

We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,900

Open access books available

185,000

International authors and editors

200M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com



Measuring and Managing Fluid Overload in Pediatric Intensive Care Unit

Dyah Kanya Wati

Additional information is available at the end of the chapter

<http://dx.doi.org/10.5772/intechopen.79293>

Abstract

Fluid management is one of the regular aspects of care in pediatric intensive care unit (PICU) setting, and its importance has been stressed in previous studies. Fluid resuscitation, as part of fluid management, may be needed to maintain intravascular volume, and prior studies showed that early aggressive fluid resuscitation may improve outcome in critical illness, especially in endothelial-dysfunction associated conditions. Unfortunately, this routine management often leads to the development of positive fluid balance and, consequently, fluid overload. Many evidences have stated that excessive fluid administration is closely associated with negative effects for children who were admitted in PICU. Moreover, fluid balance before PICU admission is also important because uncertainty about quantification fluid balance before admission can lead to underestimated fluid overload.

Keywords: positive fluid balance, children, pediatric intensive care, managing

1. Introduction

Fluid management is one of the regular aspects of care in PICU setting, and its importance has been stressed in previous studies [1]. Fluid resuscitation, as part of fluid management, may be needed to maintain intravascular volume [2], and prior studies showed that early aggressive fluid resuscitation may improve outcome in critical illness [1], especially in endothelial-dysfunction associated conditions [3]. Unfortunately, this routine management often leads to the development positive fluid balance and consequently, fluid overload (FO) [1, 3, 4]. Many evidences have stated that excessive fluid administration is closely associated with negative effects for children who were admitted in PICU [3, 4]. FO was known to cause

increased risk of morbidity, mortality, additional time of mechanical ventilation, additional hospitalization time, and increased need for renal replacement therapy (RRT) [5, 6].

In patients who already have critically ill also shown that fluid overload shows a negative effect. Flori et al. [2] conducted post-hoc study about the association positive fluid balance with worse clinical outcomes in children with ALI. This study showed the increment of 10 mL/kg/day fluid balance was associated with increasing mortality. Moreover, the increments were also associated with fewer ventilator-free days. Flori also suggested that fluid overload itself may be a risk factor for mortality regardless of initial presenting severity of illness [2]. In another study involving 778 patients with septic shock post resuscitation also found that fluid overload increased up to twice the mortality rate [5]. Vincent et al. [7] in their research on sepsis patients found that each addition of a positive fluid balance after 72 h was associated with an increased odds ratio of mortality by 10%. Sutawan et al. [6] study also found that fluid overload was associated with mortality (OR 11.5; 95% CI: 3.7–35.6; $p < 0.001$) with a range of $12.9 \pm 7.9\%$ on 120 subjects.

2. Pathophysiology and measuring fluid overload

In general, the vascular endothelial allows free exchange of water, electrolyte, glucose, and nutrients components into and out of the tissue independently because of their permeability to the components. This transcapillary component exchange capability is affected by factors such as hydrostatic pressure, endothelial tone, and oncotic pressure. The fluid passing through the intact endothelial barrier and going to the extravascular generally will be reabsorbed by the lymphatic system to reduce edema. However, damage of endothelial barrier caused by the inflammatory process and edema will be easier to occur. The endothelial barrier is commonly known as glycocalyx, a network-rich carbohydrate and protein bond that regulates the process of exchanging fluid to extravascular (**Figure 1**) [8].

Beside its own endothelial tissue structure, intravascular volume stability is also regulated by baroreceptors located in the carotid, atrial, and afferent renal arterioles. The renin-angiotensin-aldosterone system (RAAS) will be readily activated resulting in natriuretic peptide secretion in the event of intravascular volume changes [10]. Activation of the RAAS system and the secretion of natriuretic peptides make water and sodium retained by the kidneys to maintain intravascular volume. Imbalance between intravascular and extravascular fluid or component like natrium will facilitate intravascular fluid to the interstitial so that edema, ascites, pleural effusion may occur. Some studies use FO percentage (FO%) as a tool to estimate the amount of fluid retention [9, 10].

$$\text{FO \%} = \left[\frac{\text{fluid administrated} - \text{fluid eliminated}}{\text{body weight when first arrived}} \right] \times 100 \quad (1)$$

The fluids are measured in liters while the body weight measured in kilogram. $\text{FO\%} \geq 10\%$ is associated with high morbidity rates, such as worsening oxygenation levels, longer mechanic ventilator usage time, increased risk of renal replacement therapy (RRT), even to an increase

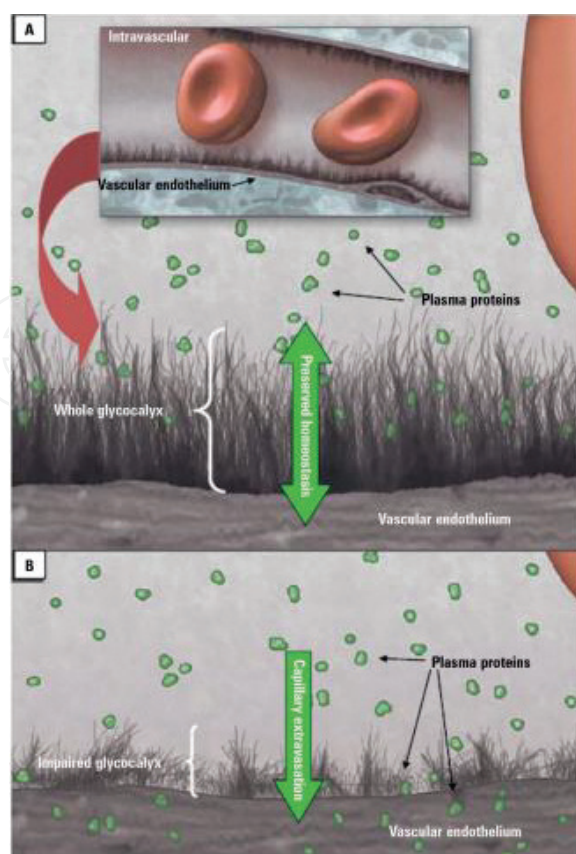


Figure 1. Schematic representation of glycocalyx [8].

in mortality. Patients who received RRT increased by 25% in critically ill patients. One of the risk factors is an increase in FO% levels between 10 and 20% [1, 11]. Similarly, in patients with ARDS, it is known that fluid retention increases mortality. Fluid overload with edema and extravasation manifestations into the third cavity is associated with failure of several systems such as the cardiovascular system, central nervous system, hepatic system, and digestive systems that stimulate malabsorption of nutrients and malnutrition in children. Fluid management for each critical illness in children is not the same depending on the clinical condition of the patient, but patients with high levels of FO% more frequently can cause failure of several organs [1–3, 12].

3. Pathophysiology fluid overload in sepsis and ARDS

In ARDS patients, some theories suggest that fluid overload can aggravate the patient's condition. Widespread injury of both lung and systemic endothelium with a resultant increase in permeability and expression of adhesion molecule is characteristic of ARDS/ALI [13]. Injury to the microvascular endothelium of the lung was first known almost 30 years ago [14, 15]. A variety of circulating markers of endothelial cell injury and activation have been studied in patients with ARDS/ALI. Endothelin-1, a vasoconstrictor and proinflammatory peptide is

released by endothelial cell as a result of injury, is increased in the plasma of patients with ARDS/ALI as is von Willebrand factor (VWF) antigen, another marker of endothelial cell activation and injury [13, 16]. Higher levels of plasma VWF were independently associated with mortality by multivariate analysis in two independent studies. Although injury to the lung microvascular endothelial is the underlying cause of increased permeability pulmonary edema in ARDS/ALI, endothelial injury and activation may also lead to obstruction or destruction of the lung microvascular bed in ARDS/ALI case [15]. The degree of obstruction and destruction of the lung microvascular bed is an important determinant of outcome and can be estimated by the pulmonary dead space fraction [1, 15].

Fluid management in sepsis patients is necessary to increase the perfusion of vital organs in order to restore the patient's hemodynamics. However, there has been no research suggesting the amount of fluid dosage in sepsis patients. Based on early goal directed therapy (EGDT) for the treatment of severe sepsis and septic shock, targeted fluid therapy used central venous pressure (CVP) [7, 17]. However, the target cvp is 8–12 mmHg to ensure intravascular volume. However, the EGDT guidelines do not limit the extent to which these fluids should be administered to patients. Even some recent studies suggest that fluid administration according to the EGDT concept has been abandoned because it is more likely to make hypervolemia and increase mortality rates in the first 48, 72, and 96 h post-EGDT [17]. This increase in mortality rates is more likely to be caused by FO, as FO may aggravate capillary leakage and contribute to or worsen edema in patients' lung with sepsis and septic shock. FO can also create intraabdominal hypertension, leading to organ hypoperfusion that will eventually fall on organ failure [18].

4. Managing fluid overload

4.1. Composition of resuscitation fluids

There is no ideal fluid used for resuscitation of shock patients. At least the fluid used has a similar chemical composition to the plasma and can eliminate shock signals without adding fluid extravasation to the interstitial cavity. Currently, the fluid used is colloidal fluid and crystalloid fluid [19].

Crystalloids are more recommended as first-line therapy to restore hemodynamics in patients with shock [20]. Crystalloids are made up of ions with various tonicities and can be freely distributed. The saline liquor is more isotonic to the plasma but has a higher concentration of chloride and is more at risk of hyperchloremic metabolic acidosis and increases the risk of kidney failure [18]. The fluid such as the ringger is more hypotonic than the extracellular fluid and is also associated with hyperchloremia but has a pH that is more similar to plasma pH [19–21].

Colloid is a fluid containing macromolecules with the usefulness of increasing the oncotic pressure and maintaining the amount of fluid that already exists in the vascular and even absorb fluid in extracellular to intracellular [5, 8]. Colloids are classified according to natural

(albumin) and artificial (gelatin, dextran, and hydroxyethyl starch (HES)) [7]. In contrast to the crystalloid fluid distributed among compartments, the colloidal fluid will remain in the vascular cavity for more than 16 h [8].

Gelatins, a polypeptide derived from collagen bovine, have the same extravascular extension as albumin but are associated with the risk of renal damage. HES is a high-molecular weight synthetic polymer and is associated with high incidence of renal failure and coagulation disease [8].

A study comparing the effects of crystalloid with HES found that the use of HES could reduce the amount of fluid intake (30% less than crystalloid), increasing CVP faster, decreasing the incidence of shock but increasing chances for RRT and increasing mortality [22].

4.2. Volume resuscitation

The resuscitation phase aims to restore intravascular volume, increase blood pressure, increase urine output, restore peripheral perfusion and increase consciousness level [17]. Aggressive fluid administration in this phase is associated with fluid overload [21]. The amount of fluid required in this phase also varies and depends on the individual patient [23]. Fluid management without adequate monitoring can increase the risk of volume overload [21]. Management using a vasopressor need not be delayed and aims to restore and maintain renal perfusion, optimize diuresis, and prevent fluid accumulation [10].

Predicting fluid delivery can reduce the risk of over-giving and unnecessary fluid [24]. Monitoring cardiac output and evaluation of vena cava diameter with ultrasound is one of the mechanisms used to monitor the amount of incoming fluid [25]. This method still has limitations due to the varied reference values that are used to assess the clinical patient, as each individual differs in the amount of fluid that enters depending on body weight, renal ability, and type of illness being suffered [26]. Some of these hemodynamic variables cannot be adequately calculated in patients with inadequate ventilation and receive low tidal volume. In the case of unstable hemodynamics, relative hypovolemia may occur due to the administration of sedative drugs or infectious processes [27].

Calculating central venous saturation and CVP does not show high sensitivity and specificity to predict fluid response [21]. It is estimated that more than 50% of patients are admitted to the ICU because of sepsis and do not respond adequately to this volume test [28]. Signs of tissue hypoperfusion such as lactate and central venous saturation are generally used to evaluate the appropriate time to stop fluid resuscitation [29]. A retrospective study of 405 septic patients receiving therapy based on the central venous saturation target and mean arterial pressure (MAP) protocols indicated a high risk of FO and mortality [30]. However, regular evaluation of venous saturation to evaluate resuscitation responses is more commonly used and is associated with fluid overload [31].

4.3. Maintenance volume

In patients with critical illness and treated in the ICU, FO should be avoided [23]. Treatment of fluid administration depends on each individual in the resuscitation phase. As described

earlier, FO is associated with high morbidity and mortality [28]. After returning blood pressure or on children returning heart rate is more valuable, the primary focus is adequate oxygen delivery to the tissue, which is directly related to cardiac output, hemoglobin concentration, and arterial saturation [32].

Conservative fluid management is associated with increased oxygen levels, decreased ventilator usage time, and decreased hospitalization. Patients treated in the ICU room on average will get fluid overload problems. Beside direct administration of fluids through venous access, these patients also receive fluids through drug administration and nutrient feeding and thus increasing the risk of fluid overload. However, in the maintenance phase, it is important to minimize the administration of unnecessary fluids [1, 33]. When FO is identified in a patient with stable hemodynamic and vasopressor reduction, fluid reduction should be the primary target to avoid negative FO effects [32].

4.4. How to monitor fluid overload in our patients?

Conventional indicators, such as MAP, pulse, weight, peripheral edema, are not reliably used in patients with critical illness. MAP and pulse rate are highly fluctuative due to drug use. Indicators of fluid volume such as end-diastolic volume and intrathoracic volume may be useful but still require further study for clinical validation. Cardiac index monitoring and ejection fractions can be used to diagnose FO. In patients with mechanical ventilation, the absence of variation in pulse pressure may indicate the presence of FO [10].

A study of 49 patients using Doppler crosslinks could predict better diuresis using the index compared with changes in pulse pressure and increased MAP after fluid administration. This suggests that renal hemodynamic enhancement is essential for the occurrence of urinary output and reduces FO [34].

In sepsis patient with hypotension, the renal autoregulation mechanism is damaged by microcirculation changes. In this phase, vasopressor administration is often used to keep renal perfusion adequate, and a diuretic process still exists. Research in adults who analyzed the use of noradrenaline to keep MAP between 65 and 75 mmHg showed increased renal perfusion, with increased urine output, and less likely to require RRT. Furthermore, noradrenaline administration in patients with septic shock becomes an option for optimizing renal perfusion. The target of MAP in patients with septic shock differs depending on the history of blood pressure in patients, and patients with a normal history of takanan do not show significant gains for achieving MAP targets [35].

The use of loop diuretics such as furosemide to prevent fluid retention was said effective for inducing diuresis in children and adults. Low doses of diuretics (furosemide = 0.2 mg/kg/dose) may prevent the acute episode from hypovolemia. Continuous administration of furosemide infusions (0.1–0.3 mg/kgbb/day) may also be performed, and both can maintain drug concentrations in the renal tubules and prevent compensatory mechanisms of sodium reabsorption. A decrease in blood volume is also avoided to avoid hemodynamic deterioration. The use of long diuretics can cause resistance and known to use combination of loop diuretic and thiazide are also said to be effective [23].

The use of sedation drugs may cause vasiness and increase hemodynamic instability and thus increases the risk of excessive fluid administration. Provision of sedation also makes the patient should bed rest and is a risk factor for microvascular dysfunction and eventually fluid fertilization returns. This of course increases the time of ventilator use and increases the length of stay in the ICU and the hospital [36].

5. Conclusion

Fluid overload is an event that is often found in the intensive care room of children. This is in because the more severe the patient the more fluid administered, not only through infusion, but the provision of drugs and nutrients are also no less. Some recent research has found that fluid overload has many negative effects, particularly, in patients who have both sepsis and ARDS. In sepsis and ARDS patients, the initial fluid administration is able to increase disease survival rate but at 48, 72 and 96 h of fluid administration may result in an increase in mortality. Strength monitoring and restriction of fluid volume after resuscitation phase become an important step in order not to fall on fluid overload. Resuscitation should be subjective, and when the hemodynamic is stable, the volume of fluid should be handled either by direct reduction or by diuretics. Fluid overload generally associated with increased mortality, morbidity, duration of mechanical ventilation, length of hospitalization and the need for renal replacement therapy (RRT).

Author details

Dyah Kanya Wati

Address all correspondence to: dyahpediatric@yahoo.com

Critical Care Medicine, Udayana University Sanglah Hospital, Denpasar, Bali, Indonesia

References

- [1] Willson DF, Thomas NJ, Tamburro R, Truemper E, Truwit J, Conaway M, et al. The relationship of fluid administration to outcome in the pediatric calfactant in acute respiratory distress syndrome trial. *Pediatric Critical Care Medicine*. 2013;**14**:666-672
- [2] Flori HR, Church G, Liu KD, Gildengorin G, Matthay M. Positive fluid balance is associated with higher mortality and prolonged mechanical ventilation in pediatric patients with acute lung injury. *Critical Care Research and Practice*. 2011;**2011**:854142
- [3] Arian AA, Zappitelli M, Goldstein SL, Naipaul A, Jefferson LS, Loftis LL. Fluid overload is associated with impaired oxygenation and morbidity in critically ill children. *Pediatric Critical Care Medicine*. 2012;**13**(3):253-258

- [4] Sinitsky L, Walls D, Nadel S, Inwald DP. Fluid overload at 48 hours is associated with respiratory morbidity but not mortality in a general PICU: Retrospective cohort study. *Pediatric Critical Care Medicine*. 2015;**16**:205-209
- [5] Semler MW, Rice TW. Sepsis resuscitation: Fluid choice and dose. *Clinics in Chest Medicine*. 2016;**37**(2):241-250. DOI: 10.1016/j.ccm.2016.01.007
- [6] Sutawan RIB, Wati DK, Suparyatha IB. Association of fluid overload with mortality in pediatric intensive care. *Critical Care and Shock*. 2016;**19**(1):8-13
- [7] Vincent JL et al. Sepsis in European intensive care units: Results of the SOAP study. *Critical Care Medicine*. 2006;**34**:344-353. PubMed: 16424713
- [8] Aditjaningsih D, George YW. Guiding principles of fluid and volume therapy. *Best Practice & Research. Clinical Anaesthesiology*. 2014;**28**(3):249-260
- [9] Lopes CLS, Piva JP. Fluid overload in children undergoing mechanical ventilation. *Revista Brasileira de Terapia Intensiva*. 2017;**29**(3):346-353. DOI: 10.5935/0103-507X.20170045
- [10] Subramanian S, Ziedalski TM. Oliguria, volume overload, Na⁺ balance, and diuretics. *Critical Care Clinics*. 2005;**21**(2):291-303
- [11] Ketharanathan N, McCulloch M, Wilson C, Rossouw B, Salie S, Ahrens J, et al. Fluid overload in a South African pediatric intensive care unit. *Journal of Tropical Pediatrics*. 2014;**60**(6):428-433
- [12] Wang N, Jiang L, Zhu B, Wen Y, Xi XM, Beijing acute kidney injury trial (BAKIT) work-group. Fluid balance and mortality in critically ill patients with acute kidney injury: A multicenter prospective epidemiological study. *Critical Care*. 2015;**19**:371
- [13] Lorraine B. Pathophysiology of acute lung injury and the acute respiratory distress syndrome. *Seminars in Respiratory and Critical Care Medicine*. 2006;**27**(4)
- [14] Alphonsus CS, Rodseth RN. The endothelial glycocalyx: A review of the vascular barrier. *Anaesthesia*. 2014;**69**(7):777-784
- [15] Burke-Gaffney A, Evans TW. Lest we forget the endothelial glycocalyx in sepsis. *Critical Care*. 2012;**16**(2):121. DOI: 10.1186/cc11239
- [16] Murphy LS, Wickersham N, McNeil JB, et al. Endothelial glycocalyx degradation is more severe in patients with non-pulmonary sepsis compared to pulmonary sepsis and associates with risk of ARDS and other organ dysfunction. *Annals of Intensive Care*. 2017;**7**:102. DOI: 10.1186/s13613-017-0325-y
- [17] Zhang L, Zhu G, Han L, Fu P. Early goal-directed therapy in the management of severe sepsis or septic shock in adults: A meta-analysis of randomized controlled trials. (Research article) (Report). 2015;**13**:71
- [18] Boyd JH, Forbes J, Nakada TA, et al. Fluid resuscitation in septic shock: A positive fluid balance and elevated central venous pressure are associated with increased mortality. *Critical Care Medicine*. 2011;**39**(2):259-265

- [19] Raman S, Peters MJ. Fluid management in the critically ill child. *Pediatric Nephrology*. 2014;**29**(1):23-34
- [20] Dellinger RP, Levy MM, Rhodes A, Annane D, Gerlach H, Opal SM, Sevransky JE, Sprung CL, Douglas IS, Jaeschke R, Osborn TM, Nunnally ME, Townsend SR, Reinhart K, Kleinpell RM, Angus DC, Deutschman CS, Machado FR, Rubenfeld GD, Webb SA, Beale RJ, Vincent JL, Moreno R, Surviving Sepsis Campaign Guidelines Committee Including the Pediatric Subgroup. Surviving sepsis campaign: International guidelines for management of severe sepsis and septic shock: 2012. *Critical Care Medicine*. 2013;**41**(2):580-637
- [21] Ogbu OC, Murphy DJ, Martin GS. How to avoid fluid overload. *Current Opinion in Critical Care*. 2015;**21**(4):315-321
- [22] Myburgh JA, Finfer S, Bellomo R, Billot L, Cass A, Gattas D, Glass P, Lipman J, Liu B, McArthur C, McGuinness S, Rajbhandari D, Taylor CB, Webb SA, CHEST Investigators; Australian and New Zealand Intensive Care Society Clinical Trials Group. Hydroxyethyl starch or saline for fluid resuscitation in intensive care. *The New England Journal of Medicine*. 2012;**367**(20):1901-1911. Erratum in Hydroxyethyl Starch or Saline for Fluid Resuscitation in Intensive Care. [The New England Journal of Medicine 2016]
- [23] Ingelse SA, Wösten-van Asperen RM, Lemson J, Daams JG, Bem RA, van Woensel JB. Pediatric acute respiratory distress syndrome: Fluid management in the PICU. *Frontiers in Pediatrics*. 2016;**4**
- [24] Carsetti A, Cecconi M, Rhodes A. Fluid bolus therapy: Monitoring and predicting fluid responsiveness. *Current Opinion in Critical Care*. 2015;**21**(5):388-394
- [25] Marik PE, Monnet X, Teboul JL. Hemodynamic parameters to guide fluid therapy. *Annals of Intensive Care*. 2011;**1**(1):1
- [26] Caille V, Jabot J, Belliard G, Charron C, Jardin F, Vieillard-Baron A. Hemodynamic effects of passive leg raising: An echocardiographic study in patients with shock. *Intensive Care Medicine*. 2008;**34**(7):1239-1245
- [27] Walker LJ, Young PJ. Fluid administration, vasopressor use and patient outcomes in a group of high-risk cardiac surgical patients receiving postoperative goal-directed haemodynamic therapy: A pilot study. *Anaesthesia and Intensive Care*. 2015;**43**(5):617-627
- [28] Joosten A, Alexander B, Cannesson M. Defining goals of resuscitation in the critically ill patient. *Critical Care Clinics*. 2015;**31**(1):113-132
- [29] Rivers E, Nguyen B, Havstad S, Ressler J, Muzzin A, Knoblich B, Peterson E, Tomlanovich M, Early Goal-Directed Therapy Collaborative Group. Early goal-directed therapy in the treatment of severe sepsis and septic shock. *The New England Journal of Medicine*. 2001;**345**(19):1368-1377
- [30] Kelm DJ, Perrin JT, Cartin-Ceba R, Gajic O, Schenck L, Kennedy CC. Fluid overload in patients with severe sepsis and septic shock treated with early goal-directed therapy is associated with increased acute need for fluid-related medical interventions and hospital death. *Shock*. 2015;**43**(1):68-73

- [31] Mouncey PR, Osborn TM, Power GS, Harrison DA, Sadique MZ, Grieve RD, Jahan R, Harvey SE, Bell D, Bion JF, Coats TJ, Singer M, Young JD, Rowan KM, ProMISe Trial Investigators. Trial of early, goal-directed resuscitation for septic shock. *The New England Journal of Medicine*. 2015;**372**(14):1301-1311
- [32] Rewa O, Bagshaw SM. Principles of fluid management. *Critical Care Clinics*. 2015;**31**(4):785-801
- [33] Grissom CK, Hirshberg EL, Dickerson JB, Brown SM, Lanspa MJ, Liu KD, Schoenfeld D, Tidswell M, Hite RD, Rock P, Miller RR 3rd, Morris AH, National Heart Lung and Blood Institute Acute Respiratory Distress Syndrome Clinical Trials Network. Fluid management with a simplified conservative protocol for the acute respiratory distress syndrome. *Critical Care Medicine*. 2015;**43**(2):288-295
- [34] Moussa MD, Scolletta S, Fagnoul D, Pasquier P, Brasseur A, Taccone FS, et al. Effects of fluid administration on renal perfusion in critically ill patients. *Critical Care*. 2015;**19**:250
- [35] Piva J, Alquati T, Garcia PC, Fiori H, Einloft P, Bruno F. Norepinephrine infusion increases urine output in children under sedative and analgesic infusion. *Revista da Associação Médica Brasileira* (1992). 2014;**60**(3):208-215
- [36] Lunardi N, Bryant M, Smith K, Lowson S. Early mobilization in critically ill patients. *ICU Director*. 2012;**3**(1):17-20