Electrolytes and micronutrients

CAUSES OF ELECTROLYTE DERANGEMENTS IN ACUTE RENAL FAILURE

<table>
<thead>
<tr>
<th>Hyperkalemia</th>
<th>Hyperphosphatemia</th>
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<td>Decreased renal elimination</td>
<td>Decreased renal elimination</td>
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<tr>
<td>Increased release during catabolism</td>
<td>Increased release from bone</td>
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<tr>
<td>2.38 mEq/g nitrogen</td>
<td>2 mmol/g nitrogen</td>
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<td>0.36 mEq/g glycogen</td>
<td>Increased release during catabolism:</td>
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<tr>
<td>Decreased cellular uptake/</td>
<td>0.6 mmol/L rise/0.1 decrease in pH</td>
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<td>increased release</td>
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Electrolytes in acute renal failure (ARF): causes of hyperkalemia and hyperphosphatemia. ARF frequently is associated with hyperkalemia and hyperphosphatemia. Causes are not only impaired renal excretion of electrolytes but release during catabolism, altered distribution in intracellular and extracellular spaces, impaired cellular uptake, and acidosis. Thus, the type of underlying disease and degree of hypercatabolism also determine the occurrence and severity of electrolyte abnormalities. Either hypophosphatemia or hyperphosphatemia can predispose to the development and maintenance of ARF [37].

Electrolytes in acute renal failure (ARF): hypophosphatemia and hypokalemia. It must be noted that a considerable number of patients with ARF do not present with hyperkalemia or hyperphosphatemia, but at least 5% have low serum potassium and more than 12% have decreased plasma phosphate on admission [38]. Nutritional support, especially parenteral nutrition with low electrolyte content, can cause hypophosphatemia and hypokalemia in as many as 50% and 19% of patients respectively [39,40].

In the case of phosphate, phosphate-free artificial nutrition causes hypophosphatemia within a few days, even if the patient was hyperphosphatemic on admission (black circles) [41]. Supplementation of 5 mmol per day was effective in maintaining normal plasma phosphate concentrations (open squares), whereas infusion of more than 10 mmol per day resulted in hypophosphatemia, even if the patients had decreased phosphate levels on admission (open circles).

Potassium or phosphate depletion increases the risk of developing ARF and retards recovery of renal function. With modern nutritional support, hyperkalemia is the leading indication for initiation of extracorporeal therapy in fewer than 5% of patients [38]. (Adapted from Kleinberger et al. [41]; with permission.)

Micronutrients in acute renal failure (ARF): water-soluble vitamins. Balance studies on micronutrients (vitamins, trace elements) are not available for ARF. Because of losses associated with renal replacement therapy, requirements for water-soluble vitamins are expected to be increased also in patients with ARF. M alnutrition with depletion of vitamin body stores and associated hypercatabolic underlying disease in ARF can further increase the need for vitamins. Depletion of thiamine (vitamin B1) during continuous hemofiltration and inadequate intake can result in lactic acidosis and heart failure [42]. This figure depicts the evolution of plasma lactate concentration before and after administration of 600 mg thiamine in two patients. Infusion of 600 mg of thiamine reversed the metabolic abnormality within a few hours. An exception to this approach to treatment is ascorbic acid (vitamin C); as a precursor of oxalic acid the intake should be kept below 200 mg per day because any excessive supply may precipitate secondary oxalosis [43]. (From Madl et al. [42]; with permission.)
Micronutrients in acute renal failure (ARF): fat-soluble vitamins (A, E, K). Despite the fact that fat-soluble vitamins are not lost during hemodialysis and hemofiltration, plasma concentrations of vitamins A and E are depressed in patients with ARF and requirements are increased [44]. Plasma concentrations of vitamin K (with broad variations of individual values) are normal in ARF. Most commercial multivitamin preparations for parenteral infusions contain the recommended daily allowances of vitamins and can safely be used in ARF patients. (From Druml et al. [44]; with permission.)

Hypocalcemia and the vitamin D–parathyroid hormone (PTH) axis in acute renal failure (ARF). ARF is also frequently associated with hypocalcemia secondary to hypoalbuminemia, elevated serum phosphate, plus skeletal resistance to calcemic effect of PTH and impairment of vitamin-D activation. Plasma concentration of PTH is increased. Plasma concentrations of vitamin D metabolites, 25-OH vitamin D3 and 1,25-(OH)2 vitamin D3, are decreased [44]. In ARF caused by rhabdomyolysis rebound hypercalcemia may develop during the diuretic phase. (Adapted from Druml et al. [44]; with permission.)

Micronutrients in acute renal failure (ARF): antioxidative factors. Micronutrients are part of the organism’s defense mechanisms against oxygen free radical induced injury to cellular components. In experimental ARF, antioxidant deficiency of the organism (decreased vitamin E or selenium status) exacerbates ischemic renal injury, worsens the course, and increases mortality, whereas replenishment of antioxidant status exerts the opposite effect [45]. These data argue for a crucial role of reactive oxygen species and peroxidation of lipid membrane components in initiating and mediating ischemia or reperfusion injury.

In patients with multiple organ dysfunction syndrome and associated ARF (lightly shaded bars) various factors of the oxygen radical scavenger system are profoundly depressed as compared with healthy subjects (black bars): plasma concentrations of vitamin C, of β-carotene, vitamin E, selenium, and glutathione all are profoundly depressed, whereas the end-product of lipid peroxidation, malondialdehyde, is increased (double asterisk, P < 0.01; triple asterisk, P < 0.001). This underlines the importance of supplementation of antioxidant micronutrients for patients with ARF. (Adapted from Druml et al. [46]; with permission.)
Acute Renal Failure

**Metabolic Impact of Renal Replacement Therapy**

**METABOLIC EFFECTS OF CONTINUOUS RENAL REPLACEMENT THERAPY**

- Amelioration of uremia intoxication (renal replacement)
- Plus
  - Heat loss
  - Excessive load of substrates (e.g., lactate, glucose)
  - Loss of nutrients (e.g., amino acids, vitamins)
  - Elimination of short-chain proteins (hormones, mediators?)
  - Induction or activation of mediator cascades
  - Stimulation of protein catabolism?

**FIGURE 18-25**

A. B. Impact of nutritional interventions on renal function and course of acute renal failure (ARF). Starvation accelerates protein breakdown and impairs protein synthesis in the kidney, whereas refeeding exerts the opposite effects [49]. In experimental animals, provision of amino acids or total parenteral nutrition accelerates tissue repair and recovery of renal function [50]. In patients, however, this has been much more difficult to prove, and only one study has reported on a positive effect of TPN on the resolution of ARF [51].

**Nutrition, Renal Function, and Recovery**

Infusion of amino acids raised renal cortical protein synthesis as evaluated by $^{14}$C-leucine incorporation and depressed protein breakdown in rats with mercuric chloride-induced ARF [49]. On the other hand, in a similar model of ARF, infusions of varying quantities of essential amino acids (EAA) and nonessential amino acids (NEAA) did not provide any protection of renal function and in fact increased mortality [52]. However, in balance available evidence suggests that provision of substrates may enhance tissue regeneration and wound healing, and potentially, also renal tubular repair [49]. (From Toback et al. [50]; with permission.)