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Preparation of the Intensive Care Patient for Major Surgery

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Improved methods for monitoring and treating critically ill patients have increased the number of surgical candidates with multiorgan system impairment. Whereas such patients may have been considered "too sick to undergo surgery" in the past, many such patients linger in the intensive care unit unless definitive therapy is accomplished. Specific attention to review of the patient's preoperative preparation for surgery on a system-by-system basis may improve outcome substantially. The need for possible mechanical ventilation prior to transport to the operating room must receive particular attention. Pneumothorax, if present, must be treated prior to institution of positive-pressure ventilation so progression to tension pneumothorax can be avoided. Deficits in the circulating blood volume must be identified and corrected preoperatively if possible. A need for enhancement of cardiac output or alteration of vascular tone requires pulmonary arterial catheterization and indicates an increased operative risk. Metabolic abnormalities such as disturbances of acid-base balance, sodium or potassium concentration, and endocrinopathies are identified and corrected as much as possible prior to operation. Antibiotics are instituted as appropriate. Replacement of the red blood cell mass is dictated primarily by anticipated or actual blood loss. Factors of coagulation are infused on a replacement basis as necessary. Great care must be taken during transport to the operating room, as maintenance of intravascular monitoring devices, therapeutic infusions, and mechanical ventilation must continue during transport. Precautions must be taken to avoid hypothermia during transport and institution of anesthesia. Critical illness mandates specific considerations of the anesthetic agents to be utilized.

The number of critically ill patients presenting for consideration of major operative procedures has increased substantially in recent years. Factors involved in this increase include substantial advances in the ability to provide critical care support to patients with a variable degree of organ dysfunction and failure. As a result, patients who were formally thought "too sick to tolerate an operation" can be maintained in an intensive care unit for prolonged intervals. Such patients commonly require operative procedures as definitive or primary therapy for their underlying condition. Careful consideration of their preoperative status and preparation can have a substantial impact on their chance for a successful outcome after operation. This preparation requires (1) physical examination, (2) appropriate therapeutic intervention, and (3) arrangements for the safety of the patient during transport. A careful system-by-system evaluation with specific interventions to improve each system function can optimize the risk-benefit ratio. In critically ill patients, the question often arises as to whether these evaluations and preparations produce a delay in accomplishment of an urgently required operative procedure, thereby negating any benefit they may accomplish. The criteria for weighing the risks and benefits of immediate versus delayed operation for critically ill patients include the following: (1) The operation is immediately required for the patient's survival (e.g., repair of exsanguinating hemorrhage from trauma or a ruptured aortic aneurysm). In such urgent circumstances, the risk of organ failure during operation is a minor consideration in the decision to operate. (2) The operation is clearly necessary for the patient's survival, but time is available for preoperative evaluation and preparation. In this circumstance, the focus of decision making is on timing the operation to allow maximum risk reduction. (3) The operation is elective or not critical for the patient's immediate survival. In this circumstance, the patient's response to preoperative therapeutic intervention is useful for evaluating physiologic reserve and for predicting tolerance of operative stress. The operation is generally delayed until the conditions necessitating intensive care have resolved somewhat.

It must be emphasized that despite the heavy reliance of the intensive care unit (ICU) on monitoring the physiologic parameters, extensive testing of blood, and other mechanical devices, a careful and complete history and physical examination must always be the first step when evaluating a patient for operation. For an in-depth discussion of each of the organ systems discussed below, the reader is referred to the two volume book *Care of the Surgical Patient* published by the Committee on Pre and Postoperative Care of the American College of Surgeons.

Ventilation

Evaluation

A history of smoking, asthma, previous pulmonary resection, or bronchitis calls for investigation to determine the patient's pulmonary reserve. Even in the absence of previous pulmonary problems, however, respiratory failure may occur secondary to shock, sepsis, or other catastrophic illness.

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During the physical examination, particular attention should be paid to the patient's respiratory rate and breathing pattern.

1. Shallow, rapid breaths (> 24/minute), combined with anxiety or altered mental status, are often the first signs of respiratory insufficiency preceding the development of hypoxemia.
2. Thick, purulent secretions associated with fever mandate examination and culture of a sputum smear for white blood cells and microorganisms.
3. Tracheal deviation, localized rales or rhonchi, or decreased breath sounds should be investigated with a preoperative chest roentgenogram, which can also be used to confirm the position of endotracheal and nasogastric tubes, central venous and pulmonary arterial catheters, pacemakers, and other devices.

If pneumothorax is present, it should be treated with tube thoracostomy before positive-pressure ventilation is begun so progression to tension pneumothorax can be avoided. Hydrothorax and empyema are also treated with tube thoracostomy, but this procedure may be performed after anesthesia has been induced.

Time permitting, elderly patients and those with known pulmonary disease, chronic cough or dyspnea, or a history of smoking should be evaluated with pulmonary function tests. Reductions in forced expiratory volume (FEV), the ratio of FEV to forced vital capacity (FVC) (i.e., FEV/FVC), and maximum ventilatory volume (MVV) indicate airway obstruction, decreased effectiveness of the cough mechanism, and probably postoperative sputum retention [1]. Obstructive airway disease increases the risk of pulmonary complications even if the patient's resting $PaCO_2$ is normal (35–42 mmHg); carbon dioxide retention markedly increases this risk [2].

Restrictive lung disease, which is characterized by decreases in inspiratory capacity, vital capacity, and total lung capacity, may complicate lung resection. Diminished respiratory muscle strength, as indicated by reduced FVC and maximum inspiratory force (MIF), forecasts difficulty weaning the patient from mechanical ventilation.

Assessment of patients with established respiratory failure who are undergoing mechanical ventilation should include measurement of pulmonary function (including arterial blood gas analysis), ventilator settings: fraction of inspired oxygen (FIO_2), positive end-expiratory pressure (PEEP) level, respiratory rate and inspiratory versus expiratory rates, tidal volumes, peak inspiratory pressures, and inspiratory flow rate and pattern). Information concerning the mode of ventilation employed (controlled mechanical ventilation, synchronized intermittent mandatory ventilation, pressure support, inverse-ratio ventilation) should be obtained to determine requirements and limitations for continuing patient care during transport and in the operating room. Endotracheal tube position can be confirmed by chest roentgenographic examination and chest auscultation.

Therapeutic Intervention

If ventilatory impairment is anticipated, an arterial catheter should be inserted for frequent measurement of the patient's PaO_2, $PaCO_2$, and pH. Hypoxemia should be corrected with supplemental oxygen. If therapy with a nasal cannula or mask fails, endotracheal intubation and mechanical ventilation are indicated. The guidelines for institution of mechanical ventilation include (1) abnormal respiratory mechanics (respiratory rate > 35 breaths/minute; tidal volume < 5 ml/kg body weight; vital capacity < 15 ml/kg body weight; maximum inspiratory force < 25 cm H_2O); (2) disturbances of oxygenation (PaO_2 < 60 mmHg with $FIO_2 > 0.6$; alveolar arterial oxygen [$P_{(A-a)}O_2$) difference 350 mmHg); and (3) inadequate ventilation ($PaCO_2$ > 60 mmHg; deadspace: tidal volume ratio > 0.6). Endotracheal intubation for airway control may also be required in patients at risk of pulmonary aspiration (altered level of consciousness, faciomaxillary trauma, abdominal distension, intestinal obstruction, gastrointestinal hemorrhage, or gastric outlet obstruction).

During the perioperative period the patient's fractional concentration of oxygen in inspired gas (FIO_2) should be maintained as high as is necessary to reverse hypoxemia. However, maintaining an FIO_2 of more than 50% for long intervals increases the risk of oxygen toxicity and absorption atelectasis. For such a patient, PEEP should be initiated and gradually increased to optimize oxygenation and allow reduction of FIO_2 to below toxic levels [3]. As the PEEP increases to more than 10 cm H_2O, tidal volume should be decreased to avoid high peak inspiratory pressures, which can cause pneumothorax or reduced cardiac output [4].

Preoperative and postoperative pulmonary physiotherapy should be performed with voluntary patient effort. Incentive spirometry and cough induction are effective ways to open areas of atelectasis and to drain secretions; in an intubated patient, bronchoscopy readily removes major plugs, thereby restoring airway patency and lung volume. Bronchodilators can be administered and titrated to clinical response, serum concentration, and adverse reactions such as tachycardia. If pulmonary infection is suspected or demonstrated, systemic antibiotics can be administered to reduce secretions and minimize sepsis. Organism-specific antibiotics should be used whenever possible to avoid the overgrowth of resistant bacteria.

Circulation

Evaluation

Critically ill patients are prone to the development of circulatory collapse during operations as a result of the induction of anesthesia or intraoperative blood loss. Preoperative hemodynamic evaluation is therefore critical and should include assessment of (1) intravascular volume, (2) myocardial performance, and (3) vasomotor tone.

Hypotension (systolic blood pressure < 90 mmHg) with impaired tissue perfusion requires aggressive evaluation and treatment. Initial evaluation is focused on distinction of hypotension and impaired perfusion on the basis of hypovolemia as opposed to cardiac dysfunction. The evaluation should include a baseline electrocardiogram looking for evidence of ischemia or arrhythmia and chest roentgenography, although the chest film is of limited value for determining cardiac and intravascular filling in the critically ill patient.

Myocardial performance and oxygen delivery must be optimized preoperatively to the extent that time allows. Tissue perfusion is evaluated at the bedside by physical examination to include the patient's mental status, skin color, and turgor by temperature, blood pressure, heart rate, and urine output. Urine output of at least 0.5 ml/kg/hr indicates adequate end-organ perfusion in the absence of primary renal disease, glycosuria, diuretic therapy, or diabetes insipidus. In patients with oliguria, laboratory studies my be required to distinguish prerenal from intrinsic renal disease and secondary oliguria. Urine specific gravity or elevated urine osmolality (> 500 mOsm/L), urine sodium concentration < 20 mEq/L, or a ratio of blood urea nitrogen (BUN) to creatinine > 20:1 suggests inadequate renal perfusion [5]. The issue of prerenal versus intrinsic renal oliguria in fact is most often evaluated by a fluid challenge of 0.5 to 1.0 liter of a rapidly infused balanced electrolyte solution as a diagnostic as well as a therapeutic maneuver. This maneuver can be done only in patients with no history of cardiac failure and with no clinical signs or concerns regarding cardiac impairment or pulmonary edema. Increased urine output in response to this fluid challenge indicates volume depletion and the need for more aggressive volume replacement.

In the presence of intrinsic renal disease or cardiac insufficiency, invasive monitoring is necessary to access the adequacy of intravascular fluid volume and cardiac action. The central venous pressure measures venous return on the right side of the heart and reflects volume status reasonably accurately in patients with normal cardiac function. Many critically ill patients, however, have potential or known associated pulmonary or cardiac disease, such that the function of the left side of the heart may not be adequate despite normal right cardiac function. These patients require pulmonary arterial catheterization for estimation of pulmonary arterial wedge pressure (PAWP) for determination of cardiac output by thermal dilution and for calculation of peripheral vascular resistance [6]. Pulmonary arterial catheters should not be used routinely, however, because they are associated with a number of complications including cardiac arrhythmias as they are placed, sepsis including acute bacterial endocarditis, and subclavian vein thrombosis [7]. Extrapolation of PAWP to assessment of left ventricular filling pressure and function is commonly done but must take into account a variety of technical and physiologic assumptions that may be clinically unreliable [8]. Nevertheless, the data obtained by the pulmonary arterial catheterization may be crucial to therapeutic management of circulation in all but the most stable and youngest critically ill patients being prepared for a major operation.

Therapeutic Intervention

If possible, anesthesia induction should not be done in hypovolemic patients. Balanced electrolyte solutions are the first choice for fluid replacement; and administration is guided by serum electrolyte concentration and profusion responses. The use of blood or its components is discussed below. The use of compounds such as albumin, dextran, and other plasma expanders is controversial and generally not necessary for ICU patients being prepared for operation.

The fluid replacement can usually be aggressive and timely. Careful monitoring is essential and is effective in avoiding acute fluid overload in most patients. Patients who demonstrate impaired cardiac contractility or valvular disease may not experience correction of diminished cardiac output despite establishment of adequate filling pressures. These patients require careful determination of the relation of filling pressure to cardiac output (Frank-Starling relation), and manipulation of myocardial contractility and vascular tone must be considered. In such patients only the most urgent or emergent operations should be done, as the mortality risk is substantial. This pharmacologic manipulation must be coordinated with the anesthesiologist, as its continuation during anesthesia is necessary. Risk factors associated with myocardial infarction or death among patients undergoing noncardiac operation include (in order of decreasing impact): (1) S_3 heart sound or jugular venous distension; (2) myocardial infarction during the preceding 6 months; (3) cardiac arrhythmias other than premature atrial contractions and other than premature ventricular contractions occurring at a rate of < 5/minute [9].

Metabolism

Evaluation

The history and physical examination may reveal multiple factors that predispose the patient to metabolic abnormalities. For example, acid-base disturbances occur in patients with impaired respiratory function or circulation. Vomiting, nasogastric suction, or enterocutaneous fistulas lead to loss of body fluids and electrolytes. Endocrine disturbances such as diabetes, steroid therapy, or thyroid disease have a substantial impact on critical illness. Routine preoperative diagnostic laboratory studies should include measurements of the arterial blood gases and pH, serum electrolyte levels, BUN, and creatinine. Calcium, phosphorus, and magnesium concentrations should also be determined, as depletion is common among critically ill patients.

Therapeutic Intervention

Acid-Base Abnormalities. Any of the four classic acid-base disturbances (metabolic acidosis, metabolic alkalosis, respiratory acidosis, and respiratory alkalosis) may be identified preoperatively in critically ill patients. In general, when the pH is < 7.30 or > 7.50, correction is a priority [10]. Otherwise the following measures should be instituted when the abnormality is detected, although rapid correction or delay of operation is not generally required.

1. *Metabolic acidosis* (pH < 7.35, HCO_3^- < 20 mEq/L, base deficit −3 or more, $PaCO_2$ < 35 mmHg) occurs most commonly in the presence of impaired tissue perfusion and accumulation of lactic acid. Such impaired tissue perfusion is generally due to hypovolemia and should be corrected as much as possible preoperatively. Other causes of metabolic acidosis, such as diabetic ketoacidosis or renal failure, should be treated specifically. Rapid correction of pH abnormalities require administration of sodium bicarbonate to restore myocardial function.
2. *Metabolic alkalosis* (pH > 7.45, HCO_3^- > 25 mEq/L, $PaCO_2$ > 40 mmHg) is associated with predisposing factors that include hypersecretion of aldosterone secondary to reduced renal perfusion with HCO_3 retention, nasogastric aspiration of gastric acid, and administration of large doses of antacids. Treatment consists in maximizing tissue perfusion particularly

by volume replacement, placing greater reliance on H_2-receptor blockers for management of gastric acidity, and increasing infusion of potassium chloride.

3. *Respiratory acidosis* (pH < 7.35, HCO_3^- > 25 mEq/L, $PaCO_2$ > 45 mmHg) requires improved alveolar ventilation. Endotracheal intubation and institution of mechanical ventilation may be required prior to transport to the operating room.

4. *Respiratory alkalosis* (pH > 6.47, HCO_3^- > 24, PCO_2 > 35) is caused by hyperventilation. Hypoxemia, if present, should be corrected, and sedation may be necessary. A rebreathing mask or increased deadspace may also be necessary.

Sodium Concentration Abnormalities. Sodium concentration changes in plasma usually precede clinical manifestations except when the change is rapid or marked. When treating either hyponatremia or hypernatremia, primary consideration must be given to total body fluid (volume) status as well as sodium concentration. With hyponatremia, the amount of water excess should be calculated. Restriction of free water is most commonly indicated. Administration of hypertonic saline is rarely indicated unless the patient has neurologic signs. With hypernatremia, estimation of the water deficit with or without a sodium deficit indicates the need for infusion of appropriate therapy.

Potassium Concentration Abnormalities. Ninety-eight percent of total body potassium is contained in the intracellular space such that serum potassium concentration may not accurately reflect total body potassium status. Hypokalemia is usually a result of excess excretion or loss of potassium. Overzealous correction can be hazardous [10]. Potassium lost is easily replaced with intravenous solutions. No more than 40 mEq/hr should be infused [10]. If hyperkalemia is associated with peaked T waves or other electrocardiographic (ECG) changes, infusion of exogenous potassium should be discontinued. Intestinal potassium binders can be used. In addition, temporary reduction of serum potassium can be stimulated by enhancing potassium uptake into cells with the use of glucose and insulin.

Renal Failure. If a preoperative ICU patient has existing acute or chronic renal failure, urine output may not be an accurate measure of tissue perfusion. In such patients, monitoring the pulmonary arterial wedge pressure and cardiac output is often necessary to ensure appropriate preoperative and intraoperative fluid therapy. All medications must be reviewed and the appropriate dosage estimated.

Endocrine Disease

1. *Adrenocortical insufficiency* may be suggested by the history and physical examination, but an inadequate stress response secondary to past or current steroid therapy is the most common cause of adrenocortical insufficiency in ICU patients. Perioperative stress dosages of hydrocortisone are indicated (100 mg three times daily), although weaning from this dosage can be accomplished within 3 days postoperatively if the patient is stable.

2. *Diabetes mellitus* may produce exaggerated hyperglycemia in diabetic patients as the result of increased gluconeogenesis, glucose recycling, or resistance to the action of insulin in certain tissues such as muscle. Principles of management include frequent monitoring of plasma glucose and electrolyte concentrations and avoidance of hyperosmolar dehydration, limitation of glucose intake to 150 grams/day, and providing appropriate doses of insulin. Both hypoglycemia and hyperglycemia should be avoided. Hyperglycemia is followed by glycosuria, osmotic diuresis, and a risk of hyperosmolar coma if sustained. In addition, hyperglycemia leads to glycosylation of circulatory proteins, thereby altering their function [11, 12]. Immune proteins may be among those proteins affected adversely by hyperglycemia [13]. Adjustment of a continuous intravenous insulin infusion is the most effective means of controlling the variable degrees of glycemia that may occur in critically ill diabetic patients being prepared for operation.

3. *Thyroid disease* requires that a careful history and physical examination be obtained to establish a suspicion of either hyper- or hypothyroidism, as laboratory screening is not routine and many of the findings of both conditions occur commonly among ICU patients. Rapid treatment of hypothyroidism may require intravenous levothyroxine [14]. Hyperthyroid conditions are treated by blocking thyroid hormone synthesis with propylthiouracil. Thyrotoxic crisis requires immediate control and includes β-blockade.

Malnutrition. Protein-caloric malnutrition (PCM) is common in critically ill patients, especially if an operation has been required and nutrients cannot be taken by mouth. Recognition of PCM preoperatively is useful so nutritional support can begin promptly after the operation. PCM associated with critical illness cannot be corrected in a matter of days, and routine provision of intravenous feeding to preoperative patients does not necessarily improve outcome [15]. Therefore urgent operations should not be delayed for the purpose of providing preoperative nutritional support. Micronutrients (vitamins, minerals, and trace elements including magnesium, phosphorus, and zinc) can be replaced preoperatively over 1 to 2 days if time permits [16]. Magnesium depletion is particularly common among critically ill patients and requires aggressive replacement [17]. Vitamin therapy, including vitamin K, is given empirically. If the patient is receiving parenteral nutrition, the rate of glucose infusion should arbitrarily be reduced by half prior to operation to avoid production of acute hyperglycemia associated with anesthesia and operation.

Alterations in Body Temperature

1. *Hypothermia* is a distinct possibility in ICU patients, as they are prone to developing it during transport to the operating room and institution of the operative procedure. Hypothermia is to be avoided, as it is associated with increased ventricular irritability, decreased contractility, and altered hemostasis. Adequate attention to prevention is generally sufficient.

2. *Hyperthermia* is common preoperatively in critically ill patients with sepsis, a common indication for operation. Only marked hyperthermia (> 40°C) requires pharmacologic or mechanical cooling [18]. Mechanical cooling in particular may be deleterious, as the patient may respond with increased energy expenditure (due to shivering, for example) in order to maintain the centrally mediated hyperthermic state.

Infectious Complications

Sepsis is the most frequent cause of death among critically ill surgical patients, and control of sepsis is one of the more common indications for urgent operation in ICU patients. In addition, critically ill patients are at particular risk for the development of nosocomial infection. They are commonly immunosuppressed to some degree from the stress of their primary illness and from reticuloendothelial system blockade by bombardment with cellular debris from injured tissue. Medications including antibiotics also contribute to immunosuppression.

Evaluation

For any patient in whom clinical parameters suggest the presence of sepsis, serial blood cultures should be done preoperatively so as to focus on postoperative antibiotic therapy. Intravascular devices that may be a source of sepsis should either be evaluated by blood culture aspirated through the device, exchange of the catheter over a guidewire with associated blood and semiquantitative cultures of the device [19], or removal. Appropriate body fluids and potentially infected material should also be cultured. Imaging studies to locate an infectious focus are indicated depending on clinical circumstances. Patients with immunosuppressive diseases or conditions secondary to medication require particularly careful assessment for infection.

Therapeutic Intervention

Drainage of infected material such as a wound abscess or a localized internal infection should be accomplished if possible prior to operative intervention. Broad-spectrum antibiotic coverage is indicated for septic patients [20].

Antibiotic prophylaxis is indicated for patients undergoing operations that are associated with a 10% or higher incidence of wound infection or other infectious complications [21]. Prophylactic antibiotics should be given no earlier than 2 hours preoperatively and continued for a maximum of 24 hours. A single preoperative dose may provide maximum benefit.

Hematologic Considerations

Evaluation

Evaluation of hematologic status in ICU patients is focused on detection of anemia, coagulopathy, bone marrow suppression, and risk factors for thromboembolic complications. In addition to the history and physical examination for each of these considerations, a complete blood count, platelet count, prothrombin time, and partial thromboplastin time are obtained.

Red Blood Cell Mass

Critically ill patients are commonly anemic as a result of blood loss and reduced hematopoiesis. Blood loss occurs during operative procedures, as clinically occult blood loss, and from phlebotomy (average 41.5 ml/day) [22]. Impaired hematopoiesis persists in critically ill patients, especially septic patients, despite provision of appropriate nutrients. Excess iron should not be provided to preoperative patients in view of evidence that suppressed iron concentration in septic patients may depress growth of pathogenic bacteria, an action that suggests a teleologic response [23].

The role of preoperative blood transfusion to correct anemia is uncertain. Although increasing severity of anemia among both ICU and preoperative patients is statistically predictive of an adverse outcome [24, 25], preoperative transfusion of red blood cells to achieve an arbitrary hemoglobin concentration such as 10 grams/dl does not necessarily improve outcome because of the complications of the transfusion itself. Autologous blood is rarely available for critically ill preoperative patients such that exposure to transmission of infectious disease and transfusion-induced immunosuppression may more than offset the benefit of the increased red blood cell mass [26]. Intraoperative blood loss is a stronger predictor of adverse outcome and a need for a blood transfusion than is preoperative anemia [27]. The decision for preoperative blood transfusion should therefore be based on the needs to establish adequate parameters of the circulation and the degree of anticipated operative blood loss rather than the preoperative hemoglobin concentration alone.

Disorders of Coagulation

Acquired coagulopathies are far more common among ICU patients than inherited disorders, such as hemophilia A. Most cases of hemophilia A are apparent from the history. Treatment consists in factor VIII concentrate.

The most common bleeding disorders encountered by surgeons are disseminated intravascular coagulation, coagulopathies associated with massive transfusions or circulating anticoagulants including drugs, and decreased hepatic synthesis of coagulation factors. Each of these situations should be evaluated independently and corrected as indicated. Thrombocytopenia may not require replacement transfusions unless severe ($< 50{,}000/mm^3$), the bleeding time is prolonged, or diffuse intraoperative bleeding occurs. Factor replacement in preoperative patients is generally nonspecific, consisting of fresh frozen plasma. The prothrombin time and partial thromboplastin time are guides to therapy. Severe deficits of clotting factors may require 6 units of fresh frozen plasma for replacement.

Risk of Thrombosis

The critically ill patient is known to be at risk for thromboembolic disease due to venous stasis, hypercoagulability, and associated endothelial injury. Risk factors include advanced age, malignancy, venous disease or a history of deep venous thrombosis, history of pulmonary embolism, congestive heart failure, and prolonged bed rest. Hypercoagulable states may also be familial (e.g., antithrombin III, protein C or protein S deficiency). Subcutaneous heparin injection of 10,000 to 15,000 units per day may accomplish effective prophylaxis, although a continuous intravenous infusion of heparin of 1000 units per hour or more sufficient to slightly prolong the partial thromboplastin time provides more effective prophylaxis with an acceptable risk of bleeding [28].

Prophylactic measures such as lower extremity sequential pneumatic compression devices are helpful for patients at low risk and should be used routinely in critically ill patients undergoing operative procedures. Dextran and aspirin have been advocated in the past for prophylaxis against venous thrombosis but are less effective than the other methods described above. Warfarin may provide effective prophylaxis but is difficult to regulate in critically ill patients.

Gastrointestinal Complications

Gastrointestinal complications that may be life-threatening include ischemic necrosis or perforation, stress ulceration with hemorrhage or perforation, and infection. Diarrhea, which is common among critically ill patients, may complicate fluid management, cause skin breakdown, and increase the risk of nosocomial infection to other patients. Evaluation and management of diarrhea generally consists in adjusting an acid dosage, examining the stool for fecal leukocytes, culture, and assay for *Clostridium difficile* toxin. Occult blood is frequently present in the nasogastric aspirate because of tube trauma and requires no specific evaluation. Gastrointestinal hemorrhage, however, requires diagnostic endoscopy if time permits.

Most surgically ill patients require nasogastric decompression preoperatively because of gastric atony, which can lead to aspiration during endotracheal intubation. Maintenance of the gastric pH above 4 at all times is essential to prevent stress ulceration. *C. difficile* infection is treated with metronidazole or vancomycin. Agents that induce hypomotility, such as narcotics, must be used with caution to avoid worsening any infection or causing paralytic ileus, which is common in critically ill patients.

Central Nervous System Abnormalities

Impaired mental function is common in patients with a critical illness. This dysfunction is often attributed to "metabolic encephalopathy." All patients should undergo a mental status examination. When a patient's mental status is impaired, consent for operation must be obtained in accordance with local law and procedures. If any evidence suggestive of a localized process is present, it should be evaluated further with a cranial computed tomography (CT) scan. Management of encephalopathy generally consists in attempts to resolve the metabolic disturbances responsible. The need for psychological support must be emphasized.

Transport to the Operating Room

Patients in the ICU are clearly placed at increased risk while they are transported to the operating room. Appropriate monitors and apparatus for mechanical ventilation must be provided to continue the same level of care as is accomplished in the ICU. Great care must be taken to avoid loss or occlusion of vascular access devices. Special attention must be paid to maintaining body temperature. A physician should directly participate in and supervise the transport. The operating room must be fully prepared to accept the patient promptly so the monitoring and therapeutic intervention can immediately resume following transfer to operating room equipment.

Anesthetic Considerations

General Issues

Despite optimal care, patients undergoing transport from the ICU to the operating room often sustain deterioration in cardiovascular and respiratory status. The patient must be immediately reevaluated following his or her connection to the monitors and anesthesia ventilators in the operating room. The position of the endotracheal tube must be confirmed. Continuous monitoring of the end-tidal carbon dioxide concentration is instituted. The endotracheal tube is suctioned following confirmation of its position. Continuation of intravenous infusions is confirmed, and adequate additional intravenous access is established as needed. Adjustments to ventilation may be required to correct for deterioration and respiratory function associated with patient transport or patient positioning.

Anesthetic Agents

High-dose opioid (fentanyl, sufentanil) techniques provide the most stable conditions in patients with poor cardiovascular function [29]. Opioid anesthesia may necessitate postoperative mechanical ventilation due to central respiratory depression; however, it may be desirable in the unstable patient as endotracheal intubation and mechanical ventilation may well continue to be required immediately after the operation. Gaseous anesthetic agents have been associated with depression of immune responses, whereas opioid agents are less likely to interfere with immune function [30]. Nitrous oxide should be avoided in critically ill patients owing to the risk of anemia as well as gaseous distension of organs, such as intestine. Volatile anesthetic agents in common usage (halothane, isoflurane, and enflurane) may worsen intrapulmonary shunts through inhibition of hypoxic pulmonary vasconstriction [31], although the severity of this problem under clinical conditions is uncertain. Succinylcholine may be associated with the rapid potassium efflux from muscle. This effect occurs to a lesser extent with longer-acting depolarizing agents.

Résumé

L'amélioration des méthodes de surveillance et de prise en charge des patients de réanimation fait que l'on est de plus en plus souvent amené à opérer des patients dont plusieurs fonctions vitales sont gravement perturbées. Beaucoup de ces patients, qui autrefois auraient été jugés inopérables, vont rester en unité de soins intensifs à moins qu'un traitement définitif ne soit réalisé. L'étude pré-opératoire de ces patients organe par organe permet le plus souvent d'améliorer de façon importante les suites opératoires. La nécessité d'une éventuelle ventilation artificielle pré-opératoire doit notamment être envisagée. Un pneumothorax devra être drainer avant de débuter une ventilation en pression positive afin d'éviter la survenue d'un pneumothorax suffocant. Une hypovolémie doit être évaluée précisément et corrigée dans la mesure du possible avant l'intervention. La nécessité d'améliorer le débit cardiaque ou des modifications des résistances vasculaires périphériques témoignent d'un risque opératoire accru et nécessitent la prise de la pression artérielle pulmonaire. Des perturbations

métaboliques telles qu'un déséquilibre acido-basique, ou des modifications de la kaliémie ou de la natrémie de même que des perturbations endocriniennes doivent être reconnues et corrigées autant que possible avant l'intervention. Une antibiothérapie est débutée lorsqu'elle est indiquée. Les transfusions de culots globulaires sont indiquées en fonction des pertes sanguines escomptées ou en cours. Des facteurs de coagulation sont administrés pour corriger des déficits lorsque cela est nécessaire. De grande précautions doivent être prises durant le transport en salle d'opération pour ne pas arracher les cathéters de mesure de pressions centrales et les cathéters de perfusions, la ventilation artificielle doit être maintenue pendant le transport. Des précautions doivent être prises pour éviter un refroidissement durant le transport et au moment de l'induction anesthésique. Les drogues anesthésiques utilisées seront sélectionnées en fonction de l'état du patient.

Resumen

Los métodos avanzados de monitoría y tratamiento de pacientes en estado crítico han resultado en un incremento en el número de candidatos a cirugía con alteraciones orgánicas multisistémicas. En tanto que tales pacientes puedan ser considerados como "demasiado enfermos" para ser sometidos a cirugía, muchos de ellos pueden quedar confinados por largos periodos a menos que se emprenda una terapia quirúrgica definitiva. El cuidado especial hacia revisar la preparación preoperatoria con bases en el análisis sitema-por-sistema puede mejorar sustancialmente el resultado final. Especial atención se debe prestar a la necesidad de posible ventilación mecánica con anterioridad al transporte a la sala de cirugía; si existe neumotórax, éste debe ser tratado antes de instaurar ventilación de presión positiva, con el objeto de evitar que progrese a un neumotórax a tensión. Los déficits en el volumen circulatorio deben ser identificados con certeza y, en lo posible, ser corregidos preoperatoriamente. La necesidad de mejorar el débito cardiaco o de alterar el tono vascular exige la cateterización arterial pulmonar y es indicativa de mayor riesgo operatorio. Las alteraciones metabólicas tales como desequilibrio ácido-base o en la concentración del sodio y del potasio, así como la presencia de endocrinopatías, deben ser identificadas y corregidas tanto como sea factible con anterioridad a la operación. Se deben administrar antibióticos en forma apropiada. El reemplazo de la masa corpuscular roja está primordialmente indicado por las pérdidas de sangre previsibles o reales. Los factores de coagulación son infundidos según necesidad. Gran cuidado debe prestarse al transporte a la sala de cirugía, por cuanto el mantenimiento de los sistemas de monitoría intravascular, de las infusiones terapéuticas y de la ventilación mecánica es essencial en el curso del transporte. Se deben tomar precausiones para evitar la hipotermia durante el tranporte y durante la inducción de la anestesia. El estado crítico exige consideraciones específicas en cuanto a los agentes anestésicos que deban ser usados.

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