Managing Fluid Balance in the Critically Ill Patient

Overview

- Importance of optimizing patient fluid balance
- Fluid overload in critical illness
- Renal replacement therapy for fluid management
- Impact of fluid removal rate on hemodynamics
- Monitoring patient fluid status during treatment
- Advantages of continuous renal replacement therapy
- Guideline recommendations for hemodynamically unstable patients
- Managing fluid overload: Septic shock
- Managing fluid overload: Acute decompensated heart failure
- PRISMAFLEX CRRT system
- Summary and conclusions
- References

Optimizing Patient Fluid Balance

Optimum Fluid Balance Is Central To Critical Care[1-4]

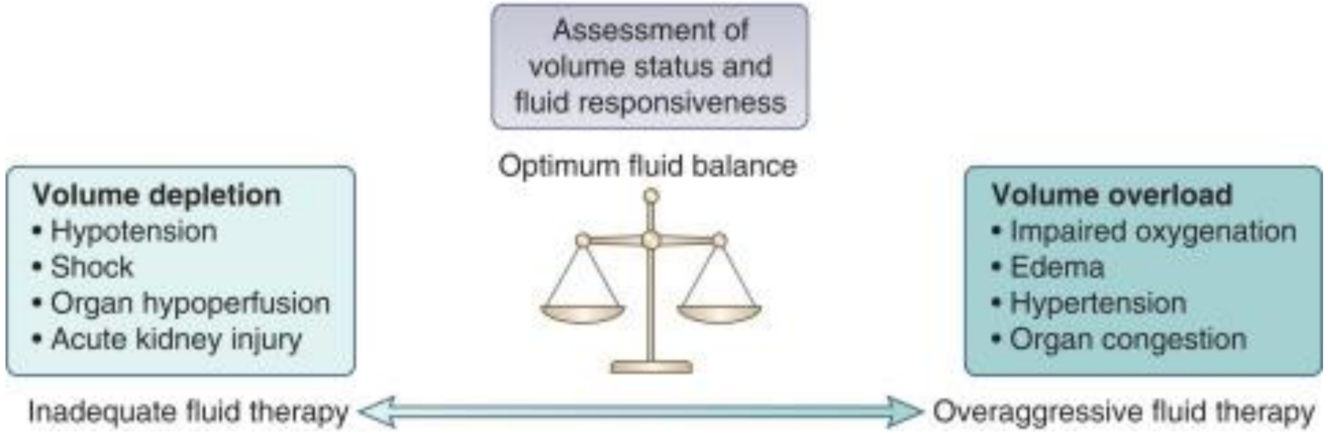


Image source :Kalantari K, et al. 2013.

Volume Depletion

Hypotension

Shock

Organ Hypoperfusion

Acute Kidney Injury

Volume Overload

Edema

Impaired Oxygenation

Organ Congestion

Hypertension

1. Scales K, Pilsworth J. Nurs Stand. 2008 Jul 30-Aug 5;22(47):50-7.
2. Bouchard J, Mehta RL. Contrib Nephrol. 2010;164:69-78.
3. Murugan R, et al. Blood Purif. 2016;42(3):266-78.
4. Kalantari K, et al. Kidney Int. 2013 Jun;83(6):1017-28.

Fluid Management in Critical Illness Is Challenging

Critical illness characteristics can make optimizing fluid balance difficult

- Hemodynamic compromise
- Leaky capillary beds
- Multi-organ failure
- Large volumes of IV fluids

Murugan R, et al. Blood Purif. 2016;42(3):266-78.

Fluid Overload in Critical Illness

Causes of Fluid Overload in the ICU

IV fluids

- Fluid resuscitation and continuous intravenous administration of fluid can lead to fluid accumulation and overload

Acute kidney injury

- ICU populations are at increased risk for acute kidney failure (AKI) and oliguria, which often lead to fluid accumulation

Sepsis

- Risk of fluid overload is increased with systemic inflammation, reduced oncotic pressure, and increased capillary permeability

Congestive heart failure

- Congestion, or fluid overload, is a classic clinical feature of patients presenting with heart failure

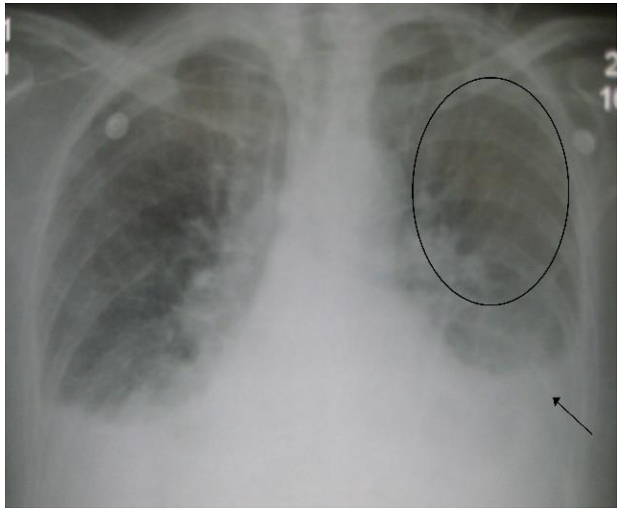
Rosner MH, et al. Br J Anaesth. 2014 Nov;113(5):764-71.

Clinical Indicators of Fluid Overload

- 10% or greater increase in body weight[1,2]
- Pitting edema, anasarca[1,2]
- Lung crackles, rales[1,2]
- Chest x-ray[2]
  - Congestion
  - Pulmonary edema
  - Pleural effusions

Pitting edema .

Image source: : *https://upload.wikimedia.org/wikipedia/commons/thumb/8/84/Combinpedal.jpg/1222px-Combinpedal.jpg*



Acute pulmonary edema. Note enlarged heart size, apical vascular redistribution (circle), and small bilateral pleural effusions (arrow).

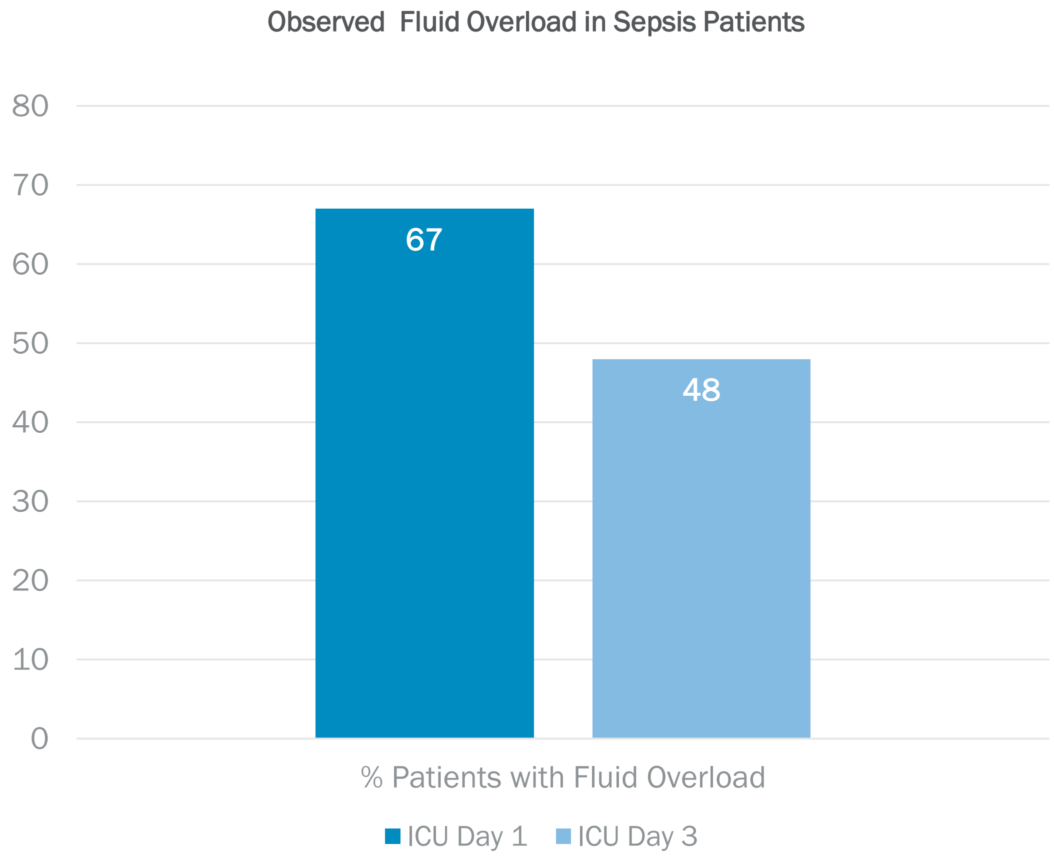
Image source: : https://commons.wikimedia.org/wiki/File:Pulmonaryedema09.JPG

1. Frazee E, Kashani K. FKidney Dis (Basel). 2016 Jun;2(2):64-71.
2. Claure-Del Granado R, Mehta RL. BMC Nephrol. 2016;17(1):109.

Fluid Overload Is Extremely Common in the ICU

ICU patients with severe sepsis or septic shock (N = 405)

- Day 1: 67% evidenced fluid overload
- Day 3: 48% evidenced fluid overload



Kelm DJ, et al. Shock. 2015 Jan;43(1):68-73.

Fluid Overload Is Associated with Poor Outcomes

- Increased mortality[1]
- Pulmonary edema[1,2]
- Myocardial dysfunction[2]
- Impaired coagulation[2]
- Delayed wound healing[2]
- Acute kidney injury[2]
- Impaired bowel function[2]
- Reduced liver function[2]
- Prolonged mechanical ventilation[3]

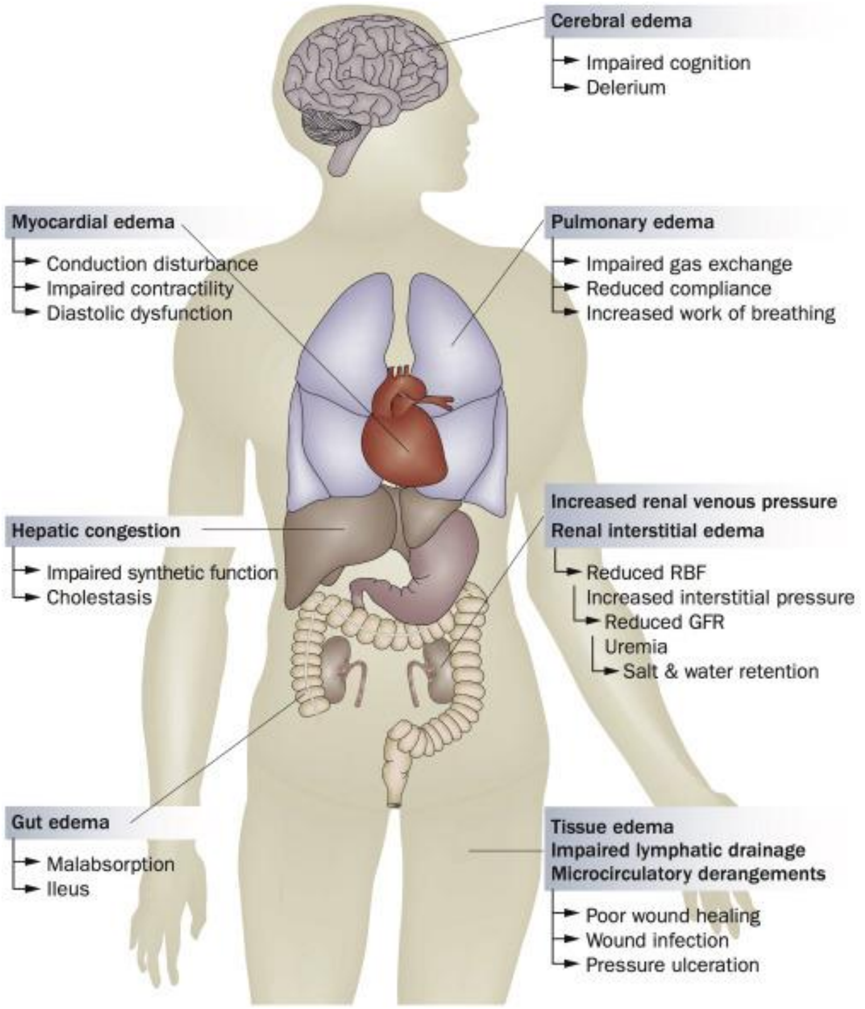


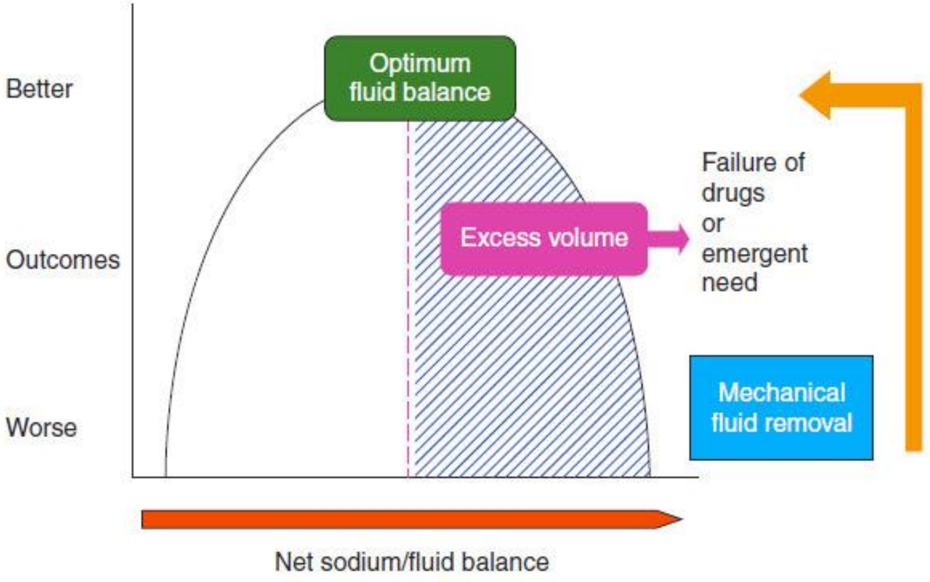
Image source: O'Connorr & Prowle et al. 2015

1. Claure-Del Granado R, Mehta RL. BMC Nephrol. 2016;17(1):109.
2. Ogbu OC, et al. Curr Opin Crit Care. 2015 Aug;21(4):315-21
3. O'Connor ME, Prowle JR. Crit Care Clin. 2015 Oct;31(4):803-21.

Renal Replacement Therapy for Fluid Management

Managing Fluid Balance with Renal Replacement Therapy

- Renal replacement therapy (RRT) may be utilized for volume management in critically ill patients with fluid overload[1]
- Large volumes of fluid required to treat underlying condition can result in fluid accumulation that is often difficult to correct in the absence of renal support[2]
- Effectiveness of medical management alone can be limited by diuretic-resistance and acute kidney injury[3]



Mechanical fluid removal should be considered when emergent and rapid fluid removal is needed or when pharmacological therapies have failed[3]

1. Claure-Del Granado R, Mehta RL. BMC Nephrol. 2016;17(1):109.
2. Murugan R, et al. Blood Purif. 2016;42(3):266-78.
3. Rosner MH, et al. Br J Anaesth. 2014 Nov;113(5):764-71..

Choice of Appropriate RRT Modality

Considerations[1-3]

- Total amount of fluid required to be removed to achieve clinical goals
- Rate at which fluids need to be removed
- Ongoing fluid administration needs
- Patient's illness and comorbidities
- Patient's hemodynamic status
- Need for solute removal, electrolyte correction or control of uremia
- Available resources and expertise

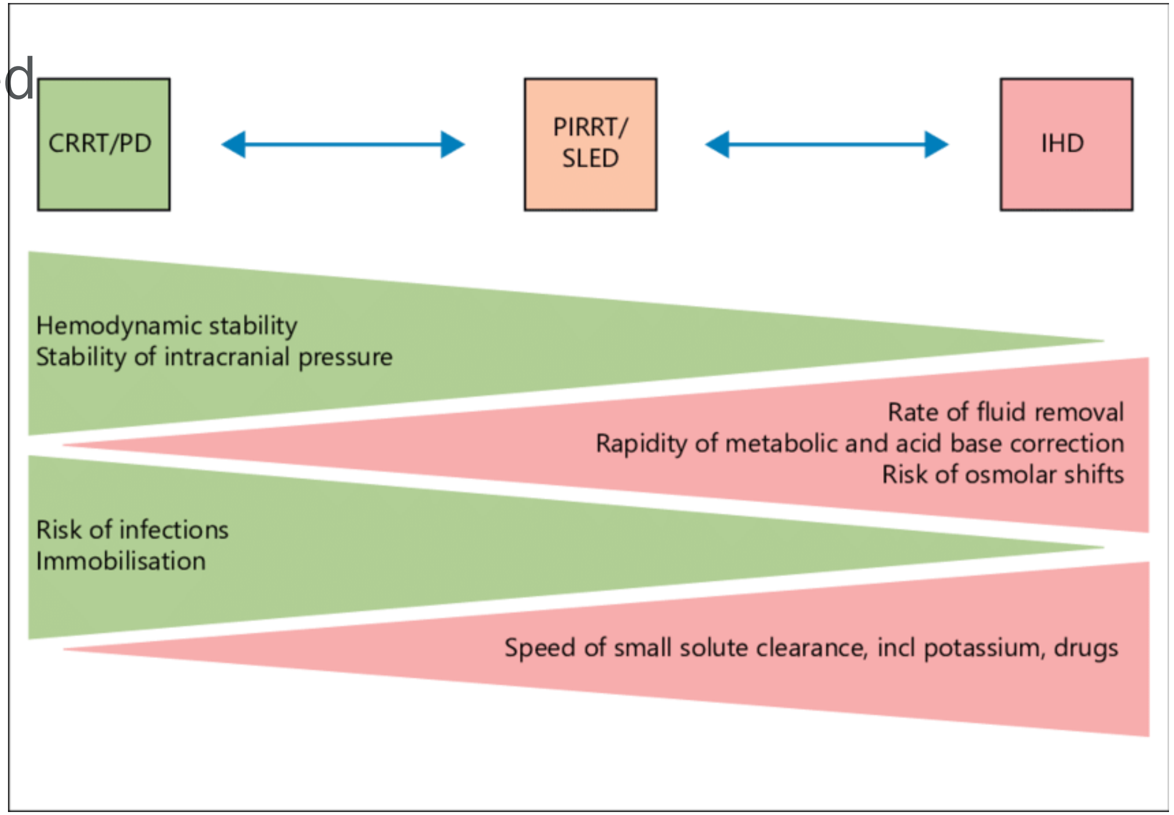
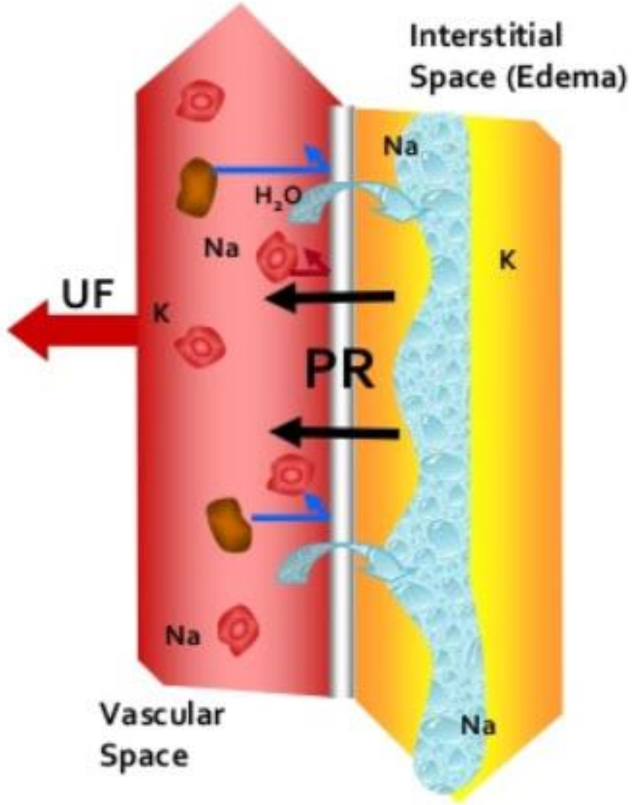


Image source: Ostermann M, et al. Blood Purif. 2016;42(3):224-37

1. Ostermann M, et al. Blood Purif. 2016;42(3):224-37.
2. Rosner MH, et al. Br J Anaesth. 2014 Nov;113(5):764-71.
3. Bagshaw SM, et al. Intensive Care Med. 2017 Jun;43(6):841-854.

Plasma Refilling Rate and Hemodynamic Stability

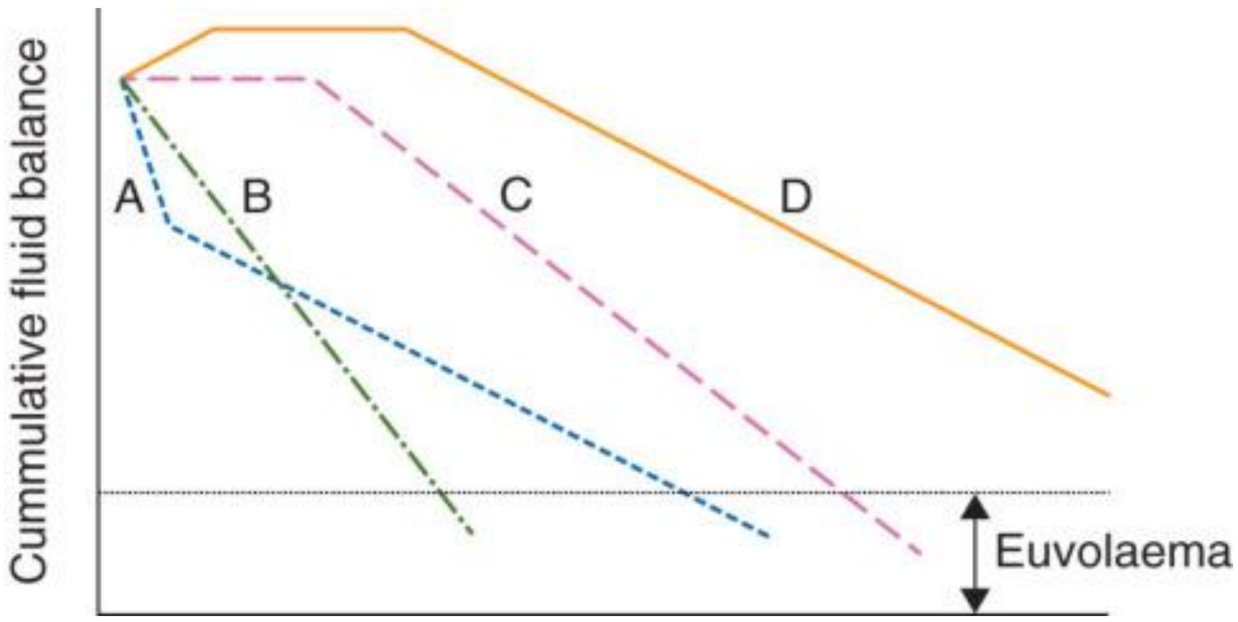
- During RRT, fluid is primarily removed from the intravascular compartment[1]
- The rate of change in intravascular blood volume is determined by plasma refilling rates from the interstitial compartment[1]
- When the rate of fluid removal exceeds that of plasma refilling, the decrease in circulating blood volume can lead to hemodynamic instability, hypotension and hypoperfusion[1]
- A slow, sustained rate of fluid removal allows time for vascular refilling and promotes hemodynamic stability[1,2]



1. Murugan R, et al. Blood Purif. 2016;42(3):266-78.
2. Rosner MH, et al. Br J Anaesth. 2014 Nov;113(5):764-71

Optimal Fluid Removal Rate

- Safe rate of fluid removal varies by patient condition and may change over the course of treatment
- The rate at which fluid should be removed requires consideration of
  - Expected fluid inputs and losses
  - Expected speed of vascular refilling
  - Patient's physiological tolerance to transient reduction in intravascular volume
- Slow, sustained fluid removal is more likely to achieve net negative fluid balance with greater hemodynamic stability



Rapid early fluid removal may be indicated in cardio-renal syndrome but a slower removal may be required for hemodynamic tolerability after resolution of pulmonary edema (A)[1]

Patients with single organ renal failure (B) may tolerate more rapid fluid removal than those with AKI complicating severe sepsis (C) or septic shock (D) [1]

Rosner MH, et al. Br J Anaesth. 2014 Nov;113(5):764-71.

Monitoring Patient Fluid Status

- Meticulous monitoring of patient fluid status is critical for effective fluid removal[1]
- Fluid losses or gains outside the control of RRT treatment system must be accounted for[2]
  - IV fluids, nutrition, medications, blood products
  - Urine output, drain outputs
- Patient fluid status is monitored by[2]
  - Accurate charting of all fluid intakes and outputs
  - Daily weighing
  - Physical assessment

1. Claure-Del Granado R, Mehta RL. BMC Nephrol. 2016;17(1):109.
2. Rosner MH, et al. Br J Anaesth. 2014 Nov;113(5):764-71.

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Continuous Renal Replacement Therapy for Fluid Management

Advantages of CRRT for Fluid Management

- **Hemodynamic stability**
  - Slow, gradual fluid removal allows adequate time for the vascular space to refill, reducing the impact on hemodynamics and organ perfusion
- **Precise fluid balance control**
  - Accurate measurements of fluid removal and infusion volumes help facilitate precise control of patient fluid balance
- **Flexibility to tailor treatment to clinical needs**
  - Continuous and gradual process allows fluid removal rates to be customized to varied clinical scenarios and fine-tuned on an ongoing basis

Effectiveness

Precision

Flexibility

Murugan R, et al. Blood Purif. 2016;42(3):266-78.

Guidelines: CRRT for Hemodynamic Stability

Acute Dialysis Quality Initiative (ADQI) [1]
"Continuous types of RRT are recommended in situations where shifts in fluid balance and metabolic fluctuations are poorly tolerated."
Kidney Disease | Improving Global Outcomes (KDIGO) [2]
"We suggest using CRRT, rather than standard intermittent RRT, for hemodynamically unstable patients."
Surviving Sepsis Campaign (SSC) [3]
"We suggest using CRRT to facilitate management of fluid balance in hemodynamically unstable septic patients."

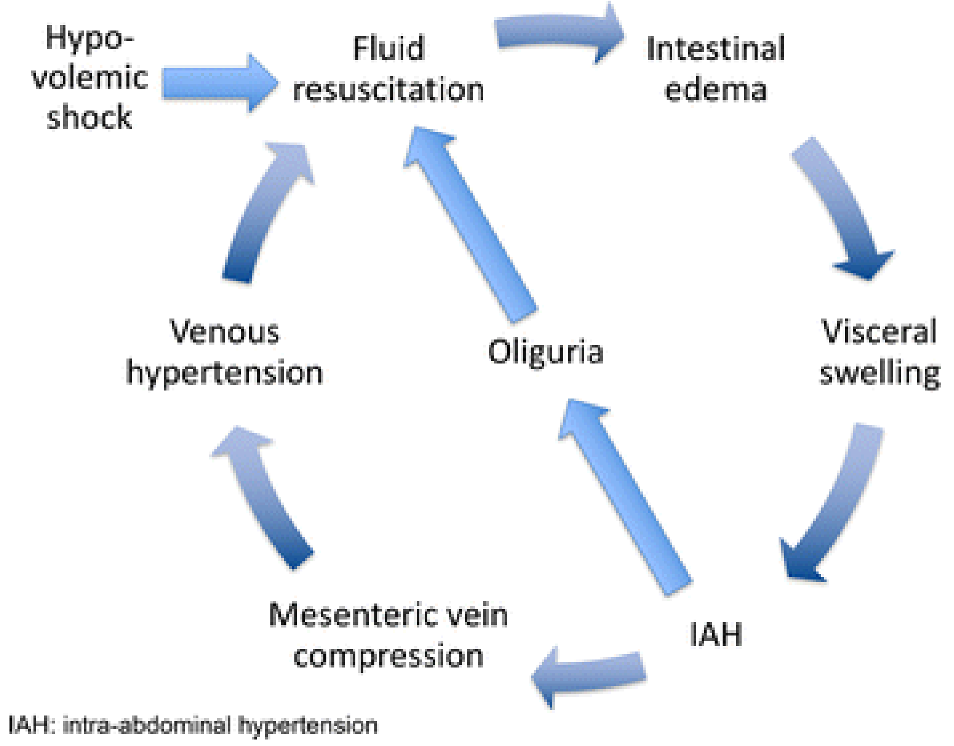
1. Ostermann M, et al. Blood Purif. 2016;42(3):224-37.
2. KDIGO Acute Kidney Injury Work Group. Kidney Int Suppl. 2012;2(1):1-138.
3. Rhodes A, et al. Intensive Care Med. 2017 Mar;43(3):304-377.

Fluid Overload: Septic Shock

Fluid Overload in Septic Shock

Causes of fluid overload

- Initial fluid resuscitation aimed at restoring intravascular volume
- Administration of large volumes of fluid as drug diluents, artificial nutrition and maintenance fluids
- Further fluid administration to counter relative hypovolemia resulting from capillary leak
- Interstitial edema induces organ dysfunction that contributes to further fluid accumulation



Vicious Cycle of Septic Shock Resuscitation

Malbrain MLNG, et al. Ann Intensive Care. 2018 May 22;8(1):66.

RRT in Septic Shock

- Aggressive fluid removal can cause hemodynamic deterioration, which may result in hypoperfusion and worsening organ failure[1]
- Slow, continuous removal of fluid supports hemodynamic stability[1]
- Sepsis clinical guidelines recommend use of CRRT in hemodynamically unstable patients[2]

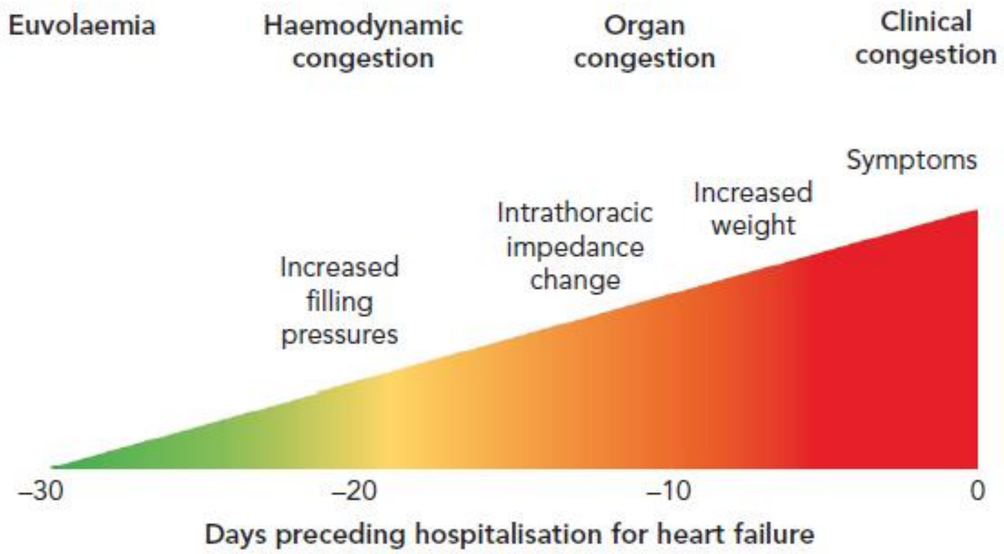
1. Murugan R, et al. Blood Purif. 2016;42(3):266-78.
2. Rhodes A, et al. Intensive Care Med. 2017 Mar;43(3):304-377.

Fluid Overload:
Acute Decompensated Heart Failure

Volume Overload in Acute Decompensated Heart Failure

- Congestion is the primary reason for hospitalization in patients with acute decompensated heart failure[1]
- Diuretic resistance is common in advanced heart failure and limits the efficacy of fluid removal by medical management alone[2]
- Nearly 40% of patients treated with conventional diuretic-based regimens still have congestive symptoms at discharge[1]
- Incomplete decongestion is associated with increased post-discharge events and hospital readmission[3]
- 2013 ACCF/AHA guideline for the management of heart failure recommend that RRT be considered in patients with obvious volume overload, diuretic resistance and/or impaired renal function[4]

Figure 2: The Typical Cascade of Systemic Congestion



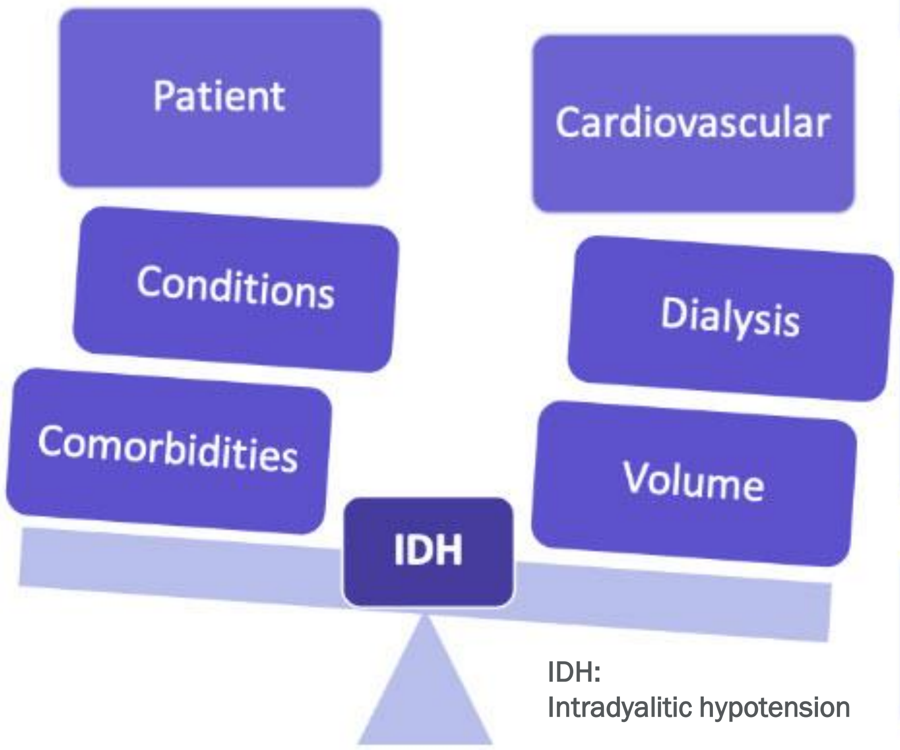
Modified from Adamson, 2009.[49] Published with permission from Springer Nature.

Image source: Cardiac Failure Review 2018;4(1):38–42.

1. Kazory A, Costanzo MR. Adv Chronic Kidney Dis. 2018 Sep;25(5):434-442.
2. Costanzo MR, et al. J Am Coll Cardiol. 2017 May 16;69(19):2428-2445.
3. Muñoz D, Felker GM. Curr Cardiol Rep. 2013 Feb;15(2):335.
4. Yancy CW,et al. J Am Coll Cardiol. 2013 Oct 15;62(16):e147-239.

RRT in Acute Decompensated Heart Failure

- Multiple trials have demonstrated the detrimental effect of hypotension in ADHF[1]
- Maintenance of hemodynamic stability is key to avoiding hypotension and worsening renal function[1]
- Desirable volume status should be achieved without causing a rapid reduction in intravascular volume[1]
- CRRT results has demonstrated improved hemodynamics and better fluid balance control compared with intermittent RRT[2]



IDH:
Intradyalitic hypotension

Image source:
https://www.renalfellow.org/2019/04/19/the-case-of-intradialytic-hypotension%EF%BB%BF/

1. Teerlink JR, et al. Curr Cardiol Rev. 2015;11(1):53-62.
2. Claure-Del Granado R, Mehta RL. BMC Nephrol. 2016;17(1):109.

Prismaflex CRRT System

PRISMAFLEX CRRT System

Highly accurate, scale-based fluid management system

- Fluid removal accuracy is provided through algorithms and self-calibrating fluid scales
- Monitors accumulated fluid balance/imbalance and adjusts accordingly to help reduce risk of patient injury
- Allows for easier dose tracking

Scale-based system enables accurate fluid management

https://www.baxter.com/sites/g/files/ebysai746/files/2017-11/Prismaflex-07.11-Brochure-New_Accts.pdf

Summary and Conclusions

Summary and Conclusions

- Optimizing fluid balance in the ICU is challenging
- Fluid accumulation and overload are common in critically ill patients
- Fluid overload is associated with increased morbidity and mortality
- Effective fluid management strategies can help mitigate fluid accumulation and improve outcomes
- Diuretic resistance and acute kidney injury may limit the efficacy of medical diuresis
- Renal replacement therapy may be considered to help achieve fluid removal goals
- Hemodynamic stability is essential to preserving organ perfusion and optimizing recovery
- Fluid removal with CRRT is slow and sustained, and has demonstrated hemodynamic tolerance
- CRRT may facilitate precise control over patient fluid balance by enabling accurate, ongoing measures of fluid removal and replacement volumes
- CRRT allows customization of fluid removal rates to varied clinical scenarios and changing patient needs[1]
- Fluid inputs and outputs outside the CRRT system must be accounted for during treatment
- CRRT is the suggested modality for mechanical fluid removal in hemodynamically unstable patients with considerable fluid accumulation[2,3,4]

1. Murugan R, et al. Blood Purif. 2016;42(3):266-78.
2. Ostermann M, et al. Blood Purif. 2016;42(3):224-37.
3. KDIGO Acute Kidney Injury Work Group. Kidney Int Suppl. 2012;2(1):1-138.
4. Rhodes A, et al. Intensive Care Med. 2017 Mar;43(3):304-377.

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Rx Only. For the safe and proper use of the devices mentioned herein, please refer to the appropriate Operator's Manual.