Acute Dialysis Quality Initiative
Fifth International Consensus Conference

Workgroup 1

Volume Management by Renal Replacement Therapy in Acute Kidney Injury

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Introduction

Management of fluid balance is one of the basic but vital tasks in the care of critically ill patients. Hypovolaemia results in a decrease in cardiac output and tissue perfusion and may lead to progressive multiple organ dysfunction, including the development of acute renal injury (AKI). However, in an effort to reverse pre-renal oliguria, it is not uncommon for patients with established oliguric acute renal failure, particularly when associated with sepsis, to receive excessive fluid resuscitation leading to fluid overload. In many patients, this can be managed by the use of diuretics but in others, renal replacement therapy may be required to treat hypervolaemia.

Refractory hypervolaemia is a clinically accepted indication for the initiation of renal replacement therapy to remove excess fluid. Additionally, patients with oliguric AKI often become fluid overloaded due to obligatory fluid intake including vasopressors, nutrition and multiple IV medications. Frequently, these patients require early ultrafiltration even though they have not yet become clinically uraemic (in part, due to dilution of the biochemical markers), acidotic or hyperkalaemic.

In pediatric practice, there is evidence of improved patient survival, shorter ICU and/or hospital stay, if fluid overload is avoided utilizing extracorporeal fluid removal (1) Improved outcomes have also been reported by avoidance of fluid overload and maintenance of strict fluid volume control in other clinical

Authors are listed in alphabetic order. *Denotes group facilitator.
settings including post-cardiac surgery, lung transplantation, acute respiratory distress syndrome, Hantavirus pulmonary syndrome and the abdominal compartment syndrome (2-6).

**What are currently accepted terminology for fluid regulation in RRT: Process and techniques?**

Unless lost by blood loss associated with dialyser rupture or due to extracorporeal circuit disconnection, fluid is typically removed by the technique of ultrafiltration (7-12).

*Ultrafiltration*

Ultrafiltration is the process in which plasma water is removed from the circulation across a semi-permeable membrane in response to a transmembrane pressure gradient. Ultrafiltration results in the formation of an ultrafiltrate. Factors which influence ultrafiltration include transmembrane pressure, membrane hydraulic permeability, reflection and sieving-coefficients, filtration fraction, and convective solute flux.

*Ultrafiltrate composition*

Ultrafiltrate (Uf) during postdilutional haemofiltration and hemodiafiltration has approximately the same composition as plasma water containing crystalloids but not colloids or cells. As proteins do not cross membranes, solutes and drugs which are protein-bound will not be readily ultrafiltered. Similarly, due to electrical charges on plasma proteins, the final electrolyte concentrations in the ultrafiltrate will be slightly different from that in plasma, due to the Gibbs-Donnan effect. This explains why the sieving coefficient of small plasma solutes does not equal 1. During predilution haemofiltration, the sieving coefficients can be altered by the composition and the replacement rate of the replacement solution.

*Total ultrafiltrate*

Total Uf is the amount of ultrafiltrate removed by the RRT circuit. In isolated ultrafiltration, total Uf represents the net fluid removed from the patient by RRT. In haemofiltration, total Uf measures treatment efficiency, but not fluid balance. In haemodialysis total Uf controls fluid balance but only marginally contributes to (convective) treatment efficiency. Similarly, in hemodiafiltration, total Uf only measures treatment efficiency but does not influence fluid balance. When a high-flux hollow fiber filter is used, total Uf can be partially masked by a significant amount of back filtration. Total Uf depends on various extracorporeal circuit parameters, including blood flow, vascular access, filter and fiber design, transmembrane pressure, membrane hydraulic permeability, membrane surface area and machine specifications.

*Ultrafiltration rate*

The ultrafiltration rate is the amount of ultrafiltrate produced by the RRT circuit per time interval (minute, hour). Uf rate is prescribed to achieve a desired total Uf within the scheduled treatment duration. In haemodialysis, as total Uf rate and net Uf rate are equivalent, this parameter must also take into account the patient’s haemodynamic tolerance. Uf rate is prescribed to achieve desired total Uf within scheduled
treatment duration. In haemodialysis, as total Uf rate and net Uf rate are equivalent, this parameter must also take into account the patient’s haemodynamic tolerance.

*Total replacement*

The total replacement is the amount of fluid replaced into the RRT circuit. In haemofiltration, total replacement measures treatment efficiency and fluid balance. In haemodialysis, replacement is insignificant (except when at the end of the treatment a small amount of replacement fluid is given to reinfuse the blood from the extracorporeal circuit). In hemodiafiltration, total replacement measures treatment efficiency and fluid balance. It is crucial to understand the different impact of replacing fluid in pre- or post dilution mode.

*Replacement rate*

The replacement rate (Qr) is the amount of fluid replaced into the RRT circuit per time interval (minute, hour). The replacement rate should be prescribed based on ultrafiltration rate, to achieve a desired net ultrafiltration rate.

*Net ultrafiltration*

Net ultrafiltration is the net amount of fluid extracted from the patient (Total ultrafiltration – total replacement).

*Net ultrafiltration rate*

The net ultrafiltration rate is the net amount of fluid extracted from the patient per unit time (minute, hour) (Ultrafiltration rate – replacement rate).

*Total effluent*

The total effluent is the overall amount of fluid collected in the drainage bag.

*Total effluent rate*

The total effluent rate is the amount of fluid collected in the drainage bag per unit time (minute or hr).

*Ultrafiltration*

The process of ultrafiltration can occur in different modes: isolated, sequential or concomitant to diffusive processes. A number of the definitions above must be further expanded depending on the process used.

It is important to understand that the extracorporeal system is not the sole component in overall fluid balance, as many anuric patients have other sources of fluid loss including insensible losses, losses from burns, wounds and the gastrointestinal tract. When prescribing an ultrafiltration rate, these sources of fluid loss and simultaneous fluid intake must be considered.
What are the physiological targets and goals for fluid management with RRT?

To preserve tissue perfusion in patients with AKI, one of the key purposes of any form of RRT is to optimize fluid balance by effectively removing fluid without compromising the effective circulating fluid volume (see algorithm Group 3). In these patients, it can be difficult to accurately assess fluid balance by simple clinical examination, due to both patient- and disease-specific factors (14,15). When patients are first connected to an extracorporeal circuit, profound hypotension may occur even before any ultrafiltration has taken place, due to blood-membrane interactions (16). In addition to bradykinin and nitric oxide generation, which is typically membrane and pH related, severe allergic reactions can also occur with heparins (17).

Hypotension is also the major complication when the rate of removal of plasma water exceeds the refilling capacity of compensatory fluid movement from the intracellular and extracellular compartments. In ambulatory patients, refraining from eating during dialysis, and lying flat rather than sitting up can reduce the incidence of intradialytic hypotension. Increasing the frequency of dialysis sessions from alternate-day to daily reduces the net amount of ultrafiltrate required per session and is associated with a corresponding reduction in hypotensive episodes (18). Similarly, reducing the ultrafiltration rate or lengthening the dialysis session has been associated with reduced hypotensive episodes, and probably accounts for the cardiovascular stability reported with hybrid techniques such as SLED and the Genius® system (19,20). Deliberately cooling the dialysate has also been shown to reduce intradialytic hypotension (21). Some machines allow isothermic dialysis, so the dialysate is cooled according to the heat generated during dialysis. Other changes to the dialysis prescription designed to reduce hypotension include increasing the dialysate sodium concentration and prolonging the duration of the dialysis session (22-27). Most haemodialysis machines are now equipped with monitors to assess the effect of ultrafiltration on haematocrit, and some have the capacity to regulate the ultrafiltration rate with biofeedback. This advance has been reported to reduce the incidence of intradialytic hypotension during chronic haemodialysis sessions (28).

Many centres use a treatment bundle, or combination of measures to reduce the incidence of hypotension during acute haemodialysis, including using a slower blood flow rate compared to maintenance chronic intermittent haemodialysis, extending the duration of the treatment session, using a high sodium dialysate concentration with a cooled dialysate, profiling ultrafiltration and not starting ultrafiltration until the patient is stable on dialysis (24, 29).

In terms of modality, cooling tends to be greater with convective therapies than dialysis, particularly when predilution fluid replacement is used (30). In addition, when the same sodium concentration is used in dialysate and replacement solutions, convective therapies tend to result in a more positive sodium balance than dialysis because the sodium sieving coefficient is less than 1.0 as discussed above (31, 32). Consequently, convective therapies may provide greater cardiovascular stability than pure dialytic techniques for the same net rate of ultrafiltration (33). Intradialytic hypotension can also be reduced by the
administration of sympathomimetic drugs, such as midrodine and, in the intensive care setting, de-novo infusion of vasopressors or an increase in baseline inotropic support during RRT (34, 35). Recently, it has been recognized that the blood levels of vasopressin do not increase during haemodialysis-associated ultrafiltration; parenteral administration of vasopressin analogues have been reported to reduce the incidence of intradialytic hypotension (36). Small cohort studies suggest that high volume CVVH may also improve cardiovascular stability during RRT. Whether this is due to the effect of thermal losses, positive sodium balance or other factors remains to be determined (37,38).

Summary: Safe prescription of fluid loss during RRT requires intimate knowledge of the patient’s underlying condition, understanding of the process of ultrafiltration and close monitoring of the patient’s cardiovascular response to fluid removal. Recommendations for clinical practice: Ultrafiltration should only be commenced once the patient has been stabilized on RRT and RRT circuits should be thoroughly rinsed prior to starting therapy (grade D). The following treatment bundle should be considered to minimize hypotensive episodes during intermittent forms of RRT (grade C):

1. Choosing the appropriate dialyzer.
2. Cooling the dialysate to ≤36°C or using isothermic dialysis.
3. Keeping the dialysate sodium 10 mEq/l greater than the plasma sodium concentration.
4. Prescribing an initial blood flow ≤ 250 ml/min.
5. Prescribing longer duration of dialysis sessions.
6. Increasing the frequency of RRT treatments.
7. Utilizing dialysis machines equipped with biofeedback.
8. Regularly reviewing patient response to ultrafiltration rate and adjusting accordingly.
9. Avoiding medications that cause vasodilation.

Start of new question? Please state the question.

Initiation of ultrafiltration

It is vitally important to clinically assess the patient, and then review charts and other physiological parameters, to determine the degree of relative extracellular fluid overload. The decision on which modality of RRT to use will depend upon both the patient’s clinical status and the resources available. The rate of fluid removal will depend upon the individual patient’s effective circulating volume at the time of assessment prior to starting RRT. Ultrafiltration should only be commenced once the patient has been stabilized on RRT. Thereafter, the net ultrafiltration rate should be adjusted according to changes in physiological parameters (39).
Are these two sections part of same question?

Maintenance phase

Once the patient has been stabilized on RRT, it is important to prevent continuous fluid removal, as this can lead to hypovolemia and reduced effective circulating volume and compromise renal tissue perfusion. Animal studies in AKI have shown that renal autoregulation can take weeks to recover, thus making the recovering kidney potentially vulnerable to further ischaemic episodes (40). In addition, Augustine and colleagues have shown that hypotension during the first haemodialysis treatment is the major risk factor for failure to recover renal function following AKI (41). This may explain why some recent studies have shown a higher rate of renal recovery in patients with acute kidney injury treated with CRRT than with intermittent haemodialysis (42-44). During CRRT, although the patient may be stabilized and maintained at a stable weight, many patients are at risk of developing a negative sodium balance and to become relatively hypovolemic due to low sodium and nutritional intake. It is therefore important to maintain patients not only in an isovolaemic state, but also to maintain an appropriate sodium balance. Sodium fluxes into and out of the patient depend mainly on convective movement and, therefore, total ultrafiltration during CRRT, rather than diffusion with the standard dialysate sodium concentrations currently used in clinical practice (13). It is therefore important to regularly reassess patients treated by CRRT to determine whether they have developed a reduced effective plasma volume, by assessing the response to a volume challenge (see Workgroup 3 algorithm). On the other hand, patients may become hypervolemic during the maintenance phase of RRT due to administration of additional parenteral fluids, such as antibiotics, inotropic infusions, and repeated colloid infusions. Moreover, CRRT itself reduces insensible losses due to patient cooling.

??? where do these relate? You don’t mention hybrid therapies above.

Recommendations for preventing complications during ultrafiltration with hybrid/CRRT modalities: (Grade E)

1. Regularly reassess clinical response to ultrafiltration rate and readjust accordingly

2. Regularly check for signs of reduced effective circulating volume, by determining the response to and increased cardiac preload.

Start of new question? Please state the question.

Machine and/or operator fluid balance errors

20 years ago, it was common for fluid balance errors to occur during ultrafiltration, as control systems in haemodialysis machines were not volumetrically controlled, and infusion pumps designed to pump fluids into patients, were used to control ultrafiltration losses during CRRT systems. Today, adverse effects due to erroneous fluid management can still occur during renal replacement therapies because of inadequate
prescription (including both the rate of net ultrafiltration or the overall amount (total) of net ultrafiltration) or errors in delivery due to machine malfunction or misuse (in the presence of a correct prescription).

The degree of risk to the patient can be classified as serious, if it can lead to permanent impairment or requires a medical intervention to prevent it, or potentially fatal if it may lead to patient death or require urgent medical intervention to prevent serious injury and death. The nature and the severity of a fluid balance error during RRT depend upon both the magnitude of the error and the patient’s clinical condition.

**Start of new question? Please state the question.**

This section generates a risk analysis for fluid balance error based on expert opinions, literature and current experience (45-48). Fluid Balance prescription should be made based on an accurate assessment of fluid status of the patient. The total net ultrafiltration and ultrafiltration rate should be determined by the severity of fluid overload in conjunction with clinical and haemodynamic tolerance to fluid removal. Despite an appropriate prescription, errors in fluid balance may still occur due to errors in the machine ultrafiltration control system and/or operator’s errors in the input of treatment parameters. In clinical practice, fluid imbalances can potentially result in patient morbidity due to both positive and/or negative errors in fluid balance. In an attempt to describe the worst possible case scenario, an example using a standard intermittent haemodialysis session of 4 hours duration will be taken, as the same error in continuous therapies, being distributed over 24 hours may cause less morbidity. Nevertheless, even in continuous therapies, errors in fluid balance may occur in a specific period of time during the daily session. Figure 1 summarizes fluid imbalance classification and provides insight into the potential hazardous situations that may result. This section attempts to quantify the clinical severity of the fluid balance error, and describe threshold values for each fluid imbalance scenario that may lead to marginal, serious injury or even death.

**Are these new questions? Please state the question(s).**

**Negative fluid imbalance: general considerations**

Negative fluid imbalance, due to errors causing excessive fluid removal from the patient, can result in clinically relevant consequences. In some cases the problem may occur due to an error in the original prescription. Alternatively, when the prescription is correct, the error may be due to a software or hardware dysfunction leading to excessive fluid removal compared to that which was prescribed. Negative fluid balance errors may lead to either excessive cumulative amounts of fluid removal (total net Uf) or excessive rate of fluid removal from the patient (Ultrafiltration rate).

**Cumulative error**

Cumulative error leads to excessive fluid removal from the patient with consequent hypovolemia. As extracorporeal fluid removal is achieved by ultrafiltration of plasma water from the intravascular compartment, it is normally assumed that this compartment is refilled by the transfer of water from interstitial and intracellular spaces.
Ultrafiltration rate error

Ultrafiltration rate error leads to permanent or transient reduction of circulating blood volume with immediate haemodynamic consequences. This can be due to errors in the original prescription or discrepancies between the effective ultrafiltration rate delivered and prescribed. Although different patients tolerate different rates of ultrafiltration, it has been shown that prescriptions above 0.35 ml/(min*kg) are associated with a high probability of haemodynamic complications (49).

Start of new question? Please state the question. Please organize the rest of this to match the style used in the attached example from group 2.

Rationale for threshold values and harm severity evaluation

Cumulative Error

According to expert opinion and current clinical practice, this could be classified as marginal, serious and/or potentially fatal. In adult patients, an error between 0 and 1.5% body weight (BW) is classified as marginal, resulting in minimal discomfort or moderate hypotension. This range corresponds to 600 g for a 40 kg patient. Thus, in the worst case scenario, such a volume equates to the fluid volume returned (wash back) at the end of treatment from the extra-corporeal circuit e.g., 300 ml and the sum of the saline re-infused and possible oral water intake during treatment. In any given treatment, the patient must reach a weight of 600 g below the prescribed weight in order to meet the target value after reinfusing the blood in the extracorporeal circuit. This range of error is not considered to cause a clinical problem in adult patients and it generally results in a severity score range of 1-2 (negligible or marginal) with no symptoms or general discomfort, cramps, or only moderate hypotension. A serious volume error between 1.5 and 2.5% BW may cause hypotension, nausea and vomiting, cramps, changes in cardiac output and heart rate, followed by hypertensive rebound due to medical intervention (lifting of legs, saline and/or other fluid infusion and reduced Ufr) (severity score level 3-4: serious). A fluid error greater than 2.5% of BW may, unfortunately, result in severe symptomatic hypovolemia and even death (severity score 4-5, potentially fatal). Such an error not only affects cumulative values, but also has an impact on the ultrafiltration rate error. It would be similar to increasing the normalized ultrafiltration rate to approximately. 0.1ml/min.kg (dialysis time = 4h; BW = 40kg). According to previous work, this additional ultrafiltration rate leads to a doubling in the frequency of symptomatic hypotensive episodes compared to a Ufr rate of 0.35ml/min.kg (49).

In low weight pediatric patients, the marginal volume error range of 1.5% BW results in 220 g (BW = 15 kg), which can be assimilated to a pediatric extra-corporeal circuit volume of approx. 120 ml and a fluid intake/administration of approximately 100 ml.
Ultrafiltration Rate Error

In terms of Uf rate prescription error, only Uf rates greater than 0.35 ml/(min*kg) have been considered as potential causes of harm during standard haemodialysis treatments. As discussed above, this Uf rate increases the incidence of hypotensive episodes (49). During continuous therapies this level of error is less likely to occur, as Uf rates prescribed are traditionally much lower than those for intermittent treatments.

Positive fluid imbalance: general considerations and risk analysis

Positive fluid imbalance occurs when errors determine insufficient fluid removal compared to prescribed and result in fluid gain, i.e. net positive fluid administration to the patient.

Insufficient Fluid Removal

If insufficient total net Uf (fluid removal) is achieved, compared to that prescribed (prescribed patient fluid loss). In a chronic kidney disease dialysis patient, this results in the post-treatment body weight below the pre-dialytic weight but above the prescribed end-dialytic weight (dry weight). Within this range, patients usually show haemodynamic tolerance. As such, this error is marginal and can be easily corrected by prolonging the treatment time, scheduling an additional treatment or increasing the Uf rate in the remaining scheduled treatment time (monitoring haemodynamic tolerance to the new Uf rate regime). However, if left uncorrected, a serious situation may develop. In the case of intermittent haemodialysis, this then results in a greater pre-dialytic weight prior to the next scheduled treatment session, and thus makes achieving the desired dry weight more difficult. In the case of continuous renal replacement therapies the same error results in a prolonged state of overhydration, but as the error is distributed over 24 hours it can be detected and remedied more easily.

Fluid gain

Positive fluid balance results from an actual net fluid gain during the haemodialysis session. In clinical practice, the severity of the effect will depend upon the magnitude of weight gain and/or whether the patient needs an isovolaemic treatment. Greater adverse clinical effects can be observed if the patient gains fluid during a treatment intended to achieve significant fluid removal. The overall difference between prescribed fluid loss and effective fluid removal (net Uf prescribed – net Uf achieved), will be negative, indicating net fluid gain. Furthermore, the clinical effects of fluid gain may vary depending upon body weight. Thus, evaluation of this serious situation must consider both patient weight and prescribed total net ultrafiltration.
Rationale for threshold values and harm-severity evaluation

Threshold values for positive fluid imbalance can be calculated as percentage of body weight (BW) (Table 1 and table 2). When prescribed total Uf – Achieved Total Uf [ml] (assuming an equivalence of 1 ml = 1 g) is from 0 - 2.5% BW, patients may be asymptomatic or have slight discomfort, headache, and/or moderate hypertension (severity grade 1-2, marginal). When the increase rises to 2.5 - 7.5% BW, there may be serious clinical consequences with increased severity of symptoms and signs, including dyspnoea (continuation of symptoms if they were present from the beginning of the session) severe hypertension, seizures, pulmonary oedema (requiring specific medical interventions including; increased Uf rate, prolonged or additional dialysis session, pharmacological support, or admission to hospital).

When the fluid gain is > 7.5% BW, this may be so severe that it may be potentially fatal. Between intermittent dialysis treatments, the average inter-dialytic fluid accumulation is between 2.5-4% of body weight (e.g., it corresponds to 2000-2500 ml for a patient of 60-70 kg). Typically, the patient tolerates this extra volume until the next dialysis session. Thus an average fluid loss of 2-3 liters is generally scheduled in a 4 hour haemodialysis session. Insufficient fluid removal in this range should not result in catastrophic consequences. In the case of continuous renal replacement therapy, the maximum total net ultrafiltration in a day may reach values up to 7.5 % of body weight but is generally well tolerated; as such weight loss is distributed over 24 hours, with greater chances of both adaptation and recognition.

Fluid gain, within a 4 hour treatment (intermittent HD) has a different effect compared to that during the inter-dialytic period. In particular, the more weight the patient has to loose (i.e. the more fluid accumulates during inter-dialytic period), the less fluid gain can be tolerated, particularly for the smaller patient. The same considerations apply for continuous therapies although the fluid gain is distributed over an extended period of time.

PROBLEMS WITH CURRENT MACHINES

The older generation of machines for intermittent HD, and the previous generation of CRRT equipment were often unable to accurately control fluid balance. The Uf control system in haemodialysis was subject to temperature and flow variations, and errors were often significant and frequent. In CRRT, the use of adoptive technology involved different pumps and not fully integrated control systems, and which were often used inappropriately from their original design. These systems are inadequate for accurate fluid control and should not be used outside of a setting of strict and continuous supervision.
The newer generations of CRRT machines are definitely more reliable but may still cause some problems (50). For example, the “fluid balance error” alarm can be overridden on multiple occasions, without stopping the treatment. Fortunately, the most recent software releases force the operator to stop the therapy after a given number of repeated alarms. In these machines a fluid balance error between 20 and 50 ml triggers an alarm. Before the software improvements, the alarm could be overridden up to 10 times, leading to a possible cumulative error between 200 and 500 ml. It will not make sense to trigger alarms for a smaller error since this would result in a continuous stop of the treatment. On the other hand, the operator should not override the alarm more than 3 times without correcting the source of the alarm.

A recent study has provided information on how some machines handle fluid balance errors (48) Most CRRT machines do not stop treatment and leave to the user the opportunity to override the alarm multiple times. This could lead to potential hazards to the patient. However, based on the relatively lower volume threshold of 20-50 ml, and on the short reaction time for each alarm to occur, the user will receive a specific warning adequate to prevent clinical problems. In fact, we should differentiate between technically relevant fluid balance errors and clinically relevant fluid balance errors. While 50 grams might represent a technically relevant fluid balance error, from a clinical perspective, an overnight 12 hour fluid balance error of 500 grams can be easily tolerated. Importantly, the largest number of such mistakes occurs overnight. Nevertheless, both physicians and nurses should be professionally engaged to reduce and be aware of machine errors (48). Alarms should not be silenced without thought and attention to the cause of the alarm, even in the absence of any immediate risk for the patient. Alarms can be deliberately overridden by bypassing a temporary circuit fault, whilst trying to correct the problem. However, sometimes the fault is not easily corrected and the alarms are overridden multiple times. If the operator does not recognize that errors sum up, this action may lead to large cumulative fluid imbalances. Continually overriding alarms might be commoner than expected. For this reason, a flow chart of operations and a strict adherence to certified procedures should be practiced in the ICU (51-53).

All machines are accompanied by manuals which are carefully prepared and exhaustive in their information. The section on troubleshooting always describes all the causes for any particular problem that the user may encounter and in most of the cases the error is displayed on the machine. However, the importance of in-center, hands-on training, precise protocols and defined procedures for CRRT cannot be underestimated (54-56).

Recommendations for preventing complications during ultrafiltration with hybrid/CRRT modalities: Grade E level 5.
All operators of intermittent and/or continuous renal replacement machines should be appropriately trained and certified initially and on a periodical basis.

All operators of such machines should be aware of the potential complications of over-riding machine alarms.

Intensive care and dialysis units should record hourly and total effluent volumes during continuous renal replacement therapies, and pre and post treatment weights, and ultrafiltration loss for intermittent therapies.

ADQI group 1 proposes as a research agenda:

Establish threshold values for clinical fluid balance errors in adult and pediatric practice.

Develop additional monitoring measures to prevent fluid balance errors (bioimpedance, on-line blood volume etc).

Assess whether intra-treatment hypotensive episodes impact on renal recovery and/or delay renal recovery.

Fluid balance errors and monitoring should be emphasized in CRRT and HD training courses. A professional certification may be an appropriate method to prevent fatal errors due to machine malfunction or especially machine misuse by incompetent operators.

References


Fig. 1 – A classification of fluid imbalance.
Fig. 2. When excessive volume contraction has occurred, no fluid is available for further refilling. In this case, both bioimpedance and blood volume measurements demonstrate a progressive hypovolaemia; hypotension is caused by reduction of the extracellular fluid volume (ECFV).
Table 1. Reference Table for “Insufficient fluid removal/Fluid gain” values in the severity range 1-2

Note: the table shows the “Actual fluid removal”(net Uf achieved), that is the difference between start-dialysis and end-dialysis patient weight. When the value in the table is negative, the actual fluid removal is to be read as “Fluid gain”
### Table 2. Reference Table for “Insufficient fluid removal/Fluid gain” values in the severity range 1-5

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**Note:** The table shows the “Actual fluid removal” (net Uf achieved), that is the difference between start-dialysis and end-dialysis patient weight. When the value in the table is negative, the actual fluid removal is to be read as “Fluid gain.”

### Authors:
In alphabetic order:

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Insufficient fluid removal = 7.5% BW --> Severity = 5