbidity and mortality worldwide.[1–3] Current septic shock guidelines recommend initiation of vasopressor agents after adequate volume resuscitation and now include a consideration statement for initiation of PIV vasopressor administration.[4–6] Early vasopressor administration has been associated with improved outcomes including reduced mortality.[7–10]

Historically, vasopressors have been administered through a central venous line (CVL) due to the theoretical risk of local tissue ischemia and injury if extravasation occurred from PIV infusion.[11–18] There is also the theoretical concern of losing venous access altogether due to PIV-only placement. However, CVL insertion is a time-consuming process that typically necessitates a physician or advanced-level practitioner for insertion and often requires confirmation by chest radiography for above-diaphragm CVLs.[19] Initiating vasopressors infusion through a more rapidly obtainable PIV prioritizes early hemodynamic stability and organ perfusion over extravasation risk. In sepsis, a time-sensitive diagnosis and treatment paradigm, rapid

[1,3]Department of Emergency Medicine, Washington University in St Louis, School of Medicine, Barnes-Jewish Hospital, St Louis, Missouri, United States of America

[2]Division of Critical Care Medicine, Department of Anesthesiology, Washington University in St Louis, School of Medicine, St Louis, Missouri, United States of America

[4]Department of Emergency Medicine, Washington University in St Louis, School of Medicine, St Louis, Missouri, United States of America

[5]Department of Anesthesiology and Emergency Medicine, Washington University in St Louis, School of Medicine, St Louis, Missouri, United States of America

Corresponding Author: Brian Todd Wessman, Department of Anesthesiology and Emergency Medicine, Washington University in St Louis, School of Medicine, St Louis, Missouri, United States of America, Phone: +13143628538, e-mail: brianwessman@wustl.edu

How to cite this article: Kilian S, Surrey A, McCarron W, Mueller K, Wessman BT. Vasopressor Administration via Peripheral Intravenous Access for Emergency Department Stabilization in Septic Shock Patients. Indian J Crit Care Med 2022;26(7):811–815.

Source of support: Nil

Conflict of interest: None

vasopressor administration appears even more important as it impacts mortality.[7–10]

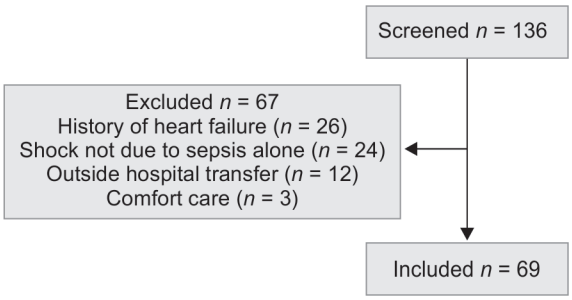
A growing body of evidence from predominately intensive care unit (ICU) and operating room (OR-)-based studies suggests that vasopressors can be administered through a PIV with low rates of extravasation or injury.[20–27] These findings were recently replicated in ED- based studies and in a meta-analysis.[28–30] However, as this practice remains a conditional recommendation in the recent 2021 Surviving Sepsis Guidelines,[4] there is a need for additional investigation regarding peripheral administration for patients in the ED, specifically with septic shock. Furthermore, among health centers that have embraced PIV vasopressor infusions, there is limited data on how frequently, and under what circumstances, vasopressors are administered initially via PIVs as compared to CVLs or indwelling tunneled lines existing prior to ED arrival (Prior-CVLs). The objective of this study was to evaluate PIV vasopressor infusion practice patterns, potential complications, and patient-centered outcomes among patients with septic shock presenting to a large urban single-center academic ED that had recently transitioned to allowing PIV vasopressor administration.

Materials and Methods

This is a single-center, retrospective, observational cohort study of patients presenting to an urban, academic, quaternary-care hospital with septic shock. Our septic shock standing order set includes an order for nursing to obtain PIV access in all patients with either an 18- or 20-gauge standard intravenous catheter being placed in an upper extremity. Further venous access interventions: non-extremity placement, ultrasound-guided access, etc. require discussion with the physician team. Our system order sets for norepinephrine and phenylephrine allow these medications to be administered in a critical care setting (including our ED) through a PIV that "flushes without difficulty". However, system pharmacy guidelines have set an arbitrary administration ceiling limit of 0.2 µg/kg/min for norepinephrine PIV infusion.

The study received approval from the Institutional Review Board. Patients over 18-years-old admitted via the ED with a diagnosis of septic shock who received a vasopressor infusion in the ED were included. Patients were excluded if they were transferred to the ED from an outside hospital (due to impact on the initial route of vasopressor), had a history of heart failure, or if the patient's shock was not attributable to sepsis or was due to a mixed shock state. Patient encounters were identified using clinical classifications software (CCS) to try to include a near consecutive sample with the assumption that encounters would be missed if only searching for sepsis or septic shock. Selection of CCS codes for septicemia, pneumonia, peritonitis, intestinal abscess, biliary tract disease, urinary tract infections, skin and subcutaneous tissue infections, and meningitis were used in conjunction with an order in the electronic medical record for an infusion of norepinephrine, phenylephrine, vasopressin, epinephrine, or dopamine to identify patient encounters. Data were collected on patient demographics, vasopressor type and dosages, time to vasopressor initiation, site of vasopressor administration, presumed source, antibiotic administration, the total amount of intravenous fluid administered, and major complications of extravasation and digit ischemic events. Cases were grouped and then analyzed by the site of vasopressor initiation: ED-CVL, PIV, or Prior-CVL. The ED-CVL and PIV groups were compared. Data were analyzed using descriptive statistics as well as statistical analysis with two-tailed *t*-tests using SPSS. While our comparison focused on the PIV and CVL groups, the prior-CVL group was included for a complete description of the current state of the administration of vasopressors in this cohort.

Flowchart 1: Flow diagram demonstrating included and excluded patients for the route of vasopressor administration in the emergency department cohort



Results

A total of 136 unique patient encounters were identified, of which 69 were included (Flowchart 1). The most common reasons for exclusion were a history of heart failure[26] and shock due to non-septic or mixed shock state.[24] Vasopressors were initiated through a PIV in 49.3% of cases and through an ED-CVL in 24.6% of cases. Patients arrived with a usable Prior-CVL in 26.1% of cases. Two patients in the PIV group had interosseous devices (IO) placed due to difficult IV access but subsequently had vasopressors switched from the IO to the PIV route and were included in the PIV cohort.

Patient baseline characteristics are summarized in Table 1. Norepinephrine was the most common first-line vasopressor, used in 85.3% of the PIV group, 100% of the ED-CVL group, and 89% of the Prior-CVL group. Phenylephrine and epinephrine were also administered through the PIV route. The time from arrival to vasopressor initiation was 214.8 minutes for PIVs and 294.7 minutes for ED-CVLs with an absolute difference of 79.9 minutes ($p = 0.24$) (Table 2). The time to initiation in the Prior-CVL group was 181.2 minutes (much of this cohort were oncologic patients with an existing indwelling venous port available to access). The average ED length of stay was 494.3 minutes for the PIV group, 465.9 minutes for the ED-CVL group, and 461.6 minutes for the Prior-CVL group. The total volume of IV fluid bolus was 2891 mL for the PIV group and 2925 mL for the ED-CVL group ($p = 0.9$). Antibiotics were given within 6 hours to all patients in the cohort, per existing sepsis guidelines.

In the PIV group, vasopressors were initiated through an IV in the antecubital fossa (AC) or more proximal in 61.9% of patients and distal to the AC in 29.3% of patients, with location not specified in 8.8% of patients. CVLs were subsequently placed in the ED in 73.5% of these PIV patients, with an additional 14.7% having a subsequent CVL placed in the ICU. No CVL was placed in 11.8% of patients in the PIV group, avoiding central line days altogether.

There were no reported extravasation events or digit ischemia in the vasopressors administered through the PIV cohort. There was no reported loss of PIV access or transient hypotension associated with the route of administration. Vasopressor days of 28-day survivors were 2.26 days for the PIV group and 3.14 days for the ED-CVL group, with an absolute difference of 0.88 days ($p = 0.05$). ICU length of stay of 28-day survivors was 4.44 days for the PIV group

Table 1: Demographics and characteristics of patients included in the cohort

	PIV (n = 34)	*ED-CVL (n = 17)*	*Prior-CVL (n = 18)*
Age (average)	64.3	63.8	60.9
% Female	44.1%	23.5%	44.4%
Active malignancy treatment	8.8%	11.8%	72.2%
ED LOS in minutes (range)	494.3 (194–1239)	465.9 (230–1314)	461.6 (225–871)
First vasopressor used			
Norepinephrine	85.3%	100.0%	89.0%
Phenylephrine	8.8%	0.0%	0.0%
Epinephrine	5.9%	0.0%	5.5%
Vasopressin	0.0%	0.0%	5.5%
>1 vasopressor in ED	32.4%	23.5%	38.9%
>2 vasopressors in ED	5.9%	0.0%	16.7%
Presumed source			
Pulmonary	17.6%	17.6%	27.8%
Urinary tract	41.2%	41.2%	0.0%
Abdominal	20.5%	17.6%	22.2%
Blood	11.8%	5.9%	38.9%
CNS	3.0%	0.0%	0.0%
Soft tissue	5.9%	17.6%	11.1%
Highest ED lactate (average)	4.15	4.31	5.56
% Intubated in ED	35.3%	29.4%	16.7%
Initial vitals			
Heart rate	106.9	113.5	115.1
Temperature	36.7	36.6	37
%Temperature ≥38 or <36	50.0%	35.3%	16.7%
MAP (average)	69.9	78.8	60.6
MAP (median)	63.5	64	60

Table 2: Comparison of time to vasopressor administration, amount of fluid resuscitation, mortality, and intensive care unit impact

	PIV	*ED-CVL*	*p-value*[*]	*Prior-CVL*
Time to initiation (minutes)	214.79	294.65	0.240	181.17
Total fluid bolus (mL)	2891	2925	0.906	3028
28-day mortality	20.6%	17.6%	0.803	61.1%
28-day survivors				
ICU LOS	4.44	4.86	0.687	
Vasopressor days	2.26	3.14	0.050	

[*]Two-tailed *t*-test

and 4.86 days for the ED-CVL group ($p = 0.69$). Mortality rates at 28 days were 20.6% for PIV and 17.6% for ED-CVL ($p = 0.81$). The 28-day mortality for the Prior-CVL group was 61.1%.

Discussion

Vasopressor administration is a vital component of the management of septic shock, with prompt initiation associated with reduced mortality.[5–10] While peripheral administration of vasopressors has become more accepted in some clinical locations, data from septic ED patients is limited.[29] In addition, limited ED data exists on clinical practice patterns, safety profile, and impact on the patient flow when PIV vasopressor administration is employed.

In this retrospective, an observational study analyzing the initiation of vasopressors in a single quaternary-care ED, the majority of patients without a Prior-CVL presenting for septic shock received initial vasopressors through a PIV. This is an accepted practice pattern at our institution when an appropriate PIV has been obtained. Nursing protocols include instructions on checking the distal infusion limb for signs of ischemia. Norepinephrine comprised the majority of initial vasopressor use in the data cohort, which would be expected as norepinephrine is the first-line agent for septic shock refractory to fluid administration.[31–34] The data also suggested a trend towards a decrease in time to vasopressor initiation by an average of 79.9 minutes in the PIV group compared to the ED-CVL group, though this did not reach statistical significance likely related to the small sample size. Future studies should look at the feasibility of expanding the practice of PIV vasopressor utilization across multiple centers.

There was no ED or ICU documentation of extravasation events or digit ischemia. This finding emulates that of recent studies.[20–30]

The majority of PIVs were placed at the AC or proximal which may reduce extravasation risk.[21] We also report no episodes of loss of intravenous access leading to patient hemodynamic instability, which is often cited as a concern when patients don't have central access. It is important to note that the patient population from this study was obtained in a "critical care" area of the ED which utilizes a 2:1 or 3:1 nursing ratio. This could limit the generalization of findings in EDs that cannot accommodate these nursing ratios that facilitate more frequent line checks. Furthermore, the safety of this clinical practice may be improved with newer PIV insertion techniques favoring ultrasound guidance.

There was a reduction in vasopressor days when initiated peripherally (absolute difference 0.88 days, $p = 0.05$), likely driven by the 11.8% of patients who received PIV vasopressors and never underwent central venous catheterization. Of note, one of those four patients received PIV vasopressors for more than 1 day without any documented complication. This subset of patients receiving PIV vasopressors might have been less critically ill than the other cohorts of patients. However, any reduction in central line need is beneficial for patients and for potential complications such as central line-associated bloodstream infections. It should also be noted that vasopressor administration was initiated about an hour earlier in the PIV cohort, thought to be associated with potential delays originating from the time needed to complete the CVL procedure. Patients in the PIV vasopressor group had these medications infused for upwards of 8 hours without limb ischemia. Further studies should look at risk stratifying length of time vs complication risk for PIV vasopressor administration.

Interestingly, 88.2% of patients ultimately ended up with an invasive central line placed, either in the ED or ICU, during their sepsis care. This CVL placement was most likely impacted by an institutional arbitrary upper limit of 0.2 µg/kg/minute for norepinephrine PIV infusion. It is hypothesized that this also negatively impacted the observed ED length of stay as the majority of patients who received CVL catheterization underwent these sterile invasive procedural interventions while in the ED. We did not gather specific procedural times or potential impact on the length of stay. Further studies should look at safety profiles and risk stratification for PIV dosing limits and help guide medication administration guidelines. Without this arbitrary dosing limit, further central line necessity and overall days may have been avoided.

We did not expect to see any impact on mortality by the intervention of PIV vasopressor administration in this small cohort. However, a mortality difference was noted in the 26.1% of patients with a Prior-CVL used for vasopressor administration. This cohort had a 61.1% mortality rate, a value much higher than that of both the PIV and ED-CVL groups as well as the general mortality rates in septic shock patients.[33] We suspect this is likely due to the higher morbidity in this patient population as patients with indwelling lines tend to have a significant underlying illnesses which may overshadow the positive effects of early vasopressor initiation. However, further studies may want to evaluate further sepsis care and treatment goals in this specific patient cohort.

Limitations

There are several limitations to this study. The retrospective nature of this study is an inherent limitation, and observational studies are at risk for selection and information bias. Data being from a single center may also limit external applicability. A small sample size may result in reduced rates of rare outcomes and complications. Data were gathered by one researcher which may add to information bias. Patients with heart failure or mixed shock were excluded due to the assumption that clinicians may treat these patients differently. However, excluding these patients may reduce applicability to the general ED population.

Conclusion

Vasopressors are being effectively initiated and administered through the PIV route for ED septic shock patients. Norepinephrine comprised the large majority of initial vasopressors used in PIVs. There were no documented episodes of extravasation or digit ischemia in the ED or ICU with initial PIV administration. The findings herein provide important baseline data for the clinical utility and safety of PIV initiation and titration of vasopressor administration in ED patients specifically with septic shock. Further studies should assess risk stratification for escalating vasopressor doses and length of exposure time of vasopressors through the PIV route with a potential goal to avoid central venous catheterization in the appropriate patient population.

Orcid

Scott Kilian https://orcid.org/0000-0002-5681-2505
Aaron Surrey https://orcid.org/0000-0001-9846-5938
Weston McCarron https://orcid.org/0000-0002-1358-8128
Kristen Mueller https://orcid.org/0000-0001-9799-0861
Brian Todd Wessman https://orcid.org/0000-0002-8020-2678

References

1. Singer M, Deutschman CS, Seymour CW, Shankar-Hari M, Annane D, Bauer M, et al. The third international consensus definitions for sepsis and septic shock (sepsis-3). JAMA 2016;315(8):801–810. DOI: 10.1001/jama.2016.0287.
2. Gaieski DF, Edwards JM, Kallan MJ, Carr BG. Benchmarking the incidence and mortality of severe sepsis in the United States. Crit Care Med 2013;41(5):1167–1174. DOI: 10.1097/CCM.0b013e31827c09f8.
3. Rudd KE, Johnson SC, Agesa KM, Shackelford KA, Tsoi D, Kievlan DR, et al. Global, regional, and national sepsis incidence and mortality, 1990–2017: analysis for the Global Burden of Disease Study. Lancet 2020;395(10219):200–211. DOI: 10.1016/S0140-6736(19)32989-7.
4. Evans L, Rhodes A, Alhazzani A, Antonelli M, Coopersmith CM, French C, et al. Surviving sepsis campaign: international guidelines for management of sepsis and septic shock 2021. Crit Care Med 2021;49(11):e1063–e1143. DOI: 10.1097/CCM.0000000000005337.
5. Khan P, Divatia JV. Severe sepsis bundles. Indian J Crit Care Med 2010;14(1):8–13. DOI: 10.4103/0972-5229.63028.
6. Javeri Y, Jagathkar G, Dixit S, Chaudhary D, Zirpe KG, Mehta Y, et al. Indian society of critical care medicine position statement for central venous catheterization and management 2020. Indian J Crit Care Med 2020;24(Suppl 1):S6–S30. DOI: 10.5005/jp-journals-10071-G23183.
7. Permpikul C, Tongyoo S, Viarasilpa T, Trainarongsakul T, Chakorn T, Udompanturak S, et al. Early use of norepinephrine in septic shock resuscitation (CENSER): a randomized trial. Am J Respir Crit Care Med 2019;199(9):1097–1105. DOI: 10.1164/rccm.201806-1034OC.
8. Bai X, Yu W, Ji W, Lin Z, Tan S, Duan K, et al. Early versus delayed administration of norepinephrine in patients with septic shock. Crit Care 2014;18(5):532. DOI: 10.1186/s13054-014-0532-y.
9. Ospina-Tascon GA, Hernandez G, Alvarez I, Calderon-Tapia LE, Manzano-Nunez R, Sanchez-Ortiz AI, et al. Effects of very early start of norepinephrine in patients with septic shock: a propensity score-based analysis. Crit Care 2020;24(1):52. DOI: 10.1186/s13054-020-2756-3.

10. Beck V, Chateau D, Bryson GL, Pisipati A, Zanotti S, Parrillo JE, et al. Timing of vasopressor initiation and mortality in septic shock: a cohort study. Crit Care 2014:18(3):R97. DOI: 10.1186/cc13868.
11. Greenwalk HP, Gootnick A, Luger NM, et al. Tissue necrosis following subcutaneous infiltration with norepinephrine. N Engl J Med 1952;246:252–253. DOI: 10.1056/NEJM195202142460704.
12. Humphreys J, Johnston JH, Richardson JC. Skin necrosis following intravenous noradrenaline. BMJ 1955;2(4950):1250–1252. DOI: 10.1136/bmj.2.4950.1250.
13. Perlow SS, Shapiro RA. Skin necrosis following intravenous use of norepinephrine; report of six cases. Am J Surg 1956;92(4):566–570. DOI: 10.1016/s0002-9610(56)80088-3.
14. Greenlaw CW, Null LW. Dopamine-induced ischaemia. Lancet 1977;2(8037):555. DOI: 10.1016/s0140-6736(77)90683-3.
15. Kahn JM, Kress JP, Hall JB. Skin necrosis after extravasation of low-dose vasopressin administered for septic shock. Crit Care Med 2002;30(8):1899–1901. DOI: 10.1097/00003246-200208000-00038.
16. Dunser MW, Mayr AJ, Tur A, Pajk W, Barbara F, Knotzer H, et al. Ischemic skin lesions as a complication of continuous vasopressin infusion in catecholamine resistant vasodilatory shock: incidence and risk factors. Crit Care Med 2003;31(5):1394–1398. DOI: 10.1097/01.CCM.0000059722.94182.79.
17. Bunker N, Higgins D. Peripheral administration of vasopressin for catecholamine-resistant hypotension complicated by skin necrosis. Crit Care Med 2006;34(3):935. DOI: 10.1097/01.CCM.0000202202.85087.37.
18. Alexander CM, Ramseyer M, Beatty JS. Missed extravasation injury from peripheral infusion of norepinephrine resulting in forearm compartment syndrome and amputation. Am Surg 2016;82(7):e162–e163. PMID: 27457846.
19. Ablordeppey EA, Drewry AM, Beyer AB, Theodoro DL, Fowler SA, Fuller BM, et al. Diagnostic accuracy of central venous catheter confirmation by bedside ultrasound versus chest radiography in critically ill patients: a systematic review and meta-analysis. Crit Care Med 2017;45(4):715–724. DOI: 10.1097/CCM.0000000000002188.
20. Delgado T, Wolfe B, Davis G, Ansari S. Safety of peripheral administration of phenylephrine in a neurologic intensive care unit: a pilot study. J Crit Care 2016;34:107–110. DOI: 10.1016/j.jcrc.2016.04.004.
21. Loubani OM, Green RS. A systematic review of extravasation and local tissue injury from administration of vasopressors through peripheral intravenous catheters and central venous catheters. J Crit Care 2015;30(3):653.e9–e17. DOI: 10.1016/j.jcrc.2015.01.014.
22. Cardenas-Garcia J, Schaub KF, Belchikov YG, Narasimhan M, Koenig SJ, Mayo PH. Safety of peripheral intravenous administration of vasopressors through peripheral intravenous catheters and central venous catheters. J Hosp Med 2015;10(9):581–585. DOI: 10.1002/jhm.2394.
23. Lewis T, Merchan C, Altshuler D, Papadopoulos J. Safety of the peripheral administration of vasopressor agents. J Intensive Care Med 2019;34(1):26–33. DOI: 10.1177/0885066616686035.
24. Datar S, Gutierrez E, Schertz A, Vachharajani V. Safety of phenylephrine infusion through peripheral intravenous catheter in the neurological intensive care unit. J Intensive Care Med 2018;33(10):589–592. DOI: 10.1177/0885066617712214.
25. Ballieu P, Besharatian Y, Ansari S. Safety and feasibility of phenylephrine administration through a peripheral intravenous catheter in the neurocritical care unit. J Intensive Care Med 2021;36(1):101–106. DOI: 10.1177/0885066619887111.
26. Pancaro C, Shah N, Pasma W, Saager L, Cassidy R, van Klei W, et al. Risk of major complication after perioperative norepinephrine infusion through peripheral intravenous lines in a multicenter study. Anesth Analg 2020;131(4):1060–1065. DOI: 10.1213/ANE.0000000000004445.
27. Padmanaban A, Venkataraman R, Rajagopal S, Devaprasad D, Ramakrishnan N. Feasibility and safety of peripheral intravenous administration of vasopressor agents in resource-limited settings. J Crit Care Med 2020;6(4):210–216. DOI: 10.2478/jccm-2020-0030.
28. Medlej K, Kazzi AA, Chehade AEH, Eldine MS, Chami A, Bachir R, et al. Complications from administration of vasopressors through peripheral venous catheters-an observational study. J Emerg Med 2018;54(1):47–53. DOI: 10.1016/j.jemermed.2017.09.007.
29. Nguyen TT, Surrey A, Barmaan B, Miller S, Oswalt A, Evans D, et al. Utilization and extravasation of peripheral norepinephrine in the emergency department. Am J Emerg Med 2021;39:55–59. DOI: 10.1016/j.ajem.2020.01.014.
30. Tran QK, Mester G, Bzhilyanskaya V, Afridi LZ, Andhavarapu S, Alam Z, et al. Complication of vasopressor infusion through peripheral venous catheter: a systematic review and meta-analysis. Am J Emerg Med 2020;38(11):2434–2443. DOI: 10.1016/j.ajem.2020.09.047.
31. Dellinger RP, Levy MM, Rhodes A, Annane D, Gerlach H, Opal SM, et al. Surviving sepsis campaign guidelines committee including the pediatric subgroup surviving sepsis campaign: international guidelines for management of severe sepsis and septic shock: 2021. Crit Care Med 2013;41(2):580–637. DOI: 10.1097/CCM.0b013e31827e83af.
32. Herget-Rosenthal S, Saner F, Chawla LS. Approach to hemodynamic shock and vasopressors. CJASN 2008;3(2):546–553. DOI: 10.2215/CJN.01820407.
33. Hollenberg SM, Ahrens TS, Annane D, Astiz ME, Chalfin DB, Dasta JF, et al. Practice parameters for hemodynamic support of sepsis in adult patients: 2004 update. Crit Care Med 2004;32(9):1928–1948. DOI: 10.1097/01.ccm.0000139761.05492.d6.
34. Vincent J-L, Jones G, David S, Olariu E, Cadwell KK, et al. Frequency and mortality of septic shock in Europe and North America: a systematic review and meta-analysis. Crit Care 2019;23(1):196. DOI: 10.1186/s13054-019-2478-6.