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From the ICU to the operating room: how to manage the patient?

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Purpose of review
To outline key points for perioperative ICU optimization of nutrition, airway management, blood product preparation and transfusion, antibiotic prophylaxis and transport.

Recent findings
Optimization entails glycemic control for all, with specific attention to type-1 diabetic patients. Transport-related adverse events may be averted with surgery in the ICU. If moving the patient is unavoidable, transport guidelines should be followed and hemodynamic optimization, airway control, and stabilization of mechanical ventilation ensured before transport. Preinduction preparation includes assessment of the airway and high-flow oxygen to prolong apneic oxygenation. Postintubation, a protective positive ventilation strategy, should be employed. Ideal transfusion thresholds are 7 g/dl for hemodynamically stable adult patients, 8 g/dl in orthopedic/cardiac surgery/cardiovascular disease and higher in specific disease states. Antimicrobial prophylaxis within 120 min of incision prevents most surgical site infections. Antibiotic therapy depends on the antibiotics being received in the ICU, the time elapsed since ICU admission, local epidemiology and the type of surgery. Tailored antimicrobial regimens may be continued periprocedurally. If more than 70% of the nutritional requirement cannot be met enterally, parenteral nutrition should be initiated within 5–7 days of surgery or earlier if the patient is malnourished.

Summary
ICU patients who require surgery may benefit from appropriate perioperative management.

Keywords
intensive care, operative, perioperative care, surgical, surgical procedures, transportation of patients

INTRODUCTION

ICU patients often require multiple surgical procedures, which may be either planned or emergent. The most complex cases are usually those that require repeat surgical interventions in the operating room because of peritonitis caused by sepsis. Complicating the care of these patients even further are the challenging decisions that must be made regarding patient preparation for transport. The following review addresses several important aspects of patient care in these specific circumstances (Fig. 1).

OPTIMIZATION OF GLUCOSE CONTROL AND NUTRITION

In surgical patients, both the antecedent illness as well as the procedure itself drive a state of catabolism and peripheral insulin resistance that can lead to abnormal glycemic homeostasis. Hyperglycemia, in particular is associated with impaired wound healing, increased length of stay, complications and mortality [1,2]. Similarly, hypoglycemia is

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- Adequate preparation for surgery in ICU patients requires nutritional optimization, careful airway management, appropriate preparation of blood products, antibiotic prophylaxis and carefully planned patient transport.
- Serum glycemia should be maintained between 140 and 180 mg/dl with continuous insulin infusions in type 1 diabetics to avoid ketoacidosis.
- Enteral nutrition should ideally be withheld during planned intervention and reinstated shortly thereafter.
- If more than 70% of the nutritional requirement cannot be met enterally, parenteral nutrition should be initiated within 5–7 days of surgery and earlier in the setting of malnourishment.
- Unstable patients with severe hypoxemia require airway control and stabilization with mechanical ventilation before transport.
- Hemodynamic stabilization may require intravenous fluids and vasopressors before induction of anesthesia.
- During rapid sequence induction, high oxygen flows maintains apneic oxygenation.
- Following intubation, tube placement should be verified with capnography and a protective positive ventilation strategy employed.
- A transfusion threshold of 7 g/dl is recommended for hemodynamically stable adult patients, with 8 g/dl recommended in orthopedic or cardiac surgery and in patients with cardiovascular disease.
- Preoperative cross matching of packed red blood cells is only necessary for procedures with a risk of significant and rapid hemorrhage.
- Timely antimicrobial prophylaxis (within 120-min of incision) may prevent 80% of surgical site infections.
- Patients who are receiving no antibiotics in the ICU and those taken from the ICU to the operating room less than 48 h following ICU admission should receive preprocedural prophylactic antibiotics in accordance with standard recommendations.
- Patients in the ICU for more than 48 h who are already being treated with a tailored antimicrobial regimen may continue this regimen periprocedurally.
- Bedside surgery in the ICU decreases transport-related adverse events.
- When moving the patient is unavoidable, implementation of transport protocols may avert transport-related complications.

associated with adverse neurological sequalae [3] and increased morbidity in critically ill patients [4].

Preoperative optimization of glycemic control ideally starts before the date of surgery as an elevated HbA1c is independently associated with perioperative complications [5]. Contrary to elective surgery, which usually requires a 20–30% dose reduction in insulin for fasting diabetics regardless of type [6,7], the ICU patient is likely to arrive to the operating room fasting with or without a short-acting insulin drip. Critically ill patients are typically hyperglycemic because of an ongoing stress response, and are therefore often managed in the ICU with a short-acting insulin infusion. Although this infusion may or may not have been withheld for the sake of simplifying patient transfer, it must be restarted in the operating room for fasting patients with type 1 diabetes in order to avoid ketoacidosis [8▪▪]. Outside of emergency surgery, oral and noninsulin injectable antihyperglycemic medications should be stopped on the morning of surgery [9].

During surgery, and in the immediate postoperative period, blood glucose monitoring is required at 1–2 hourly intervals. Early recommendations to maintain blood glucose at less than 110 mg/dl [10] were found less efficacious in avoiding morbidity compared with a more conservative target of 140–180 mg/dl [11]. If the patient remains hyperglycemic despite an insulin infusion, they should be treated with a bolus of intravenous insulin and an increase in the baseline intravenous dose. Hypoglycemia should be treated with intravenous 5% dextrose. Serum potassium levels should be monitored alongside serum glucose especially when exogenous insulin is administered.

Following surgery, once enteral feeding is reinstituted, basal insulin can be restarted although a dose reduction may be needed if caloric intake is poor. When replacing intravenous with subcutaneous insulin, a 2 h overlap between the two modes of administration should be ensured. With the exception of Metformin, which should only be restarted with adequate enteral hydration, oral antihyperglycemic medications may be restarted once enteral diet has been successfully established. Metformin should be restarted only once adequate hydration is also achieved.

Serum albumin poorly reflects nutritional status during critical illness. Although nutritional optimization ideally starts at least 7–10 days preoperatively, this is often not possible in most ICU patients. Malnourishment in the ICU is common and associated either with premorbid state or acute inflammation. When the stress of acute illness occurs in the setting of malnutrition, lean body muscle decreases precipitously [12]. As malnutrition

in the ICU is associated with infectious complications [13] and mortality in emergency surgical patients [14], preventing nutritional decline is paramount.

Nutritional support should be considered for all patients requiring greater than 48 h of ICU admission as admissions exceeding this time-frame have an increased risk of malnutrition [15]. Continuous enteral nutrition may be withheld during the period of surgery itself and ideally reinstituted in the ICU immediately after surgery. Nutritional requirements should be met gradually over 48 h and overnutrition avoided [15]. If more than 70% of the nutritional requirement cannot be met with enteral feeding, or if enteral feeding is contraindicated, supplementation via an alternative route is needed [16]. Parenteral nutrition should be initiated within 5–7 days, although if the patient is clinically or biochemically malnourished before surgery, parenteral nutrition should be initiated earlier.

MANAGEMENT OF THE AIRWAY AND VENTILATION

Management of patients with borderline hypoxemia and complicated noninvasive or invasive ventilation is challenging. Therefore, oxygenation and ventilatory support of critically ill patients should ideally be provided in a well monitored and specialist-led ICU. Optimal support of those patients requiring surgery is particularly difficult for both the intensivist and the anesthesiologist; adverse events related to airway management and mechanical ventilation are more likely to occur in ICU patients requiring treatment in the operating room than in patients undergoing elective surgery regardless of the location of intubation [17]. To reduce the risk of adverse events in critically ill patients [18▪], the following strategies should be implemented.

If the patient is being treated in the ICU with noninvasive positive pressure ventilation, transport may be unsafe if a high flow nasal cannula or high flow oxygen of more than 15 l/min is required to maintain an oxygen saturation of more than 90%. In this situation, gas exchange may deteriorate during transport. Furthermore, as urgent airway management in suboptimal conditions has been associated with a very high risk of complications [19–21], airway control and stabilization with mechanical ventilation should occur before transport to the operating room.

Before proceeding to intubation, the predicted difficulty should be assessed using scores specifically developed for critically ill patients, such as the MACOCHA score [22–23]. Severe dyspnea is often accompanied by aerophagia with resultant gastric distension, which puts the patient at increased risk of aspiration even when fasted. Therefore, in the setting of critical illness, rapid sequence induction is the technique of choice to secure the patient's airway [24]. Beforehand, preoxygenation should be optimized with noninvasive ventilation [25]. Following induction, apneic oxygenation must be maintained by using high flow oxygen via the nares [26▪]. The Montpellier Intubation Protocol, which was developed to prevent complications associated with airway management in ICU patients, can easily be adapted for intubation of critically ill patients in the operating room. In addition to preoxygenation and rapid sequence induction, this protocol includes hemodynamic optimization with fluid loading and vasopressors prior to induction of anesthesia and verification of correct tube placement with capnography [24].

Following intubation, a protective positive ventilation strategy should be used including low tidal volumes, moderate to high positive end-expiratory pressures (PEEP) and recruitment maneuvers [27]. Manual insufflations without monitoring of inspiratory pressures should be avoided [28]. Although esophageal pressure monitoring may help to titrate PEEP [29], PEEP should be balanced in order to prevent atelectases whilst simultaneously avoiding over-distension and hemodynamic compromise [30]. Spontaneous breathing has been associated with earlier weaning from mechanical ventilation and discharge from the ICU, and should therefore be allowed if possible [31]. Fastidious monitoring with revision of ventilator settings to limit lung injury will prevent the development or worsening of the acute respiratory distress syndrome.

BLOOD PRODUCT PREPARATION AND TRANSFUSION

Although 10 years ago, the practice of regular blood tests was ostracized for critically ill patients [32–34], many still undergo multiple daily blood sampling. Preoperative anemia has been associated with 30-day postoperative mortality, acute myocardial infarction, acute ischemic stroke, central nervous system complications and acute kidney injury [35▪▪].

As the association between perioperative anemia is thought to arise from the presence of underlying chronic or severe disease rather than from the anemia itself, preoperative transfusion is not key to preventing postoperative complications. In the setting of orthopedic [36] and cardiac surgery [37,38], sepsis [39], major burns [40], upper gastrointestinal hemorrhage [41], a restrictive transfusion trigger (hemoglobin of 7–8 g/dl) is similar to a liberal transfusion trigger (hemoglobin <10 g/dl) in terms

of short-term outcomes. Restrictive transfusion triggers also do not affect quality of life [42] or the rate of rehabilitation from physical disability [43] after surgery.

Current international guidelines strongly recommend a restrictive transfusion threshold for all hospitalized adult patients who are hemodynamically stable. A somewhat higher but still restrictive transfusion threshold of 8 g/dl is used for patients undergoing orthopedic or cardiac surgery and those with preexisting (i.e. chronic) cardiovascular disease. However, those patients with an acute coronary syndrome, those with bleeding diathesis who are at risk of bleeding and patients who have chronic transfusion-dependent anemia should have their hemoglobin maintained above 10 g/dl [44▪].

Wasting of blood products is an important quality measure as high wastage reflects poor use of an important resource. Measurements of the efficiency of packed red blood cell usage (pRBC), such as the ratio of pRBC units cross matched to those transfused (C:T ratio), packed red blood cell unit wastage rates, and RBC unit expiration rates have been determined in large hospital datasets. Ideally, a C:T ratio below 2, pRBC unit expiration rates below 1.0%, and pRBC unit wastage rate below 0.5% can be achieved [45]. In order to achieve these targets, cross matching of pRBC should only be performed for those patients at risk of clinically significant rapid and hemorrhage.

ANTIBIOTIC ADMINISTRATION

Over two-thirds of critically ill patients receive antibiotics during their ICU stay [46]. ICU patients are particularly susceptible to both infectious complications and drug-related side-effects. Patient comorbidities and treatment-related factors, such as the presence of intravascular catheters, artificial airways and life support devices contribute to the former. In contrast, the presence of multiorgan failure, increased creatinine clearance and volume of distribution contribute to the latter. The resultant changes in the pharmacokinetic/pharmacodynamic (PK/PD) of antibiotics may render them more likely to accumulate or, alternatively, to be ineffectual because of low therapeutic levels.

Antimicrobial prophylaxis may prevent up to 80% of surgical site infections (SSI) [47] especially in the setting of contaminated surgery and specific patient subgroups such as those with diabetes [48]. In order for prophylactic treatment to be effective it must also be administered in a timely fashion with guidelines recommending within a 120-min prior to the skin incision [49▪▪]. Antibiotic prophylaxis regimens vary dependent on the clinical setting, the expected surgical procedure, patient characteristics and local infectious disease epidemiology including patterns of antibiotic resistance. Further to these considerations are adjustments of antibiotic dosage and treatment duration following surgery in order to optimize treatment [49▪▪].

The antibiotic coverage provided to critically ill patients is often broad-spectrum. Although this strategy is considered the best way to prevent the development of multidrug-resistant (MDR) pathogens, repeated exposure to broad spectrum antibiotics may conversely create an environment for MDR pathogens to develop. Nevertheless, in the setting of antibiotics used for surgical prophylaxis, there is no association with an increased risk of antibiotic-resistant postoperative infections [50].

Whilst the guidelines for antimicrobial prophylaxis in routine operating room cases are supported by a high level of evidence [51▪], the level of evidence regarding prophylaxis in critically ill patients taken from the ICU to the operating room is much lower. A recent retrospective observational study suggested that for those patients admitted to the ICU more than 48 h before surgery, the antimicrobial therapy given in the ICU could be continued in the operating room [52]. In those patients admitted to the ICU less than 48 h before their surgical procedure, antimicrobial therapy should be given in accordance with standard preoperative recommendations. Antibiotic prophylaxis should cover the local flora, taking into consideration the specific surgery at hand and patient-related factors that may affect drug pharmacokinetics/pharmacodynamics.

A national, propensity-score-adjusted, retrospective, cohort study, which compared antibiotic prophylaxis with either vancomycin with a beta-lactam versus the use of either drug alone for prevention of SSI found that specifically in cardiac surgery, combination prophylaxis was associated with a reduction in SSIs. However, this was also associated with an increase in postoperative acute kidney injury [53].

Transport

The movement of patients to the operating room constitute between 15 and 50% of all intra-hospital transports (IHTs) [54]. Early studies demonstrated a 5% immediate mortality associated with adverse events during IHT [55,56]. However, whilst IHT itself has not been associated with excess mortality [21,57], it has been associated with poor longer term outcomes [21,54,57,58]. Transport from the operating room to the ICU, as opposed to transport from the ICU, is particularly susceptible to adverse events [56,59].

Adverse events may be reduced by reducing IHT. Thus, before exposing the critically ill patient to the

risks of transport, a decision must be made with the surgical team regarding the balance between potentially suboptimal surgery in the ICU versus IHT to the operating room with the associated risks of transport. For this reason, many procedures previously performed in the operating room are now being performed in the ICU. This includes the most commonly performed bedside procedure, tracheostomy insertion [60,61], as well as abdominal closure [62], diagnostic laparoscopy [63] and neurosurgical external ventricular drain placement [64]. Although no randomized studies have compared patient outcomes following ICU versus operating room surgical procedures, some such procedures are considered to be well tolerated and have outcomes at least equivalent to those procedures performed in the operating room [60,63]. It is important to note, however, that evidence does vary with regards to these outcomes [64].

In situations that IHT is unavoidable, the risks of IHT must be mitigated where possible. Those patients at the highest risk of complications during transport are patients who are ventilated [21,55,65,66], patients with central nervous system injury [67] and patients that are hemodynamically unstable [21,59]. Major adverse events associated with IHT include cardiovascular (arrhythmias, hypotension and hypertension), respiratory (desaturation, obstruction or dislodgment of endotracheal tube) and neurological sequalae (elevated intracranial pressure), equipment malfunction (loss of battery power or oxygen supply) and human factors (inappropriate mechanical ventilation settings, transportation of the wrong patient) [21,58,59,65,68,69]. Any immediately nonessential devices, such as hemofiltration, or medication, such as diuretics, should be discontinued for the duration of IHT in order to simplify the transfer process. The equipment used for transport and the equipment available in the operating room may not have settings similar to those used in the ICU. If this situation is anticipated, a trial using modified equipment settings to emulate the conditions that will be available either during transport or in the operating room should be undertaken in the ICU before moving the patient. If the patient remains stable, IHT may be undertaken immediately. However, if deterioration is noted, alternative solutions may need to be sought.

As the complications associated with IHT were first described in the early 1970s [55], significant strides have been made in optimizing IHT. Guidelines recommending interventions to reduce complications related to transport have been produced and supported by various professional societies [66,70–73]. Checklists have been developed to aid the implementation of these protocols with a view to further reduce complications [21,59,65,74]. These guidelines and checklists focus, among other things,

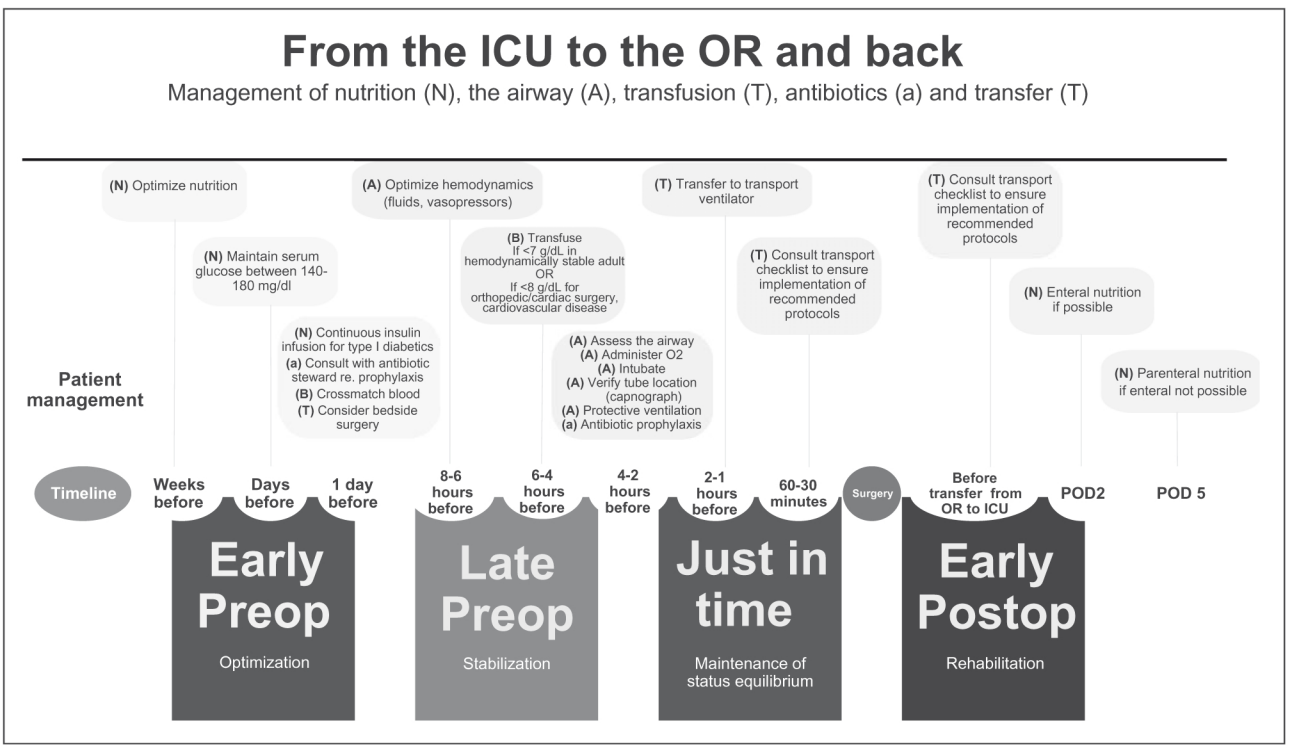

FIGURE 1. Timeline of patients management for critically ill patients requiring surgery. The aspects of care covered include nutrition, the airway, transfusion, antibiotics and transport.

on physician and critical care nurse participation in the transport team, adequate training of transport teams, sufficient pretransport preparation, effective and reliable equipment and communication within the transport team and between the transferring and receiving departments [59].

CONCLUSION

Adequate preparation of ICU patients for surgery requires an awareness of the elements that ultimately affect patient outcome. In this review, some, but not all, of the important aspects of care for these patients are discussed. Perioperative optimization of nutrition, airway management, blood product preparation, antibiotic prophylaxis and transport have all been associated with the outcomes of critically ill surgical patients who need to be transported around the hospital, and thus merit special attention when the question of additional surgery is raised in these inherently complex patients.

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