Fluid Regulation vs Fluid Removal

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Abstract

Fluid management is an integral component in the management of patients with acute renal failure (ARF) in the ICU setting. In the presence of a failing kidney, fluid removal is often a challenge and requires the use of high dose diuretics with a variable response. It is often necessary in this setting to institute dialysis for volume control rather than metabolic control. CRRT techniques offer a significant advantage over intermittent dialysis for fluid control, however if not carried out appropriately can result in major complications. In order to utilize these therapies for their maximum potential it is necessary to recognize the factors which influence fluid balance and have an understanding of the principles of fluid management with these techniques.

Introduction

Over the last decade there has been a general trend to use aggressive fluid resuscitation for patients with multi organ failure to achieve supra normal levels of oxygen delivery. This has been largely based on the findings of several studies which have shown that survival in critically ill surgical patients is associated with supra normal levels of cardiac output, oxygen delivery and oxygen utilization (56). Although this concept has now been questioned (7,8), it is still an important factor in the management of the ICU patient. The end result is often a markedly edematous patient with fluid sequestration in all organs. Third spacing of fluids is common and fluid removal by glomerular filtration is limited by plasma refilling from the interstitial compartment. Most surgeons and intensivists who believe in the value of supra normal oxygen delivery are willing to accept edema as a side effect of fluid resuscitation, however there is evidence to suggest that fluid overload by itself may be an important factor contributing to an adverse outcome. Lowell et al (9) have shown that in a group of surgical patients mortality was related to the extent of fluid overload with a 100% mortality in patients with more than 20% increase in fluid from baseline. This can be explained if one recognizes that the consequences of fluid excess are not limited to superficial edema but result in myocardial and gut edema thereby compromising vital organ functions and promoting local ischemia. It is therefore essential that the strategy of fluid management be viewed in the context of permitting support without compromising vital organ function. The goals of fluid management in this setting are to remove fluid without compromising cardiac output, compensate for the increased fluid given to achieve hemodynamic stability and maintain urine output. To achieve these goals it would be ideal to 1) have the capability of unlimited fluid removal so that any amount of fluid intake can be easily accommodated without fluid retention and 2) have the ability to alter the rate of fluid removal at will. While glomerular filtration can easily achieve the first criteria it is extremely difficult to alter the rate of urine formation. CRRT techniques offer the flexibility required to achieve these goals.

Principles of Fluid Management with CRRT

CRRT techniques have two inherent characteristics which allow their use as highly effective methods for fluid control, a) utilization of highly permeable membranes and b) the continuous nature of the technique. Both these factors permit unlimited fluid removal which is limited only by the primary driving force (mean arterial pressure for non-pumped systems and pump speed for pumped systems) and the efficacy of the filter over time. The ability to remove large volumes of fluid can be manipulated in several different ways for fluid balance. As shown in Table 1 there are three levels of intervention. In Level 1 the ultrafiltrate volume obtained is limited to match the anticipated needs for fluid balance. This calls for an estimate of the amount of fluid to be removed over 8-24 hours and subsequent calculation of the ultrafiltration rate. This strategy is similar to that commonly used for intermittent hemodialysis and differs only in that the time to remove fluid is 24 hours instead of 3-4 hours. For example if it is estimated that four liters of fluid need to be removed over a 24 hour period the ultrafiltration rate is set at approximately 170 ml/hour. With this method the CRRT technique is used essentially as a means of achieving a fixed output per hour but no attempt is made to manipulate the ultrafiltration rate or accommodate changes in fluid intake. As a consequence replacement fluid may not be used and net fluid balance achieved may vary significantly from desired balance at the end of the time period. In some instances no attempt is made to set a particular ultrafiltrate rate and fluid removed at the end of each time period (8-24 hours) is simply tabulated and listed as an output. Thus there is minimal control for fluid management.

In Level 2 the ultrafiltrate volume every hour is deliberately set to be greater than the hourly intake and net fluid balance is achieved by hourly replacement fluid administration. In this method a greater degree of control is possible and fluid balance can be set to achieve any desired outcome. The success of this method depends on the ability to achieve ultrafiltration rates which always exceed the anticipated intake. This allows flexibility in manipulation of the fluid balance so that for any given hour the fluid status could be net negative, positive or even. A key advantage of this technique is that the net fluid balance achieved at the end of every hour is truly a reflection of the desired outcome. For instance as described in the example previously if 4 liters of fluid are to be removed over 24 hours the desired outcome every hour is a - 170 ml/hr. This implies that the ultrafiltration rate should be >or= 170 ml/hr + intake every hour. The net fluid balance desired may or may not be achievable however, this method permits control of overall fluid management using the CRRT technique. The amount of replacement fluid needed to achieve fluid balance is easily calculated using a flow sheet.

Level 3 extends the concept of the level 2 intervention to target the desired net balance every hour to achieve a specific hemodynamic parameter e.g. CVP, PAWP or mean arterial pressure. Once a desired value for the hemodynamic parameter is determined fluid balance can be linked to that value. For example, if it is desirable to keep a patients PAWP between 14-16 a sliding scale for hourly fluid management can be formulated so that for PAWP values of 12-14 net fluid balance is maintained at zero, for values greater than 14 fluid is removed and for values less than 12 fluid is replaced (Table 2). In essence this method maximally utilizes the capacity of CRRT techniques to control fluids. A key issue to recognize here is that by incorporating this level CRRT techniques have tremendous flexibility and are not simply devices for fluid removal but allow overall control of fluid management as fluid regulatory devices. This external control is a key advantage over intermittent hemodialysis. Additionally it can be viewed as an advantage over the normal kidney wherein there is limited control possible. In general greater control calls for more effort and consequently results in improved outcomes.

Practical Issues in Fluid Management

1. Prescription: This is a key issue in the proper use of these techniques and one which is often misunderstood. When CRRT techniques are utilized a prescription for fluid management requires consideration not only of the type and quantity of different fluids used for replacement or dialysate

but also the desired goals for the patient in the short term (24-48 hours) and over a longer period of time. This calls for a team approach with consultation between the intensivist, nephrologist, pharmacist, nutritionist and ICU and dialysis nursing staff. For instance a patient with a hypercatabolic state and metabolic acidosis may require custom compositions of the replacement fluids and dialysate and an ongoing evaluation of the nutritional effects. Definition of fluid goals for each time period should be multidisciplinary and reflect a thorough understanding of the patients condition and the CRRT technique. We have found that targeted intervention (Level 3) is easier to achieve, quantitate and monitor and generally facilitates understanding between different care providers. For example it is usually easier to agree on a target hemodynamic parameter (PAWP) which can be optimized than it is to decide on a patients overall volume status. The fluid management prescription is therefore somewhat dynamic and subject to frequent modifications depending upon the clinical condition. It has been our experience that frequent consultations between intensivists and nephrologists on establishing target parameters are extremely useful in this regard.

2. Establishing a Sliding Scale: In order to use Level 3 fluid management effectively the following are required: (a) The hourly UF volume should be in excess of all intakes every hour; b) Hemodynamic target should be selected for ease of measurement and to reflect overall parameter desired for stability. Usual choices CVP, PAWP, MAP, Systolic BP. c) accurate record of all intakes and outputs should be kept and used for hourly calculations. The parameter can be adjusted based on patient status and the scale adjusted as needed to achieve a goal. The main aim is to target fluid management to a hemodynamic parameter thereby using CRRT as a fluid regulatory device). Table 2 shows an example of a sliding scale. In the above example the sliding scale is weighed more heavily for giving fluid back when the parameter is low. This can be adjusted depending on the circumstance, however we have found that it is safer to be slow in fluid removal and more aggressive in fluid repletion to maintain stability.

3. Fluid Balance: Most current techniques of CRRT require an hourly or more frequent assessment of fluid balance. The process although labor intensive is fairly simple provided a separate flowsheet is used for the calculations. Table 3 shows examples of a net balance of -100, + 200, and 0 ml/hr. The third column depicts a situation in which the desired balance of -100 ml for the hour could not be achieved as the ultrafiltration rate was lower than the intake. As shown the 8 hour totals reflect the net balance having accounted for all intakes and outputs. A stepwise approach in the flowsheet captures all the relevant data and translates it into an action plan to achieve a pre-determined fluid goal. It is important to reiterate that using this approach fluid replacement always follows fluid removal and is usually an hour behind. From a nursing perspective the hourly measurement of ultrafiltrate and calculation of replacement fluids necessary is tedious however, can be minimized by some of the newer devices which are now available. The newer generation of pumped systems, use meticulous balancing devices (Hospal Prisma) or volumetric control (Fresenius Acumen) to achieve an ongoing fluid balance. While these systems provide the ability to maintain a set fluid balance and eliminate the hourly measurements, unfortunately, in their current configurations all these devices permit the use of the pumps for fluid removal only thereby limiting their application as Level 2 and 3 methods. As newer integrated systems become available targeted fluid balance will

be more automated and less prone to errors. In the interim a standardized approach to fluid balance is crucial to the success of these techniques.

4. Monitoring: Ongoing monitoring should involve checks on the composition of the fluids prescribed and determination that they are infusing in the right site. For instance, marked changes in the composition of blood can occur if a calcium solution intended for IV infusion is inadvertently infused as a dialysate fluid. The nursing staff, pharmacists and physicians should independently verify the accuracy of the fluids. Rapid changes in fluid status are easily achieved with CRRT techniques however controlled fluid management necessitates periodic assessment of nursing interventions. In our center the hemodialysis nurses check the flowsheets maintained by the ICU nurses every 12 hours. These are additionally checked by the nephrologist for accuracy. Monitoring also involves evaluation for leaks from the ultrafiltrate bag, changes in fluid infusion rates and composition.

Summary

Fluid management with CRRT requires an understanding of the principles of fluid removal and fluid balance. Although these appear to be similar to intermittent hemodialysis there are significant differences. In order to utilize these techniques to their full ability a variety of strategies can be used. No matter which method is used it is imperative that the goals for fluid management be well defined and monitoring for errors be a part of the protocol.

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