

Metabolism and Nutrition in Trauma

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The main purpose of providing nutritional support to our patients is to preserve their cell body mass. This can be done either by intravenous feeding, when oral intake is not possible, or by enteral feeding. The optimal protocol for an intravenous nutritional regime is still under discussion, both with regard to energy supply and protein composition. When discussing the utilization of nutrients in patients after trauma and with sepsis, it is important to realize that in these conditions the metabolism and fuel utilization are altered, and it is essential to understand this when planning the nutrition for these types of patients. The typical metabolic response to trauma can be summarized in the following points:

1. Increased energy expenditure.
2. Increased extracellular water and sodium retention.
3. Accelerated gluconeogenesis.
4. Increased lipolysis.
5. Increased nitrogen excretion.
6. Changes in the plasma and muscle amino acid pattern and interorgan amino acid flow.
7. Decreased muscle protein synthesis.

It is not clear what initiates these metabolic changes, but the hypothalamus and the adrenergic-sympathetic system probably play very important roles. The catabolic hormones catecholamines, glucagon and cortisol can partly reproduce some of these changes when given as a triple hormone infusion to animals and healthy subjects (16,19,29,41,43,44,53). A change in the interorgan substrate flows has been demonstrated, and also increased glucose consumption and production, with an increased glucose pool. Another mechanism is the release of different polypeptides from macrophages, called monokines, which have other metabolic effects than catecholamines.

1. Increased energy expenditure: By indirect calorimetry, it has been shown that after uncomplicated elective surgery there is a moderate increase in the energy expenditure. Only in some cases after severe trauma, sepsis and burns has a 50-100% increase in energy expenditure been reported (25). This increased energy demand can be met without problems by giving glucose and fat emulsions, but in the future in critically ill patients it will be necessary to measure the energy expenditure directly by indirect calorimetry to prevent overloading of fuel substrates. Especially in patients with multiple organ failure there is a risk of providing too much energy which the patient cannot utilize. Wilson et al. (59) measured the oxygen consumption of 100 critically ill patients who had undergone major trauma or operation. The mortality rate was 30% among patients who had normal or increased oxygen consumption, in contrast to 80% in the 20 patients whose oxygen consumption was lower than normal.

On the cellular level severe illnesses such as circulatory collapse, respiratory failure and severe nutritional depletion are associated with a decreased content of energy-rich phosphates in muscle, while no alterations have been observed after hip replacement surgery or after moderate injury. After severe trauma, in spite of an adequate supply of nutrients, the concentration of ATP in skeletal muscle has been found to decrease by 18% after one week, with a further decrease after one month. Directly after the trauma the phospho-creatine level is decreased by 20% and remains so for up to one month, while the total creatine pool in skeletal muscle is unaltered. The lactate concentration increases and the glycogen content decreases. The single exception to this pattern is the greater increment of the lactate concentration and the maintenance of the glycogen levels in muscle of patients who have received a high glucose intake after severe injury (27). Otherwise, glucose and lipid calories are equally effective in supporting the cellular energy status after severe trauma. The changes in the adenylate pool are still more pronounced in patients with prolonged diseases. In a group of patients with a 100% mortality the ATP content in muscle was only 50% of the normal, despite a normal lactate content (3). The important question is whether prolonged surgical hypermetabolism in the absence of shock may be associated with a decreased efficiency of phosphorylation, producing a situation in which the patient has an increased demand for oxidative substrates and oxygen, while producing relatively less ATP and more heat.

2. Water and sodium retention: It has long been known that trauma and sepsis cause an increase in the muscle contents of water, sodium and chloride.

Retained water is mainly distributed extracellularly (4,5,32,46,49). Potassium and magnesium are less affected, but their concentrations in muscle are decreased postoperatively. These changes are more accentuated in severe trauma and sepsis. Apparently parenteral nutrition does not influence the water and sodium retention in trauma (6). On the other hand, in critically ill patients it has been possible to partly correct these water and electrolyte abnormalities with nutritional support (17,45).

3. Accelerated gluconeogenesis: It is well known that hyperglycaemia follows injury. In the initial stage this is probably a result of rapid catecholamine-mediated mobilization of body carbohydrate stores (15,22,23,48). The carbohydrate stores in the liver will last only 12-24 hours without being replenished (33). The body glucose requirement must be met by an increased hepatic production of glucose from protein precursors. In the late phase of trauma the hyperglycaemia is a result of an increased synthesis of glucose relative to an increased turnover rate. Injury and sepsis apparently do not impair the ability of the body to oxidize glucose (20); the glucose oxidation is in fact increased in septic patients and gluconeogenesis cannot be suppressed even by intravenous infusion of glucose (30,31). In an interesting study Wilmore et al. (58) have demonstrated that skeletal muscle does not utilize glucose in the postoperative state and that the wound is responsible for the increased glucose utilization, accounting for almost the entire rise in glucose production after trauma.
4. Increased lipolysis: Postoperatively the turnover rates of glycerol and free fatty acids are increased (8,35), but there is probably no increase in the production of ketone bodies. Skeletal muscle uses almost exclusively lipids as fuel. Studies by Nordenström et al. (34) suggest that intravenous fat emulsions are utilized as an energy substrate in patients with major injury, infections or nutritional depletion.
5. Increased nitrogen excretion: This represents a phase of protein catabolism in which body proteins are degraded (26). Since proteins have specific functions in the organism and the loss of protein can be considerable, protein catabolism will eventually lead to impairment of organ function. Normally there is a balance between protein synthesis and breakdown, but posttraumatically the degree of degradation becomes greater than that of synthesis. After surgery of moderate magnitude there is a decrease in whole-body synthesis rather than an increase in degradation (10,36). In the case of major trauma both synthesis and degradation increase, the enhancement of degradation being the more pronounced (7,24). In the post-

traumatic period the nitrogen balance becomes negative as a result of an increase in urinary excretion of nitrogenous compounds, mainly urea (12,13,18). A major part of the nitrogen excreted derives from skeletal muscle (13). Protein loss from skeletal muscle causes muscular fatigue and hence trauma in a patient needs to be followed by a period of convalescence, the extent of which depends upon the amount of muscle protein lost (26). Preservation of body proteins is therefore an important task in the management of posttraumatic patients. Nutritional support has been instituted posttraumatically to counteract the catabolism and reverse the negative nitrogen balance (14,26). Enteral and parenteral feeding improve the negative nitrogen balance but not to a sufficient extent for it to attain equilibrium (14). Several adjuvant therapies have been instituted in addition to postoperative nutrition: epidural blockade (11,24), pharmacological doses of insulin (60), ornithine-alpha-ketoglutarate (28,55,56), branched-chain amino acids (9) and growth hormone (57) are examples.

6. Changes in the plasma and muscle amino acid patterns and interorgan amino acid flow: Skeletal muscle supplies the major part of the excreted nitrogen posttraumatically (13). The muscle protein waste is greater than would be expected from immobilization alone (13,42). There is a postoperative efflux of amino acids from peripheral tissues (38,47), and there are typical changes in the pattern of plasma amino acids and in the intracellular concentration of free amino acids in skeletal muscle following trauma (2,50,51). When discussing amino acid metabolism (2,50) based on plasma amino acid data it should be remembered that the largest pools of free amino acids are not in the extracellular space, but within the cells. Specific patterns of free amino acid concentrations unique for different catabolic states are now recognized. Interestingly, the pattern in trauma appears not to be influenced by the degree of injury and only minor effects on the pattern were apparent when various nutritional regimes were used (1,52). The typical muscle patterns of free amino acid in trauma are increased levels of branched chain and aromatic amino acids and a decrease in basic amino acids and glutamine (1,50-52). The interest in glutamine metabolism has increased during the last few years. It seems that a 50% decline in the muscle concentration of glutamine is obligatory to all types of catabolic states and that traditional TPN has no effect on this decrease. It is also reported that in sepsis there is a further decrease in the concentration of glutamine, and that there is a correlation between the mortality rate and the glutamine concentration (39). There is a decrease in muscle protein synthesis rather than an increase in degradation following uncomplicated surgery (10,40). Therefore, estimation of muscle

protein synthesis in the posttraumatic period is necessary to understand the pathophysiology of trauma and for evaluation of the effects of nutritional support.

7. Decreased muscle protein synthesis: Patients undergoing cholecystectomy were investigated. Independent of nutritional support, the total ribosome concentration per mg of DNA and the percentage proportion of polyribosomes decreased on the first and third days postoperatively, suggesting that the operative trauma per se initiated the decrease in ribosome utilization (37). The decrease in the concentration of polyribosomes was of the same magnitude as is observed during total starvation, indicating that skeletal muscle was used as a source of nutritional substrates posttraumatically. Protein synthesis in skeletal muscle after surgery has not previously been estimated by tissue analysis. The results indicate a marked decrease both in the activity of and the capacity for protein synthesis.

Protein synthesis in skeletal muscle, as determined by the ribosome method, did not respond to the administration of postoperative TPN. This finding is in accordance with the results obtained from measurements of the concentrations of intracellular free amino acids in skeletal muscle (37) and of the efflux of tyrosine from the leg (38).

Branched chain amino acids (BCAA) are claimed to preserve muscle nitrogen when given after trauma, but the concentration of ribosomes and the size distribution of ribosomes in muscle show no differences attributable to the content of BCAA in the TPN formula (54). However, provision of ornithine-ketoglutarate together with postoperative TPN improves both the nitrogen balance and the ribosome utilization in muscle tissue (55).

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