

## CHAPTER 137

# Mechanical Fluid Removal

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## OBJECTIVES

This chapter will:

1. Provide an overview of the different types of mechanical fluid removal and their risks and benefits.
2. Summarize the results of clinical trials in this field.

Fluid overload is common during critical illness. There are a number of potential reasons why patients may be fluid overloaded. They may be fluid overloaded on admission to hospital, as in decompensated heart failure, or they may develop fluid overload later as a result of excessive fluid administration, reduced urine output, or a combination of both. Fluid overload is associated with serious complications, including an increased risk of acute kidney injury (AKI), the development of respiratory failure, a longer duration on mechanical ventilation, and increased mortality.<sup>1-4</sup> It is often difficult to manage, especially in the context of hemodynamic instability. According to data from large national registries, approximately 40% of hospitalized heart failure patients are discharged with unresolved congestion, which may contribute to further rehospitalization.<sup>5</sup>

## RATIONALE FOR MECHANICAL FLUID REMOVAL

Ultrafiltration (UF) involves the removal of an iso-osmotic solution of plasma water and electrolytes from whole blood across a membrane. During UF, the circulating blood volume is maintained by recruitment of interstitial fluid into the intravascular space (vascular refill). Ideally, both processes should occur at a similar rate to prevent hemodynamic

instability. Hypotension is a complication that can occur when the rate of removal of plasma water exceeds the refilling capacity.

Compared with pharmacologic measures, UF has several advantages. First, fluid removal by extracorporeal techniques is fully controllable and adjustable. Second, the fluid removed with extracorporeal techniques is isotonic. It has a different  $\text{Na}^+$  concentration than that of urine produced after diuretic administration, the latter is usually hypotonic. In patients with acute decompensated heart failure, the average urinary  $\text{Na}^+$  concentration after furosemide administration is 60 mmol/L, leaving behind 80 mmol of excess  $\text{Na}^+$  for every liter of urine output.<sup>6</sup> This, combined with neurohormonal activation, explains why the initial weight loss after diuretics is negated rapidly, whereas weight loss after mechanical UF may persist for longer.<sup>7</sup> Finally, in patients with absent kidney function, mechanical fluid removal is the only option.

## Options of Mechanical Fluid Removal

The techniques to remove fluid mechanically include isolated UF and renal replacement therapy (RRT) with hemodialysis, hemofiltration, or peritoneal dialysis<sup>8</sup> (Table 137.1). Ultrafiltration involves the removal of an iso-osmotic solution of plasma water and electrolytes, whereas RRT provides clearance of metabolic and uremic solutes in addition to UF. Both techniques can be applied intermittently and continuously. Continuous methods allow fluid removal more gradually at a lower rate, and, as a result, the risk of hemodynamic instability is reduced too.

## Indications for Mechanical Fluid Removal

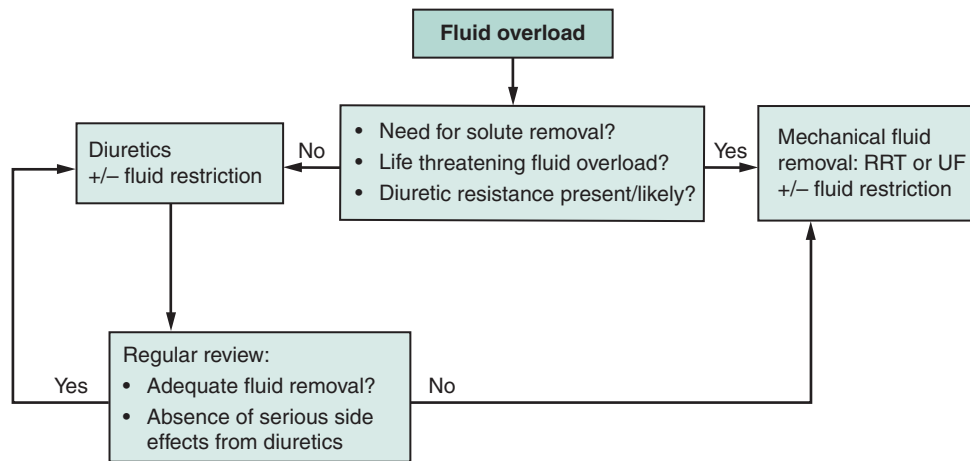
The indications for mechanical fluid removal depend predominantly on the impact fluid overload has on the

TABLE 137.1

## Techniques of Mechanical Fluid Removal

MODALITY	BLOOD FLOW RATE (mL/min)	FLUID REMOVAL RATE (mL/hr)	ADVANTAGES	DISADVANTAGES
SCUF	50–100	0–300	Slower and more sustained fluid removal	Immobilization
Intermittent UF	250–400	0–2000	Shorter procedure than continuous UF	Higher risk of hemodynamic instability
CRRT	50–100	0–300	UF and solute clearance slower and more sustained fluid removal	Immobilization
IRRT	250–400	0–2000	UF and solute clearance	Higher risk of hemodynamic instability with fluid removal fluctuating fluid balance
Peritoneal dialysis	Not applicable	0–500	UF and solute clearance no need for venous access Hemodynamically more stable No need for anticoagulation	Need for peritoneal catheter Contraindicated in patients immediately after abdominal surgery Special expertise required

CRRT, Continuous renal replacement therapy; IRRT, intermittent renal replacement therapy; SCUF, slow continuous ultrafiltration; UF, ultrafiltration. Modified from Rosner MH et al. *Br J Anaesth.* 2014;113(5):764–771.



Abbreviations: RRT = renal replacement therapy; UF = ultrafiltration

FIGURE 137.1 Algorithm for management of fluid overload.

patient, the apparent and expected trajectories, the likelihood of successful fluid removal with pharmacologic measures and the risk of side effects from diuretics (Fig. 137.1).

As suggested by the Acute Disease Quality Initiative (ADQI) expert group,<sup>8</sup> the main indications for mechanical fluid removal are the following:

1. Fluid overload after pharmacologic failure (i.e., situations in which fluid overload has not responded adequately to treatment with diuretics)
2. Presence of serious adverse effects of diuretics (i.e., situations in which treatment with diuretics cannot be continued)
3. High chance of diuretic failure (i.e., situations characterized by fluid overload and significantly reduced renal function, where treatment with diuretics is unlikely to be effective and the risk of prolonged/progressive fluid overload is high)
4. Combined fluid overload and solute accumulation (i.e., situations in which fluid removal and solute clearance are necessary)

In case of localized fluid accumulation in a confined compartment (i.e., isolated pleural effusions or ascites), UF is less likely to be effective. In the first instance, fluid removal by direct drainage should be considered.

## Prescription of Mechanical Fluid Removal

The choice and prescription of mechanical fluid removal require consideration of the urgency of fluid removal, the individual patient's clinical needs (fluid +/- solute removal), and their hemodynamic tolerance to fluid removal. The prescription should include the method (UF or RRT, intermittent vs. continuous, with or without diuretics), the target fluid balance, dose of RRT (if RRT is required), and end points detailing when to stop fluid removal. The target fluid removal rate must be set and adjusted according to the patient's effective circulating volume, their capability to refill the vasculature from the extravascular compartments, and the associated risk of hemodynamic instability. Available monitoring techniques include bio-impedance spectroscopy, online-hematocrit and relative blood volume monitoring, and biomarkers. Online monitoring of the hematocrit in the withdrawal line detects changes in hematocrit as a result of an imbalance between fluid removal and vascular refill. Existing devices can be programmed so that fluid removal is terminated if the increase in hematocrit exceeds the threshold set by the treating clinician and resumed when the hematocrit falls below the prespecified limit. Despite improved technical

advances, none of the available monitoring devices have been sufficiently evaluated to reliably predict intradialytic hypotension and adequacy of fluid removal. Importantly, there is no valid parameter that indicates that euvolemia has been achieved. In some cases, diuretics may be added to extracorporeal fluid removal, especially when using intermittent UF techniques and sufficient renal function is maintained. This combination ensures some control of fluid balance, while the extracorporeal therapy is not operative.

## Clinical Studies in Mechanical Fluid Removal

Several clinical trials have been conducted using continuous or intermittent UF in patients with congestive heart failure with mixed results.<sup>9–20</sup> Ultrafiltration has been shown to relieve signs and symptoms of congestion and improve quality of life. It also is associated with decreased length of stay in hospital and reduced 90-day readmission rate.<sup>9</sup>

The effects of mechanical fluid removal on renal function are variable.<sup>12,14,17,18</sup> Some studies showed improved renal function that could be explained by better cardiac performance and relief of renal congestion. In contrast, a substudy of the Ultrafiltration versus Intravenous Diuretics for Patients Hospitalized for Acute Decompensated Heart Failure (UNLOAD) trial showed a reduction in glomerular filtration rate that was similar in both groups (3.4 and 3.6 mL/min, respectively).<sup>14</sup> The subsequent Cardiorenal Rescue Study in Decompensated Heart Failure (CARRESS-HF) trial was terminated early because of a higher incidence of renal dysfunction in the UF group.<sup>12</sup> These discrepancies in reported renal effects may be attributable to differences in the rate of fluid removal and potential imbalance between UF rate and vascular refill capability, together with variations in the medical management of heart failure. More recently, attempts have been made to correct for this variability. In the study Continuous Ultrafiltration for Congestive Heart Failure (CUORE), patients with severe acutely decompensated heart failure were randomized to standard medical therapy versus UF.<sup>15</sup> In the UF group, hematocrit was monitored continuously and fluid removal was adjusted accordingly. The authors found that there was no significant difference in serum creatinine levels between both groups.

Finally, the large-scale AVOID-HF (Aquapheresis Versus Intravenous Diuretics and Hospitalization for Heart Failure) trial compared UF and medical treatment in acute heart failure and used an adjustable, rather than fixed, treatment regimens in both arms.<sup>16</sup> The study was terminated early after enrollment of 224 patients. At 30 days, the UF group had fewer heart failure and cardiovascular events. There was no difference in changes in renal function between both groups from 24 hours after initiation of treatment to 90 days after randomization. However, significantly more UF patients experienced an adverse effect or a serious study product-related adverse event, including bleeding and infections. Ultimately, a decision was made to terminate the trial because of safety concerns and slower-than-projected enrollment.

With regard to long-term effects, some studies have suggested differences between UF and medical treatment. In patients with congestive heart failure treated with UF, weight loss persisted at 90 days after treatment, whereas the initial weight loss with diuretics was often short lived.<sup>7</sup> This may be explained by the removal of isotonic fluid with UF rather than hypotonic urine as with diuretic therapy, combined with reduced activation of the renin-angiotensin-aldosterone axis. Despite short-term beneficial effects, isolated UF in heart failure has not been shown to prolong survival.

## CONCLUSION

Mechanical fluid removal has a role in patients with fluid overload in whom pharmacologic treatment has failed, is unsafe, or is unlikely to be effective. The decision between UF alone versus hemodialysis or hemofiltration depends on the clinical needs of the individual patient and whether clearance of metabolic products is required in addition to fluid removal. With use of extracorporeal fluid removal, implementation of a customized and individualized UF rate is essential to avoid intravascular hypovolemia and hemodynamic instability. European and North American practice guidelines state that cardiac patients with persistent congestion despite diuretic therapy, with or without impaired renal function, may, under experienced supervision, receive mechanical UF.<sup>21,22</sup> However, the benefits are limited to short-term improvement of symptoms and reduced hospitalization; there is no evidence that long-term survival improves.

### Key Points

1. Clinical studies in patients with congestive heart failure have shown that ultrafiltration is superior at relieving congestion, improving quality of life, and possibly reducing readmission rate to the hospital compared with diuretic therapy, but there was no evidence of any long-term benefits.
2. Mechanical fluid removal is associated with adverse events, especially if the prescription is not adjusted to the clinical characteristics and needs of the patient.
3. Based on expert opinion and official guidelines, mechanical fluid removal should be reserved for patients with severe fluid overload in which diuretic treatment has failed, is unsafe, or is unlikely to be effective. In this case, an individualized approach based on the dynamic needs of the individual patient is essential.
4. The decision between ultrafiltration alone versus renal replacement therapy depends on whether fluid removal alone or additional clearance is required.

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A complete reference list can be found online at [ExpertConsult.com](http://ExpertConsult.com).

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