Critical Care Medicine

13

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Learning Points

After reading this chapter, you should be able to:

- Define Critical Care Medicine and its role in the setting of Emergency General Surgery
- Describe different ICU models and their logistics, technological, and workforce need
- Discuss the principles of management of critically ill EGS patients, focusing on respiratory support.

13.1 Introduction

Critical Care Medicine (CCM) is a relatively new branch of medicine whose primary focus is treating a patient with the need for invasive organ support or at high risk of needing one.

This situation is an anomaly in the medicine panorama. It accounts for the fact that the definition of critical care medicine is "operative and instrumental." In contrast with other branches of medicine, it does not focus its interests on treating a single and specific organ- or system-specific disease, but on restoring normal physiology to "gain time" to recover. It focuses on restoring physiologic balance and the process of how to treat the patient rather than on the pathology he may suffer. In contrast, organ- or system-specific failures are still a prerogative of other areas of medicine.

In 2017, the World Federation of Societies of Intensive and Critical Care Medicine (WFSICCM) came out with this definition: "Intensive care, also known as critical care, is a multidisciplinary and interprofessional specialty dedicated to the comprehensive management of patients having, or at risk of developing, acute, life-threatening organ dysfunction." [1] This definition sums up the different ones given by national or international learned societies (Table 13.1 reports some definitions of CCM and ICUs). Clearly, every "intensive care physician" should conform to local legislation and be aware of the requirements mandatory in his jurisdiction. The intensive care physician must undergo a specific training and certification in Critical Care. He should be able to diagnose, manage, monitor, intervene, arbitrate, and individualize the Care to each critically ill patient affected by single or multiple health care issues [6, 7]. Lastly, the intensive care physician is the coordinator and leader of the multidisciplinary and often multispecialty approach to the critically ill patient [4, 6–8].

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Table 13.1 Definitions of intensive care unit and critical care medicine

Author	Year	Definition
Society of Critical Care Medicine [2]	1999	ICU serves as a place for monitoring and care of patients with potentially severe physiological instability requiring technical and/or artificial life support. The level of care in an ICU is greater than that available on the floor or intermediate care unit
European Society of Intensive Care Medicine [3]	2011	The ICU is a distinct organizational and geographic entity for clinical activity and care, operating in cooperation with other departments integrated in a hospital. The ICU is preferably an independent unit or department that functions as a closed unit under the full medical responsibility of the ICU staff in close concert with the referring medical specialists. It has a defined geographical location concentrating the human and technical resources, such as manpower, professional skills and competencies, technical equipment, and the necessary space
World Federation of Societies of Intensive and Critical Care Medicine [1]	2016	Intensive care, also known as critical care, is a multidisciplinary and interprofessional specialty dedicated to the comprehensive management of patients having, or at risk of developing, acute, life-threatening organ dysfunction. Intensive care uses an array of technologies that provide support to failing organ systems, particularly the lungs, cardiovascular system, and kidneys
College of Intensive Care Medicine of Australia and New Zealand [4]	2016	An Intensive Care Unit (ICU) is a specially staffed and equipped, separate, and self-contained area of a hospital dedicated to the management of patients with life-threatening illnesses, injuries and complications, and monitoring of potentially life-threatening conditions
Weil [5]	2009	[The ICU is] the commitment to dedicated care, on site, by physicians and specially trained professional nurses and technicians with preparedness for immediate lifesaving interventions for the most seriously ill and injured

13.2 Who Is the Critical Care Patient?

The critical patient is a patient having or at risk of developing acute, life-threatening organ dysfunction [9]. Therefore, the Surgical Intensive Care Unit (SICU) provides constant monitoring, organ support, and possibly emergency interventions to unstable, severely, or potentially severely ill patients in the perioperative setting [10].

Trauma and acute care surgical patients are very different from those presented in the non-acute care setting, and they more often require ICU admission [11, 12]. The lack of preoperative evaluation and optimization exposes these patients to a greater risk of death and complications. In addition, EGS patients present with acute physiologic derangements, requiring aggressive and timely resuscitation even before a definitive diagnosis. When the EGS patients arrive in the ICU, they may need ongoing optimization of tissue perfusion and further investigations/surgery before definitively correcting the "anatomic" disturbances [13].

13.2.1 The Critical Emergency Surgery Patient

EGS patients represent a unique population with the highest rate of death and complications [14, 15]. Recent studies have shown that EGS patients are six to eight times more likely to die than patients undergoing the same procedure electively [16]. Approximately half of EGS patients experience a postoperative complication [17].

The patient group is highly heterogeneous; therefore, the need for observation and intensive Care will vary [18]. In general, EGS patients are older, have a high fragility incidence, a reduced physiologic reserve, and are significantly more acutely ill at admission [19].

Unsurprisingly, the risk of perioperative death is higher in the elderly emergency laparotomy patient than in younger patients [20]. Green et al. reported an overall mortality of 45%, with 12% intraoperative complications and 70% postoperative complications (including myocardial infarction, wound infection, hematoma, and sepsis) in octogenarians undergoing EGS [21].

Apart from age, several factors can explain the increased risk of death following EGS, among which are the inability to optimize preoperative status before surgery and the time-sensitivity of the pathology. Nevertheless, Havens et al. showed that EGS patients have a worse outcome than non-EGS (NEGS) patients, even after controlling for preoperative variables and different procedure type [16].

A possible explanation can be found in the severe physiologic derangement associated with the acute disease: the physiology of EGS patients differs considerably from that of patients undergoing elective procedures, mainly due to the presence of shock. Indeed, while in NEGS cases, large-volume blood loss and fluid shifts might be anticipated but not yet present, bleeding or infection in EGS patients often results in substantial effective fluid loss already in place at the time of presentation [22].

Privette et al. identify a subgroup of EGS patients with higher acuity, the "acute care surgery" (ACS) patients [23]. The authors defined ACS patients as nonelective, nontrauma patients with significantly altered physiology requiring ICU admission, specific operative interventions, or both. ACS patients were more similar to trauma patients than to elective or EGS patients. They more likely required multiple operations, had longer hospital and ICU stay, higher mortality, and need for post-discharge rehabilitation. Moreover, Lissauer et al. demonstrated that ACS patients need more ICU resources than other general surgical patients: they have longer ICU lengths of stay and more frequently require mechanical ventilation and continuous renal replacement therapy [12, 24]. They do represent a distinct population.

13.2.2 The Critical Trauma Patient

According to the Trauma ICU Prevalence Project (TRIPP study), trauma patients have high medical acuity, presenting a wide breadth of pathology and requiring different interventions [25]. While no consensus definition for "polytrauma" has been recognized, generally accepted definitions use an Injury Severity Score (ISS) of greater than 15 to 17 or an Abbreviated Injury Scale (AIS) of greater than 2 in at least two body regions [26].

The TRIPP study provided a representation of patient types, injuries, and conditions in ICUs caring for trauma patients. According to this prevalence study, trauma patients can present with multiple high-intensity diagnoses (septic shock, 10.2%; multiple organ failure, 5.58%; adult respiratory distress syndrome, 4.38%). Hemorrhagic shock was present in a high proportion of patients (11.6% of trauma patients and 6.55% of all patients). A wide range of traumatic injuries was documented: head, neck, and thoracic injuries predominated, but spine, orthopedic, vascular, and intra-abdominal injuries were also prevalent. Over 69% of the trauma patients had a major operation, illustrating the ongoing surgical nature of trauma and the importance of surgical subspecialty care at trauma centers. Median ICU length of stay was 9 days; 30-day mortality was 11.2% [25].

Trauma patients present with anatomic and physiologic derangements requiring prompt identification and treatment. Correcting the physiologic derangement is the primary goal, while definitive correction of the anatomic disturbances is usually postponed until physiologic stabilization occurs. Following initial resuscitation and possibly damage control surgery, trauma patients presenting to the ICU may be far from stable with ongoing resuscitative needs and injuries still requiring definitive repair. This group of patients presents unique challenges for the ICU physician, including determining resuscitation endpoints and managing early post-resuscitation complications [27]. Trauma resuscitation has evolved from a one-size-fits-all approach to one tailored to patient physiology [28].

Virtually all critically injured patients require some degree of physiologic support on arrival to the ICU. It is essential to assess active bleeding and

the extent of unresolved shock since these two factors will guide ongoing resuscitation [28, 29].

13.2.3 Stratification of Patients

The critical care patient is defined as a patient at risk of or with ongoing organ support. This generic and highly unspecific statement can be applied to an almost moribund trauma patient as well as to an elective surgical patient after an uneventful procedure. In order to compare those two patients, two main artifices have been explored: the use of Severity of Illness Scoring Systems (SISS) and the Nursing Workload Score (NWS).

The SISSs [30] are scoring systems that predict the mortality (usually at discharge from the ICU or hospital) according to the characteristics of the patient (e.g., age, diagnosis of admission, modality of admission, comorbidities, derangement of physiologic parameters at admission or in the first 24-h stay in ICU). The aims of the SISSs are well-described by their main characteristics: the calibration and the discrimination ability [31]. Discrimination defines the probability that a test will correctly discriminate between two alternatives. In the case of SISS, it helps to identify the patient who eventually will die correctly. A SISS with excellent discrimination may have some role at the patient level when counseling the family or triggering a revision over the therapeutic ceiling. Calibration is the degree to which the predicted probability generated by a model agrees with the actual event rate observed in a population, i.e., the ability of a model to correctly stratify groups of patients accordingly to their observed incidence of death. This characteristic is helpful when comparing two different populations, for example, if higher mortality is just the effect of a more critical population. SISSs are affected by several flaws intrinsic to the way they are built. Internal validity can be severely affected by the clinician withholding or withdrawing a treatment accordingly to the SISS. This leads to the classical scenario of the self-fulfilling prophecy that creates artificial overconfidence in a model specificity and negative predictive value [32]. The external validity can be even more challenging as the outcome can be a function of the resources and expertise available to treat the patient (e.g., a high-volume academic center vs. a rural ICU) or the implementation of an effective treatment in a previously untreatable disease.

NWS are used to classify patients according to the demand of assistance and program the number of nurses a unit needs. Cullen et al. [33] in 1974 described the Therapeutic Intervention Scoring System (TISS), a 57-items score to describe the nurse workload. Every item is a typical nurse activity in ICU, and the score is the sum of those activities done in 24 h. This score is the archetype of the NWS and correlated with costs, need for nurse units, and mortality because patients with a higher severity show a higher need for assistance. The idea is to quantify the time spent by the nurse in personal activities through the record of specific activities. The negative side is that to score 57 or 76 items is time-consuming, so a simplified version, the TISS-28, with only 28-items, was developed in 1996 [34]. The Nine Equivalents of Nursing Manpower Score is a furthermost simplification of the TISS-28 [35], considering only nine items comprehensive of the 28 items of the TISS-28. 40–50 NEMS points are the maximum "amount of work" a nurse can deliver, and six of those items are directly related to the organ failure a patient can suffer in ICU. This substantial overlap between nursing workload and the number and severities of organ failures (a proxy of the severity of the patient) is the basis for the definition of Level of Care (LoC). LoC is defined as the relationship between the severity of the illness of the patient and the nurse-to-patient ratio [36]. LoC can be high, intermediate, and low (see Table 13.2), and the number of patients a nurse can attend is related to their LoC [37].

Table 13.2 Set of criteria to define the Level of Care

High level of care Major criteria	mR, mRc, mRd, mRcd, mC, mCr, mCd, mCrd, mRC, mRCd
Minor criteria	mrc, mrd, mcd, mrcd
Low level of care	m, mr, mc, md, r, c, d

m basic monitoring, *R* mechanical ventilation, *r* noninvasive respiratory support, *C* more than two vasoactive drugs on continuous perfusion, *c* only one vasoactive drug on continuous perfusion, *d* dialysis

13.3   What Is an ICU?

The WFSICCM definition [1] of ICU is: "An intensive care unit is an organized system for the provision of care to critically ill patients that provides intensive and specialized medical and nursing care, an enhanced capacity for monitoring, and multiple modalities of physiologic organ support to sustain life during a period of acute organ system insufficiency. Although an ICU is based in a defined geographic area of a hospital, its activities often extend beyond the walls of the physical space to include the emergency department, hospital ward, and follow-up clinic." According to human, technological, and organizational resources, this dense statement defines ICUs with a lesser role for technological ones. ICU is a matter of workflow rather than the place where it happens or the devices used. Several national societies pose the benchmarks for ICUs. Since 2001, the Society of Critical Care Medicine (SCCM) has classified ICUs focusing on the concept of "model," who delivers the care, and "level," how invasive and complex care can be [6]. Those definitions reflected different, regionalized, local stories that brought to the creation of ICUs and mirrored locally available resources.

13.3.1 ICUs Models

ICU model defines who is in charge of the critically ill patient and has the privileges to admit and discharge patients from ICU [6].

In the open model, every physician can admit to ICU, and those patients are under his direct care. Those physicians have compelling responsibilities in the hospital (i.e., operating rooms, outpatient clinic, or general ward) and did not receive specific training in critical care medicine. The intensivist, if available, is consulted only at the discretion of the admitting physician.

In the transitional model, the patient is admitted under the care of a nonintensivist physician, but intensivist consultation is mandatory, at least once during the ICU stay.

In the closed ICU model, only the intensivist has the privileges to admit and discharge patients. All the patients admitted to the ICU are under the direct care of an intensivist.

These models can be subclassified as high-intensity staffing if an intensivist is 24 h available and low-intensity staffing if the intensivist is not always available [38].

The classification of ICUs has a historical origin. In 1991, the SCCM published the data from a survey upon ICU organization and staffing [39, 40]. Those data comprised 40% of all ICUs from the United States. They showed a wide variety of management and organizational structure, with just 22% of units fulfilling the criteria for a closed one. Since then, compelling evidence suggested increased patient outcome [41] (reduced mortality [38], length of hospital/ICU stay [38], adherence to guidelines, and best medical practice [42]) when mainly intensivists staffed ICUs. In 2001 SCCM favored the model of an ICU with extensive, if not exclusive, presence of intensivists to reduce mortality, length of stay, and costs and increase the overall quality of work [6]. Subsequent evidence pointed out that "an intensivist-led, high-intensity team is an integral part of effective care delivery in the ICU and can lead to improved outcomes" [43] as several studies showed to fail an improvement in outcomes of a strictly closed with 24/7 onsite intensivist coverage.

One of the main drives for those studies was to overcome the shortages of intensivists and reduce costs. In 2011, the European Society of Critical Care (ESICM) rolled out the essential requirement for ICUs regarding structural and organizational aspects, coming to a different solution [3]. ESICM stated that ICUs should be staffed only by intensivists with a recognized and certified intensive care curriculum. All the other physicians participating in the care of critically ill patients should be considered a consultant. However, how an ICU is physician-staffed is often a matter of available resources. In a low-resource setting, it is more likely that the ICU will have physician and nurse staffing from different backgrounds.

Moreover, the recent COVID-19 pandemic with the tremendous surge of critically ill respiratory patients forced to stretch medical and nurse

expertise. Several institutions promoted remote consultation by intensivists and highly protocolized bundles of care taken over by nonintensivist [44]; others stretched resources as much as possible, and physicians and nurses with non-ICU backgrounds were implemented [45] to run ICUs. Despite the lack of solid evidence, this stepping back from the model of high-intensity staffing might have led to less-than-optimal results, as suggested by a striking difference in mortality favoring patients transferred to ICUs not overwhelmed by the inflow of patients from those treated locally with the available resources [46].

13.3.2 ICUs Levels

ICU level refers to the ability to provide specialized care to critically ill patients with increasing complexity of monitoring and treatment. Definitions are usually at the nation or regional level and consider the resources available on the territory and peculiarities such as underpopulated areas, remote areas, or large academic centers. Several scientific societies [1, 3, 6, 43], national societies, and governmental regulatory authorities [4, 8] defined the ICUs level, pointing out: how they should be staffed, what type of monitoring and organ support must be available, what type, and for how long they should be able to treat critically ill patients, what is their role in the community they sit. Every intensivist should be aware of the specific requirement in the area where he works.

The usual classification is in three levels, from the most basic level I to the most advanced Level III.

A level I ICU sits in a small, not specialistic, hospital. It should be able to provide essential monitoring and basic cardiovascular and ventilatory support for a short period. The unit must have a protocol for transferring and referring more complex patients to secondary or tertiary ICUs. Medical staffing can be challenging as few certified intensivists are usually willing to work full-time in small centers. However, at least the medical director should be a certified intensivist

[3, 4, 8]. Ideally, the level I ICU is in an underpopulated area or is a small clinic in an urban center dealing mainly with postsurgical patients or critically ill patients with basic needs. As a rule, they treat patients who need a short period of stabilization or patients for whom the treatment in the community they live out outweighs the advantages of a transfer in a center capable of more advanced monitoring and treatment options [8]. To maintain sufficient clinical skills, the minimal number of mechanically ventilated patients is not established, but one hundred can be considered a reasonable number [4].

A level II ICU provides a high standard of general ICU care for a prolonged period of time [1, 3, 4, 8]. It should be capable of delivering care to a patient requiring complex multisystem life support like mechanical ventilation, continuous renal replacement therapy, invasive cardiovascular monitoring, and essential invasive cardiovascular support. A level II ICU is a designated area in a medium-large hospital that treats definitively the critically ill patients referred to that hospital. Transfer of patients happens when there is no appropriate specialty within the hospital. The ICU should have a protocol in place to refer for admission and consultation patients to tertiary centers capable of neurosurgery, cardiothoracic surgery, transplant, burn, and advanced pediatric care. Despite the shortage of intensivists, a Level II ICU should be staffed only by certified intensivists [3]. A caseload of at least 200 mechanically ventilated patients per annum is advisable to maintain a high level of clinical expertise and provide adequate clinical exposure and education to staff [4].

A level III ICU is a tertiary referral unit for intensive care patients and should provide complex multisystem life support for an indefinite time [3, 4, 6, 8]. A level III ICU should sit in a tertiary referral hospital center, have academic and research commitment, and give specialized and definitive care to subspecialty patients (i.e., neuro-trauma, cardiovascular, pediatric, transplant, ECMO, and burns patients). Physicians with privileges to work there should be certified intensivists and, possibly, formally trained in the subspecialty they practice. It is difficult to identify

a minimal caseload of complex patients per annum to maintain enough clinical exposure. If 400 mechanically ventilated patients can be enough to retain enough high-level skills in complex patients [4], this number can be less critical when a tertiary center is dedicated to specific pathologies (e.g., liver transplant unit, neuro-trauma, cardiothoracic unit) or to specific treatment (e.g., ECMO center, bone marrow transplant unit).

13.3.3 ICU Workforce

13.3.3.1 Physicians

Physician staffing of ICUs is driven by local legislation, the availability of physicians trained in Intensive Care, recommendation by the national or international societies of CCM, and the ICU level. As a general rule, the majority of societies recommend that the higher the level of the ICU, the higher the share of intensive care-trained physicians [1, 4, 6, 8]. However, ESICM [3] suggests that only intensive care-certified physicians should practice in ICU, if possible.

The training and core curriculum of an intensivist is highly variable at the national level. The SCCM rolled out the first list of competencies an intensivist should have in 1992 [7]. Since that benchmarking paper, the core curriculum has become a competency-based one in several countries. In 2003, Competency-Based Training in Intensive Care medicinE (CoBaTrICE) was founded to create the first unified European curriculum in CCM. The main focus was to standardize the competencies an intensivist should have at an international level in the EU area and provide a reliable and unified assessment through the institution of a mandatory exit exam, the European Diploma of Intensive Care (EDIC). However, the training program is still very variable between countries [47]. CCM is considered: a primary specialty with direct access after undergraduate training in some countries (i.e., Sweden and Switzerland), in other, is a multidisciplinary 'supra-specialty' with access from several primary specialties to a standard national core curriculum for CCM (e.g., USA, Germany, Ireland), in other is just a piece of another specialty (e.g., Denmark,

Germany) or a dual joint certification, usually anesthesia and CCM (e.g., France, Italy). A formal national system for quality assurance of CCM training exists in the majority of the European countries, as well as some form of mandatory exit evaluation. Despite the presence of a well-recognized international standard, all EU countries are different, and the mandatory examination can range from an informal evaluation (e.g., Turkey) to a national exam (e.g., France) or a mandatory pass of the EDAIC (e.g., Denmark, Ireland).

A few papers investigate the optimal number of patients a single physician can manage (patient-to-intensivist ratio, PIR). Gershengorn et al. [48] evaluated the possible relationship between the PIR and mortality and found a U-shaped curve with a nadir of mortality for a PIR between 7 and 8. The authors argue that a PIR lower than seven probably does not assure enough exposure to the intensivist to keep him proficient in treating complex patients. On the contrary, a PIR higher than eight just overwhelms the intensivist and increases mortality.

13.3.3.2 Nurses

Nurse staffing should be provided by nurses with specific training in CCM and emergency medicine, giving rise to the critical care nurse (CCN) [1, 3, 4, 8, 43, 49] The prominent role of CCN in emergency medicine and critical care has been recognized since the first experiences in Pittsburg in the '60s. As Safar stated [50], "we discovered nursing in this area required special skills not ordinarily available in the average hospital nurse." Hence, they provided advanced training to them in mechanical ventilation and hemodynamic monitoring. Nurse education evolved from a secondary level to a tertiary level almost everywhere in the world [51, 52]. The peculiarity of the work in an ICU requires a post-tertiary (e.g., master or Ph.D.) education or, at least, some informal training in ICU while working under supervision. A recent survey in the EU [53] showed that 70% of European countries have a formal post-tertiary program to educate CCN and that 54% of the European Countries surveyed recognized CCNs as specialized and highly skilled health care professional workers. Despite acknowledging the

importance of the CCNs, the training programs were highly variable, ranging from a 240-h course to a 2-years theoretical and practical course. The survey pointed out the lack of standardization between and inside countries regarding how teaching was provided, the students assessed, and the qualification awarded. The education of CCN cannot be overemphasized as, probably, even limited education programs on specific issues, like mechanical ventilation, may reduce strong outcomes as mortality, length of stay in ICU, or ventilator acquired pneumonia [54].

National and international societies defined the number of nurses and the share with a post-tertiary education an ICU should have [1, 3, 4, 8, 55]. The LoC drives the planning of nurses' unit need because different levels need a different nurse-to-patient ratio. A patient with a high LoC needs a nurse-to-patient ratio of 1:1 or 1:2. At the same time, the 1:3 or 1:4 nurse-to-patient ratio can suffice for those with a lower or intermediate LoC [36].

13.3.3.3   Allied Health Care Professionals

Other professional figures have flanked physicians and nurses since the first experiences of ICU. Several national and international guidelines define the work in ICU as a "teamwork" [3, 4, 6, 8]. Intensivists and CCN have as a primary task to coordinate other healthcare workers in multidisciplinary or interdisciplinary care, in which team members work in parallel but maintain strict disciplinary boundaries. In 2018, Donovan et al. [56], on behalf of the SCCM, defined interprofessional care as "the care provided by a team of healthcare professionals with overlapping expertise and an appreciation for the unique contribution of other team members, working as partners in achieving a common goal." This vision goes beyond the classical teamwork to embrace a different definition of the team as "a cohesive group with shared team identity, clarity, interdependence, integration, and shared responsibility" [57]. This definition emphasizes the team over its members or the sum of them. A team-based approach demonstrated an impact on major outcomes: adherence to bungles and guidelines, reduction of cost and mortality, better end-of-life decisions, ICU rounds, and handover [56].

An ICU team can be formed by: intensivist, nonintensivist physicians, CCN, advanced practice providers (APP), clinical pharmacists, respiratory care practitioners, rehabilitation specialists, dietitians, social workers, case managers, and spiritual care providers [1, 3, 4, 6, 8, 56]. Few of those professional characters have demonstrated an impact on the outcome of the patients.

APP such as nurse practitioners and physician assistants are used with more frequency as a shortcoming to the lack of intensivists. Several studies showed no differences in strong outcomes like mortality or length of hospital stay when comparing units staffed with APPs or physicians in training [56, 58, 59]. However, the evidence was weak due to their academic single-center population, retrospective design, and failure to control for intensivist staffing models. However, those studies showed longer ICU length of stay and nonhome discharge.

Clinical pharmacists have had a longer presence in ICU teams and are common in several countries [3, 4, 8]. In 2000, SCCM defined in a position paper [60] how a critical care pharmacy service should be organized and the requirements for a clinical pharmacist to work in the ICU. Several studies reviewed the impact of clinical pharmacists on ICU outcome [61], in particular: increased adherence to specific interdisciplinary bundles, reduction of adverse events, and costs.

Respiratory care Practitioners have a central role in intubated but also for non-intubated patients. Their presence contributes specifically to the optimal provision of spontaneous breathing trials, early mobility, implementation of PAD guidelines, and ABCDEF bundles [56].

Rehabilitation therapists have a fundamental role in improving and speeding up functional and cognitive impairment in critical care patients. Their work has been demonstrated to be safe, feasible, and to have a positive effect in the following areas: decreased ICU and hospital lengths of stay, shorter duration of delirium, better functional outcomes at hospital discharge, and more ventilator-free days, reduced delirium incidence, assessment and management of dysphagia, facilitation of communication, and management of patients with tracheotomies and adherence to the ABCDEF bundle.

13.3.4 ICU Service: Operational Requirement

Quality healthcare is defined as care that is "safe, effective, efficient, equitable, timely and patient-centered" [62]. National and International guidelines [1, 3, 4, 8, 63] pose benchmarking standard of logistics, equipment, design, and technological need of an ICU as well as other operational requirements related to the development of human resources and organization. Material requirements are related to the level and model of the ICU and, most importantly, to the resources available, i.e., the availability of monitoring or expensive invasive procedure (like ECMO or continuous renal replacement therapy) is different between high, middle, and low-income countries. We will briefly overview the operational requirements related to work organization and human resources. Whereas they are still related to the available recourses, there is a cultural background that health care providers and managers should adopt and adapt to their local environment. This cultural background is founded on the concept of clinical audit, i.e., a means to find out if the healthcare provided is in line with the best standards. This is achieved by identifying how the service is performing and where improvement could be made. Quality Improvement is the ultimate step. It is the "combined and unceasing efforts of everyone –to make changes that will lead to better patient outcome (health), better system performance (care) and better professional development (learning)" [64]. Several guidelines [1, 3, 4, 8] address this goal and define some tools an ICU should have to reach it, and in some cases, they are mandatory to accredit an ICU. The most cited are: a continuous medical education system with staff nurses and physicians that have a protected time to meet the educational demands of the unit and protected time for the unit itself to continue education; mandatory participation in a national or international audit system with revision of cases, treatment, ICU performances and comparison of results with other units; a morbidity and mortality program; structured handover and clinical rounds; the participation in research and development activities; a dedicated interprofessional group for the implementation of multidisciplinary bundles; a post-ICU clinic in order to continue test long- and middle-term patients' outcome [65].

13.4 General Principle of Management

Table 13.3 reports the general principle of monitoring and respiratory management in trauma and EGS patients.

Table 13.3 Principle of monitoring and respiratory management in trauma and EGS patients

Principle of respiratory management in trauma and EGS patients
Adequacy of blood flow and oxygen delivery to tissues is the primary goal of monitoring
Basic vital signs (HR, BP, UO) should be monitored in all EGS patients; nevertheless they can miss low CO states
Focused echocardiography allows rapid, noninvasive, point-of-care assessment of the hemodynamic status
Pulse oximetry and respiratory rate should be monitored in all EGS patients
Capnography provides essential information on both ventilation and perfusion
Principle of respiratory management in trauma and ECGS patients
LPV is recommended in EGS patients at risk of ARDS
EGS patients with postoperative ARDS should be managed according to the ARDSnet guidelines
Prone positioning can be used safely in trauma and EGS patients with severe ARDS
In the setting of respiratory failure and IAH, IAP monitoring is essential, and oesophageal pressure should be considered
Prevention of lung injury is a cornerstone in the management of trauma patients
Optimal ventilation strategy varies according to lesional status and phase of treatment of trauma
Both LPV and OLV may have a role in the ventilation strategy of trauma patients
PEEP can be safely applied in the management of ARDS following TBI
When ICP is increased, the control of $PaCO_2$ takes priority on LPV

EGS emergency general surgery, *HR* heart rate, *BP* blood pressure, *UO* urine output, *CO* cardiac output, *LPV* lung protective ventilation, *ARDS* acute respiratory distress syndrome, *IAH* intra-abdominal hypertension, *IAP* intra-abdominal pressure, *OLV* open-lung ventilation, *PEEP* positive end-expiratory pressure, *TBI* traumatic brain injury, *ICP* intracranial pressure, $PaCO_2$ arterial partial pressure of carbon dioxide

13.4.1 Monitoring

The ICU provides a place for monitoring and care of patients with potentially severe physiologic instability, such as EGS patients. The critical endpoint is oxygen supply to tissues according to their metabolic needs. Therefore, both oxygenation and perfusion must be monitored in the implementation of any resuscitation strategy [66].

Despite this high acuity of ICU patients described in the TRIPP study, 'monitoring' was the reason for ICU admission for 16.6% of non-trauma surgical patients [25].

Trauma and EGS patients are prone to hemodynamic instability. Several complications may occur, so they must be monitored with various modalities, invasive and noninvasive, to detect any deterioration promptly.

13.4.1.1 Hemodynamic Monitoring
The importance of hemodynamic monitoring was highlighted in 2020 by the American Association for the Surgery of Trauma (AAST).

The AAST underlines a delicate balance between hypovolemia/hypoperfusion and volume overload, which is equally associated with complications [67].

Current practice in EGS patients involves the assimilation of multiple endpoints of resuscitation into an overall assessment. Resuscitative endpoints should be tracked in real-time, and, as they approach a normal range, resuscitation is titrated not to overshoot euvolemia [67].

Heart rate, blood pressure, and urine output are basic vital signs that should be monitored in all trauma and nontrauma EGS patients. However, they can easily miss low cardiac output (CO) states and are of limited value in the surgical ICU [68] or trauma settings [69]. Evidence of persistent hypoperfusion could be found in 80% of critically traumatized patients, despite the normalization of their vital signs [70]. Hence, different markers of low CO states have been evaluated: shock index, biomarkers like serum lactate or the oxygen saturation in superior vena cava, invasive or minimally invasive CO monitoring, and functional hemodynamic monitoring like echocar-diography. Focused echocardiography may allow rapid, noninvasive, point-of-care assessment of hemodynamic status, providing valuable information on the etiology of shock and assessing response to therapeutic interventions [71, 72]. Hemodynamic monitoring is addressed in other chapters of this book.

13.4.1.2 Respiratory Monitoring
Pulse oximetry, airway patency, and respiratory rate should be monitored in all surgical patients. Patients with hypothermia, hypotension, hypovolemia, or peripheral vascular disease, or receiving vasoconstrictive medications may have inaccurate pulse oximetry readings.

Some patients will arrive in ICU already extubated; nevertheless, they still need respiratory monitoring since postoperative pulmonary complications (PPCs) can occur. Postoperative pain and immobility may lead to decreased cough, clearance of secretions, and an inability to recruit alveoli. Monitoring pain score is essential since appropriate pain control and early mobilization are critical in preventing pulmonary complications [73].

All patients under mechanical ventilation benefit from capnography measurement because the presence of $ETCO_2$ implies adequate ventilation and perfusion; an acute decrease in $ETCO_2$ is a life-threatening emergency, representing a sudden decrease in one or both of these parameters. Frequent causes in the postoperative setting include a pulmonary embolus, low cardiac output state, or disconnection from the ventilator.

Outside the ICU, continuous monitoring of oximetry and capnography may allow the detection of pathophysiologic abnormalities earlier in postoperative patients, but the evidence for improved clinical outcomes remains weak [74].

Other respiratory monitoring techniques can include arterial blood gas analysis and imaging studies, such as chest x-ray or lung ultrasounds. In ventilated patients, monitoring respiratory mechanics may be relevant as well.

13.4.1.3 Neurologic Monitoring
A focused neurologic examination should follow every acute care surgical procedure. After anes-

thesia, patients should return to their preoperative level of consciousness and exhibit no lateralizing signs. In the immediate postoperative period, depressed mental status with nonfocal findings most commonly represents persistent anesthetic drug effects or under-resuscitation. If there is no improvement after the appropriate time, imaging may be required.

Besides clinical examination, additional monitoring may be required in trauma or emergency surgical patients (ICP, EEG, $SjvO_2$, $PtbO_2$, and TCD) [75–79].

13.4.2   Organ Function Support

Hemodynamic support (i.e., fluid therapy and vasoactive drugs) and coagulation support are addressed in other chapters. We will focus on respiratory support in the general trauma and surgical patients and special populations as the patients with an open abdomen treatment or a severe traumatic brain injury.

13.4.2.1   Respiratory Support

Postoperative pulmonary complications (PPC)—such as atelectasis, pneumonia, respiratory insufficiency- are frequent causes of morbidity and mortality after EGS [80, 81].

According to current literature, patients undergoing major abdominal EGS are the surgical patients with the highest risk of developing PCCs [82, 83].

Emergency surgery confers a two-to-six-fold increase in the risk of PPCs compared to elective surgery [84]. In the ALPINE study, 48% of patients undergoing emergency laparotomy developed a PPC, with respiratory failure being the most common one [85]. The development of PPCs after EGS has been associated with prolonged hospital stay and increased death rate [86]. Advanced age, abnormal BMI (<21 kg/m [6] or >30 kg/m [6]), upper or upper/lower incision, and multiple procedures have been associated with increased risk for PPCs [86].

Incidence of acute respiratory distress syndrome (ARDS) after trauma has been reported in 12–25% of injured patients [87]. While studies

differ on the mortality attributable to ARDS in trauma patients, with some reporting no increase in mortality in patients experiencing ALI [88], injured patients with ARDS and MOF have mortality rates as high as 50–80% [89].

Multivariable predictors of ARDS after trauma include subject age, Acute Physiology and Chronic Health Evaluation II Score, injury severity score, the presence of blunt traumatic injury, pulmonary contusion, massive transfusion, and flail chest injury (area under the receiver operator characteristic curve 0.79) [90].

13.4.2.2   Ventilation

Emergency General Surgery

There has been increasing evidence that a lung-protective ventilation (LPV) strategy is associated with reduced postoperative pulmonary complications (PPCs), mainly derived from studies on elective abdominal surgery [91]. According to the ALPINE study [85], a recent prospective multicentre observational study, only 4.9% of patients undergoing emergency laparotomy were ventilated using the LPV strategy. In contrast, most patients received a median tidal volume of 8 mL/kg ideal body weight (IBW), a PEEP of 5 cm H_2O, and a median peak inspiratory pressure (PIP) of 20 cm H_2O. The study revealed that almost half of these patients developed a PPC and that PIP, increased FiO_2, and age were significantly associated with it [85].

There is a lack of evidence regarding the best ventilator settings in the specific setting of emergency surgery. However, optimizing mechanical ventilation with protective ventilation is essential to minimize VILI in patients at risk of ARDS undergoing surgical procedures.

Moreover, evidence supports the benefit of lung-protective ventilation strategies in high-risk surgical patients, including EGS patients.

Patients undergoing EGS may present with ARDS or develop this syndrome postoperatively.

The incidence of ARDS in the postoperative period is relatively low, but the impact of ARDS on patient outcomes is significant. The postoperative development of ARDS is associated with

prolonged hospitalization, longer duration of mechanical ventilation, increased intensive care unit length of stay, high morbidity, and mortality [91]. EGS patients with postoperative ARDS should be managed according to the ARDSnet guidelines [92].

Despite prone positioning being a major intervention in severe ARDS [92], clinicians remain uncertain whether ARDS patients in the postoperative period of abdominal surgery should be turned prone because of the risk of abdominal complications. Recently, the SAPRONADONF trial demonstrated that the prone position of ARDS patients after abdominal surgery was not associated with an increased rate of surgical complication with clear benefit in terms of oxygenation [93].

Postoperative strategies to decrease the risk of respiratory complications include: head-up or sitting position, encouragement of deep breathing exercises, early mobilization, intensive physiotherapy, incentive spirometry, airway toilette, careful fluid management, and adequate opioid-sparing analgesia. However, high-quality evidence for these strategies is lacking.

Noninvasive positive pressure ventilation (NIMV) or Continuous Positive Airway Pressure (CPAP) can be used to treat early mild ARDS. However, their role as prophylactic measures is unclear in patients with previously healthy lungs at risk of ARDS [94].

Early recognition of underlying respiratory infections and pneumonia should include identifying the causative pathogens, early empiric antibiotic therapy, and subsequent de-escalation to directed therapy in patients with sepsis.

Intra-abdominal Hypertension

EGS patients present several recognized risk factors for intra-abdominal hypertension (IAH), especially in patients with a BMI > 30 kg/m^2, admitted to the ICU after emergency abdominal surgery or with a diagnosis of pancreatitis [95].

There is an association between IAH and respiratory failure due to the effects of IAH on respiratory mechanics (decrease in lung volumes, respiratory system, but especially chest wall system compliance and increase in airway pressures) and gas exchange (increased dead-space ventilation, intrapulmonary shunt, and lung edema) [96].

The presence of IAH may add to the development of VILI. Optimal ventilator management of patients with ARDS and IAH should include the following:

- Intra-abdominal, oesophageal pressure, and hemodynamic monitoring;
- Lung protective ventilation;
- Deep sedation with or without neuromuscular paralysis in severe ARDS.
- Open abdomen in selected patients with severe abdominal compartment syndrome [97].

Abdominal-thoracic pressure transmission is around 50% [98]. While keeping driving pressures within safe limits, higher plateau pressures than normally considered might be acceptable [99]. Regli et al. [97] suggest the following correction: corrected target plateau pressure = target plateau pressure − 7 + IAP (mmHg) * 0.7.

Higher positive end-expiratory pressure (PEEP) levels are often required to avoid alveolar collapse, but the optimal PEEP in these patients is still unknown. Some authors suggest setting a PEEP (in cm H_2O) equals IAP value (in mmHg) or using esophageal pressure in the most challenging case of IAH and concomitant ARDS [100].

During recruitment maneuvers, higher opening pressures may be required while closely monitoring oxygenation and the hemodynamic response.

Adjunctive therapies to consider are neuromuscular blocking agents that can reduce IAP and improve oxygenation, negative fluid balance, ascites drainage, and laparostoma [101].

Prone positioning cannot be routinely recommended for IAH patients. However, it may reduce IAP and improve oxygenation in patients with IAH and ARDS if a free-hanging abdomen is assured and no IAP increase is documented [102].

Open Abdomen

Patients with an open abdomen (OA) after trauma and nontrauma EGS are usually subjected to prolonged mechanical ventilation, likely due to the need for repeated revision of the laparostoma. Although most patients with an OA have underlying conditions that mandate intubation and mechanical ventilation, the presence of OA does not require intubation per se. Several papers showed that by maintaining negative subdiaphragmatic pressures (a factor that prevents rapid loss of volume during expiration), respiratory musculature can compensate for the loss of the abdominal wall integrity [103].

There are no guidelines or weaning protocols to guide respiratory management, particularly the feasibility of extubating patients with an OA. Taveras et al. demonstrated the feasibility of early extubation in trauma, and EGS patients managed with an OA, possibly decreasing VAP rates with minimal risk of extubation failure [104].

However, patients with OA have a significant risk of developing ARDS early in their ICU course. A lung-protective approach is recommended, and extubation of such patients should be done cautiously.

Trauma

The incidence of ARDS in severely injured trauma patients is still significant, with figures approaching 10–30% and intubation rates ranging from 25 to 75% in the specific context of chest trauma [90]. Trauma-related ARDS is a relatively infrequent ARDS risk factor (only 5% of ARDS), and it is associated with lowered mortality rates compared to other causes of ARDS [105]. Nevertheless, the development of ARDS after severe trauma has been associated with significant increases in morbidity and mortality beyond baseline severity of illness [106].

Prevention of lung injury before the onset of ARDS should be considered a cornerstone in managing patients with chest trauma. Optimal pain control and early application of positive end-expiratory pressure (PEEP) can improve the outcome of trauma patients at risk of respiratory deterioration [107, 108].

Factors predisposing multiple trauma patients to respiratory failure are not fully understood.

Several scoring systems have been developed to identify patients at risk for pulmonary complications, such as the Lung Organ Failure Score [109] or the Watkins predictive model [90]. While these scores seem to have limited value in the early identification of ARDS, the Thoracic Trauma Severity score [110] seems to be preferable since it predicts both early and delayed ARDS in almost half of the trauma patients with lung contusion [111].

ARDS after trauma may differ from other forms of ARDS. Two distinct patterns have been described: early-onset (days 1–2) ARDS that is associated with higher severity of chest trauma, more severe hypotension, and increased red blood cell transfusion requirement, and late-onset (days 4–5) ARDS where pneumonia, sepsis, and multiorgan dysfunction are the main culprits.

In the setting of trauma, ARDS may occur because of different mechanisms:

1. Direct thoracic injury;
2. Secondary mechanisms induced by trauma, such as fat embolism, transfusion-related lung injury, activation of local and systemic inflammatory mechanisms, or sepsis;
3. Mechanical ventilation: ventilator-induced lung injury (VILI) and ventilator-associated pneumonia (VAP) [112].

Many thoracic injuries can lead to respiratory impairment because they compromise gas exchange, chest-wall mechanic, or both [112]. Pulmonary contusions are well known to evolve towards respiratory failure, usually after a free interval of 24–48 h. A pulmonary contusion surface of 20% of the overall parenchyma was documented as a robust predictive threshold for ARDS (positive predictive values 80%) [113].

Despite current progress in ARDS management, only a limited body of high-quality evidence is available on the best strategy in the specific setting of chest trauma-related ARDS. Two ventilatory strategies are frequently adopted in this context: lung-protective ventilation (LPV) and open-lung ventilation (OLV).

LPV forms the basis of respiratory support, and most experts strongly recommend its use [112].

The ARDSNet protocol includes tidal volumes (VT) of 6–8 mL/kg of PBW, standardized PEEP/FiO$_2$ ratios based on oxygenation, and avoidance of elevation of plateau pressure beyond 30 cm H$_2$O [114].

Trauma is one of the recognized risk factors for ARDS. LPV strategies have never been studied explicitly in chest trauma with associated ARDS, especially in the flail chest. Trauma patients represent only 8–13% of the cohorts of the principal ARDS trials [114–119]. Although reducing mortality by using LPV strategies in patients at risk for ARDS has been well documented, LPV is not always applied in trauma patients, especially regarding VT [120]. Interestingly, Plurad et al. [121] demonstrated that the restrictive transfusion policies and ventilation strategies that potentially limit elevations in early peak inspiratory pressures are associated with the decreased incidence of late posttraumatic ARDS observed in the last decades.

OLV seems a reasonable strategy, and it has been more extensively studied in trauma. However, high PEEP may be associated with hemodynamic compromise and significant stress and strain to the heterogeneous lung parenchyma of the trauma patient [116]. Moreover, the OLV strategy is not applicable in the case of air leaks (tracheobronchial rupture, bronchopleural fistula).

In the delicate and heterogeneous trauma setting, it seems necessary to determine the optimal ventilation strategy according to lesional status and phase of treatment.

After the PROSEVA trial demonstrated a mortality benefit using prone positioning in ARDS [122], the 2017 ATS/ESICM/SCCM international consensus guidelines for ARDS management made a strong recommendation for prone positioning in severe ARDS [92].

Of note, exclusion criteria of the PROSEVA trial pertinent to the trauma population included ICP >30, unstable fractures of the spine, femur, or pelvis, burn >20% TSBA, facial trauma, and recent sternotomy or anterior chest tube presence with active air leak [122]. Nevertheless, there is increasing evidence that prone positioning can be used safely with similar oxygenation benefits in trauma and EGS patients [93, 99].

Alternative methods of mechanical ventilation have been studied in ARDS related to chest trauma, such as airway pressure release ventilation (APRV), high-frequency oscillatory ventilation (HFOV), high-frequency percussive ventilation (HFPV), high-frequency jet ventilation (HFJV), or independent lung ventilation.

APRV is a pressure-limited, time-cycled mode of ventilation where a CPAP is applied, with intermittent releases to allow for convective CO$_2$ removal. APRV allows unrestricted spontaneous breathing in any phase of the mechanical ventilation, and APVR showed significant benefit on oxygenation [123] in a cohort of trauma patients, but many issues remain unanswered. Andrews et al. [124] showed a reduction in mortality using early APRV. At the same time, Maung et al. [125] found that APRV increased the duration of mechanical ventilation when compared to conventional ventilation in trauma patients with respiratory failure.

HFOV, a mode characterized by the high-frequency application of minimal tidal volumes, may have some physiological benefit in cases of chest trauma. However, its use is not recommended due to the higher mortality rate observed with HFO in ARDS not related to trauma [117].

HFPV seems an acceptable temporary ventilation strategy in specific cases, such as refractory pulmonary contusions or broncho-pleural disruption.

HFJV may have a role only as a temporary and rescue strategy in the setting of traumatic tracheobronchial rupture during the initial management while waiting for emergent surgical repair.

Independent lung ventilation (ILV) is a complex strategy suitable in rare refractory cases of unilateral chest trauma. The asymmetry in lung pathology, resulting in different compliances between the two lungs, provides the rationale for ILV. ILV has been proposed to ventilate the diseased lung while avoiding hyperinflation in the normal lung, thus improving the ventilation/perfusion matching in each lung [126].

Despite the fear of the hemorrhagic risk, ECMO has to be considered a rescue strategy since it may improve survival [127]. Heparin-free ECMO is a safe and valid option in patients with a high risk of bleeding [128].

Traumatic brain injury (TBI) represents a challenging situation since the ventilatory management

goals for lung and brain injury may conflict. Respiratory failure develops in up to one-third of patients suffering from a severe head injury, and it fulfills ARDS criteria in 8% of patients with head abbreviated injury score (AIS) of 4 or greater [129].

In isolated brain injury, a degree of vulnerability is still present in the lung tissue secondary to the proinflammatory state, and high tidal volumes [130] ventilation aggravates it.

High levels of PEEP can increase intrathoracic pressure with a detrimental effect on cerebral venous drainage and cerebral perfusion. However, in case of decreased lung compliance, the transmission of intrathoracic pressure to the cranium is reduced, with a minor effect on cerebral perfusion. Therefore, in the case of ARDS and TBI, PEEP can be safely applied, provided the volume status and mean arterial pressure are maintained.

There is a general lack of good quality clinical studies upon the best strategies to ventilate TBI patients. In 2020, a large consensus conference from the ESICM [131] failed to reach a consensus on several topics and came out with expert-determined recommendations. As a general rule, patients without an Intracranial Pressure Elevation should receive a protective lung strategy. In case TBI and acute lung injury are present together with increased intracranial pressure, the control of $PaCO_2$ takes the priority, even if higher tidal volumes, which can lead to pulmonary injury, are required.

Take-Home Message
- An Intensive Care Unit (ICU) is an organized system that provides specialized medical and nursing care for comprehensive management of patients having, or at risk of developing, acute, life-threatening organ dysfunction.
- ICU model (open, transitional, or closed) defines who is in charge of the critically ill patient and, as a general rule, the higher the level of the ICU, the higher the share of intensive care trained physicians should be.
- ICU level refers to the ability to provide specialized care to critically ill patients with increasing complexity of monitoring and treatment.
- ICU provides a place for monitoring and care of patients with potentially severe physiologic instability, such as EGS patients.
- There is limited high-quality evidence on the best strategy in the setting of respiratory failure occurring after EGS and trauma. The ventilation strategy should be adapted to lesional status and phase of treatment.

Dos and Don'ts
Do
- Do admit to ICU only patients with potentially severe physiologic instability, such as EGS patients.
- Do optimize resource and personnel especially in high volume admission flux.

Don't
- Do not overwhelm the HUB ICU; whenever possible use the step down.
- Do not forget to organize the HUB-SPOKE step down protocols.

Multiple-Choice Questions
1. One of the following characteristics is not in the definition of critical care medicine:
   A. It is focused on the treatment of patients requiring mechanical ventilation; (Correct Answer)
   B. The main focus of CCM is restoring normal, or close to normal, physiology;
   C. It is a multidisciplinary and interprofessional specialty dedicated to the comprehensive management of patients having, or at risk of developing, acute, life-threatening organ dysfunction;

D. CCM is driven by a multidisciplinary and multispecialty approach to critically ill patients.

2. What is\are the main characteristics of a Severity of Illness Scoring System:
   A. Calibration ability;
   B. Discrimination ability;
   C. All the previous; (Correct Answer)
   D. None of them.

3. A level II ICU should transfer a patient who needs:
   A. Mechanical ventilation for a prolonged period;
   B. Continuous renal replacement therapy for acute renal failure;
   C. Invasive monitoring of Cardiac Output by a pulmonary artery catheter;
   D. Invasive monitoring of the Intracranial Pressure. (Correct Answer)

4. In the ICU multidisciplinary team can be present:
   A. Respiratory therapist;
   B. Advanced Care Providers;
   C. Clinical Pharmacist;
   D. All the above. (Correct Answer)

5. What is an "open model" ICU:
   A. It is an ICU where every physician with privileges, even without intensive care training, can admit to ICU, and those patients are under his direct care; (Correct Answer)
   B. It is an ICU where relatives can visit the patients whenever they want;
   C. It is an ICU where only intensivists have privileges to admit and discharge patients in ICU;
   D. It is an ICU where the patient is admitted under the care of a nonintensivist, but intensivist consultation is mandatory.

6. Which one of the following is the correct statement regarding monitoring of EGS patients?

A. Heart rate, blood pressure, and urine output can always identify low CO states;
B. Pulse oximetry and respiratory rate monitoring is not required in surgical patients;
C. There is a delicate balance between hypovolemia and volume overload, which are both equally associated with complication; (Correct Answer)
D. Focused echocardiography cannot be implemented in EGS setting.

7. Ventilator setting after EGS (choose the correct statement):
   A. Can be easily protocolized according to current high-level evidence in literature
   B. Is critical to minimize VILI in patients at risk of ARDS undergoing surgical procedures; (Correct Answer)
   C. Always follows the LPV strategy according to recent surveys
   D. Should never be managed according to the ARDSnet guidelines.

8. Postoperative strategies to decrease the risk of respiratory complications do not include:
   A. Head-up or sitting position and early mobilization
   B. Intensive physiotherapy and incentive spirometry
   C. Generous fluid administration; (Correct Answer)
   D. Adequate opioid-sparing analgesia.

9. EGS patients with intra-abdominal hypertension (choose the correct statement):
   A. Are not at risk of respiratory failure
   B. May require higher PEEP levels, even though optimal PEEP is still unknown; (Correct Answer)
   C. Should never undergo prone positioning
   D. Should not receive lung protective ventilation.

10. ARDS after trauma (choose the correct statement):
   A. May occur because of different mechanisms, only early (1–2 days) after trauma
   B. Is not related to the extent of pulmonary contusion
   C. May require prone positioning, which can be used safely; (Correct Answer)
   D. Cannot benefit from lung protective ventilation.
11. Respiratory failure in TBI patients (choose the correct statement):
   A. Is a rare complication in this setting
   B. Can be easily managed like other forms of respiratory failure
   C. Cannot benefit from PEEP
   D. Is a challenging a situation since the ventilatory management goals for lung and brain injury may conflict. (Correct Answer)

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