Core Topics in Cardiothoracic Critical Care

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Second Edition

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Foreword

I am very pleased to be able to provide a brief introduction to the owner, borrower or reader of this text. This book is an update of the successful 2008 *Core Topics in Cardiothoracic Care* text. When that book was published, it was the first to provide a detailed insight into the cardiothoracic critical care unit and was widely read and appreciated. Since then other authors have produced texts that explore this fascinating area of practice, but none have quite replicated that originality and quality… until now!

Cardiac critical care evolved quite separately from general intensive care. It essentially originated as a side room on the cardiac surgical ward in the 1950s where the patient who struggled after cardiac surgery was ventilated and cared for by the cardiac anaesthetist and surgeon. Today we have large multidisciplinary teams in large technology dominated purpose-built tertiary units. This has been a rapid and hugely successful evolution. Cardiothoracic critical care is now a full blooded and highly influential subspecialty in the ever expanding critical care field. Indeed I firmly believe that where cardiac intensivists tread today, general intensivists will follow tomorrow. This evolution has been accompanied by a vast expansion in research and regulation. No branch of medicine is so scrutinised and yet so open to new thinking and new solutions. The link between cardiothoracic anaesthesia and cardiothoracic critical care is vital in the joined up care of these complex patients, as is the close link with all the related specialties such as the surgeon, the cardiologist, the echocardiographer and so many more.

We are fortunate that the new generation of critical care doctors and authors from Papworth have stepped up and, combined with a very eminent US academic, revisited, reorganised and rewritten the problems and solutions in this area of practice. Kamen Valchanov and Nicola Jones have taken over the authorship from their mentors at the world leading Papworth Hospital and have produced a book that retains the vision and wisdom of the original and added the significant advances in knowledge, technology and practice. A significant positive change is the addition of Professor Charles Hogue of Johns-Hopkins, Baltimore and Northwestern University, Chicago for a North American perspective. Knowing them all, it is not in the least surprising that they have produced a book of such scope and such high quality. The contributing authors are all experts in their fields and are drawn from a wide international base.

This book will prove invaluable to the critical care nurse, the trainee anaesthetist, surgeon and intensivist. It will also be of value to the new and established consultants who are involved with patients with cardiothoracic disease, which extends well beyond the bounds of surgery now. I feel proud to have been invited to write this foreword and I am proud to fully recommend this work.

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Preface to the Second Edition

Why the second edition of *Core Topics in Cardiothoracic Critical Care*? The first edition of *Core Topics in Cardiothoracic Critical Care* was published in 2008. It has been a great success, providing a comprehensive text for the specialty and selling so many paper copies that Cambridge University Press had to reprint the book to meet the demands of the market. The first editors Dr Alain Vuylsteke, Dr Andrew Klein, and Mr Sam Nashef laid the foundation stone. However, a lot has happened in the world of medicine since 2008, not least in cardiothoracic critical care. Indeed practice has expanded so much that cardiothoracic critical care has been recognised as a separate sub-specialty by the Faculty of Intensive Care Medicine in the UK. Therefore, the current editors were tasked with providing an updated version of this textbook, which will hopefully offer to the reader state-of-the-art information on the current practice in cardiothoracic critical care.

A Few Notes from the Editors

Different sources point to different events as the birth of our specialty of intensive care medicine. Most revolve around mechanical ventilation with some believing intensive care started in Boston in 1912 when a girl suffering from poliomyelitis received mechanical ventilation. Others feel that it is the organised care for polio victims in need of invasive ventilation that laid the foundations of the specialty. It is probably a little easier to define the birth of cardiothoracic critical care medicine as this was born when cardiac surgeons needed to leave patients who had undergone heroic operations in a place where they could recover. Similarly to general intensive care medicine we do not have a specific disease to treat, rather we have very sick patients with complex disorders of the cardiorespiratory system to care for.

How do we practise in this specialty? We provide organ support to patients who have undergone cardiothoracic surgery or who have failing cardiac or respiratory function, with the hope that they will respond to treatment and survive. However, these days with modern advances in life support technology, such as extracorporeal membrane oxygenation, death is no longer a binary phenomenon. As guardians of this technology we must be ever mindful of our patients' quality of life and the long-term outcome from our interventions. Importantly we must guard against sustaining life at all costs and offer patients and their loved ones, care which makes them happy, or at least acts in their best interests.

In 2018 a vast amount of evidence exists to guide this practice. However, it can be challenging to apply evidence from trials to the heterogeneous group of patients we treat in Cardiothoracic Critical Care each with unique, rapidly changing derangements of cardiorespiratory function. The world of evidence-based medicine is also riddled with problems of spurious evidence, and an ever-increasing number of articles describing scientific trials are being retracted by the publishers. In the end among a myriad of scientific and less scientific articles, guidelines and protocols, based on expert opinion, the patient has to be supported through their critical illness and recovery after surgery. In most cases good doctors, nurses and allied healthcare professionals use patient tailored approaches in their daily work to provide patients with the best possible care. We hope that the following text will offer ample and unbiased information to help us work in the best interest of each individual patient.

Kamen Valchanov
Nicola Jones
Charles W Hogue

Link between Cardiothoracic Anaesthesia and Intensive Care: Which Patients are Admitted to Critical Care?

Andrew Klein

Introduction

Admission to an intensive care area is undertaken for the diagnosis, management and monitoring of patients with conditions that require close or constant attention by a group of specially trained health professionals. Critical care encompasses all areas that provide level 2 and/or level 3 care as defined by the Intensive Care Society document 'Levels of Critical Care for Adult Patients, 2009' (Table 1). All level 2 and level 3 areas have higher staffing levels, specialist monitoring and more advanced treatment options available. Level 2 areas are commonly referred to as High Dependency Units (HDUs), while level 3 areas are Intensive Care Units (ICUs), and we will make this distinction in our text. In some hospitals, the two are separated geographically, whilst in others they co-exist in one area.

It is extremely common for patients undergoing cardiothoracic interventions under anaesthesia to be admitted to an ICU or HDU afterwards and this can often be a preplanned decision based on the potential for the patient to become more critically unwell or unstable. However, given the current pressures placed on the health service, in terms of both bed occupancy and finances, each individual case should be considered and a decision made as to whether such an admission will be necessary. These decisions can often be very difficult and must take into consideration a number of factors.

Patient Related Factors

A patient's comorbidities, physiological reserve, prognosis and wishes should all be taken into account when planning their most appropriate postoperative destination. Prioritisation of patients for critical care beds should highlight only those patients likely to gain from an increased level of care and thus not those that are either too well or too sick to benefit.

It is clear that for some high-risk patients, such as those with known chronic organ failure undergoing cardiac surgery, admission to an ICU will be mandatory after anaesthesia. It is reasonable to expect their condition to worsen following a period of cardiopulmonary bypass, and preparations should be made for any necessary organ support, for example use of inotropes or haemofiltration.

Consideration must also be taken as to whether the patient is appropriate for long-term management on an ICU. An example of this might be a palliative thoracic oncology patient undergoing a procedure for symptom relief; such a patient might be more appropriately placed in an HDU with a limit on the medical interventions that would be appropriate. This management plan should be discussed and formulated with the patient and relatives prior to the procedure itself.

Diagnostic and Surgical Related Factors

A diagnostic model can be utilised in order to provide guidelines for admission, which identifies specific conditions and diseases where it is felt a higher level of care is always warranted. With respect to cardiothoracic intensive care, the majority of such conditions will fall under the umbrellas of the cardiac and/or respiratory systems. However, it is also possible for a patient to require admission on the basis of an additional diagnosis, such as sepsis or a neurological complication of surgery.

All patients undergoing sternotomy will mandate admission to either an ICU or cardiac recovery environment after their procedure. The differentiation between the two is discussed below. A number of cardiothoracic surgical procedures will always warrant ICU admission, due to the complex nature of the intervention and often long procedural times. Examples of these are repair of aortic dissection, or multiple valve procedures.

The majority of patients undergoing thoracic surgery will either be admitted to an HDU or discharged back to the ward following a period of close

Table 1 Levels of critical care

Level of care		Criteria for admission	Examples
0	General ward	• Requires hospitalisation but needs can be met through normal ward care	Intraveous drug administration Observations needed less than 4 hourly
1	Coronary care unit	• Recently discharged from higher level care • In need of additional monitoring/intervention, clinical input or advice • Requiring critical care outreach service support	Minimal 4 hourly observations Continuous oxygen therapy, management of epidural, chest drain in situ Risk of clinical deterioration, high early warning score
2	High dependency unit	• Requiring preoperative optimisation • Requiring extended postoperative care • Stepping down to level 2 from level 3 care • Requiring single organ support • Requiring basic respiratory plus basic cardiovascular support	Invasive monitoring to optimise fluid balance Major elective surgery, emergency surgery in unstable patient Minimal hourly observations Non-invasive ventilation, single intravenous vasoactive drug Continuous oxygen therapy and intra-aortic balloon pump
3	Intensive care unit	• Requiring advanced respiratory support alone • Requiring a minimum of two organ systems supported (except basic respiratory plus basic cardiovascular – level 2, as above)	Invasive mechanical ventilator support via endotracheal tube or tracheostomy Acute renal replacement therapy and vasoactive medication

monitoring in recovery after surgery. An HDU bed may often be requested to ensure vigilance in the immediate postoperative period, and also to allow optimisation of pain control.

Alternative Resources

Each individual institution will have slightly different facilities available for the care of their patients and these must be taken into consideration when planning postprocedural care. Early goal-directed therapy and utilisation of a 'fast-track' approach has been adopted successfully in many cardiothoracic centres and this may allow lower risk patients to be admitted to a cardiac recovery area as a temporary measure postoperatively, before being discharged back to a 'stepdown' unit or ward. For such systems to work and ensure safe patient care, there must be immediate access to critical care and adequate numbers of trained nursing staff. This model has been proven to be successful in some hospitals and can potentially improve patient flow. However, for many institutions the safest option remains to admit all cardiac surgical patients to the ICU postoperatively. The priority in such institutions is then to discharge out into a stepdown unit as soon as possible after extubation and a period of stability.

Admission to an ICU may also depend on the availability of a required specific treatment for an individual patient. Some centres provide specialised advanced organ support, such as extracorporeal membrane oxygenation. Also, cardiothoracic surgery is a high-risk specialty fraught with potential complications, some of which might require transfer out to an alternative centre, for example to access neurosurgical intervention.

Time of Admission

A well-organised cardiothoracic surgical centre should incorporate a robust system of communication with both its ICU and HDU with respect to the daily admission requirements and bed availability. The majority of patients undergoing anaesthesia will require elective admission and surgical activity will be planned according to such requirements.

However, the ICU and HDU must also always take into account the potential for unplanned emergency admissions, either transferred in for surgical intervention, or due to unexpected complications intraoperatively. Patients should be admitted to the required higher level of care before their condition reaches a point from which recovery may be extremely difficult. In reality, it is often much better practice to assume a bed will be needed for your patient, than be left in a situation where the availability is not there and the patient is unstable. This could potentially lead to a worsened patient outcome, and may also put unnecessary pressure on the relevant intensive care unit to discharge prematurely.

Conclusion

It is often assumed that all patients undergoing cardiothoracic surgery will warrant admission to either an ICU or HDU postoperatively and in many instances that remains the case. Cardiothoracic anaesthesia is a high-risk specialty and it is imperative that the postoperative care system in place in each institution is safe and robust.

However, variety in admission indications and rates does exist. In recent years there have been advances in providing 'fast-track' surgery, and cardiac recovery units have become increasingly popular. In addition, thoracic surgery does not always necessitate an HDU bed and often an adequate level of care can be provided on general wards with critical care outreach support. Requirements for a higher level of care are by no means well defined and clinical practice will continue to evolve with time.

Given the current climate in the health care system, with a constant pressure for beds and a drive to improve patient flow, it is extremely important that each case undergoing cardiothoracic anaesthesia is considered individually and the safest care for that patient determined. Such planning will take into consideration patient related factors, their diagnosis and required surgery and the resources available in the institution.

Scoring Systems and Prognosis

Allanah Barker and Sam Nashef

Crystal Balls

Knowing the likelihood of survival after cardiac surgery is useful for multiple reasons including for weighing the potential risks versus benefits of surgery. Further, accurate predicting of outcome allows for comparison with the actual outcome and thus insight into the overall performance of the cardiac surgical unit. Knowledge of who is likely to develop major morbidity also has an impact on the use of valuable resources and may allow for sensible planning of operating lists. In addition, some believe that being able to predict mortality with some certitude may help clinicians to determine when further efforts are futile. Unfortunately, the perfect predictor – a crystal ball to foresee the future – has not yet been fully developed.

Risk Models or Scoring Systems

Scoring systems allow reasonable prediction of outcome after cardiac surgery. Many models have been devised to work out the likelihood of survival, and these and others have also been shown to predict major morbidity, long-term survival and resource use with some accuracy. Models can be broadly divided into two groups:

- *Preoperative models*, applied before the operation, with no knowledge of intraoperative events; and
- *Postoperative models*, applied immediately after the operation on admission into the critical care unit, taking some account of what the operation did to the patient.

Preoperative Models

These are most useful for

- Establishing the risk of surgery as an adjunct to surgical decision making (determining the indication to operate on the basis of risk-to-benefit assessment);
- Providing the patient with information, which is helpful in obtaining consent;
- Helping to measure the performance of the service by comparing actual and predicted outcomes; and
- Comparing the performance of different institutions, surgeons and anaesthetists by correcting for risk when outcomes are assessed.

Preoperative models take no account of what happens in the operating theatre and are therefore less useful in predicting which of a number of postoperative patients with complications are likely to emerge intact from the critical care unit.

There are probably more risk models in cardiac surgery than in any other branch of medicine. Most rely on a combination of risk factors, each of which is given a numerical ‘weight’. Weights are added, multiplied or otherwise mathematically processed to come up with a percentage figure to predict mortality or survival. In additive models, the weights given to the risk factors are simply summed to give the predicted risk. They are easy to use and can be calculated mentally or ‘on the back of an envelope’. They are less accurate than more sophisticated systems and have a tendency to overscore slightly in low-risk patients and to underscore considerably in very high-risk patients. Examples of such models are the Parsonnet (the pioneering heart surgery risk model) and the original additive EuroSCORE for cardiac surgery overall. Other models deal specifically with cardiac surgical subsets, like coronary surgery and valve surgery. Sophisticated models use Bayesian analysis, logistic regression or even computer neural networks. They do not allow easy bedside calculation, necessitating a computer for determining risk. They are, however, more stable than additive models across the risk range and slightly more accurate in exact risk prediction. Examples of such models are the Society of Thoracic Surgeons (STS) model, the logistic EuroSCORE and EuroSCORE II for overall cardiac surgery.

The widespread application of scoring systems in heart surgery has allowed robust performance measurement and probably contributed to the dramatic drop in cardiac surgical mortality seen in the last 15 years.

Preoperative Model Risk Factors

Not surprisingly, several common risk factors are included in all models (age, gender and left ventricular (LV) function). Other risk factors are included in some models but not in others, such as hypertension, diabetes and obesity. Models also differ depending on whether they deal with all cardiac surgeries or a specific subset, such as coronary surgery or valvular surgery. They share many risk factors and it would be repetitive to list them all here, but the models are easily accessible and there are interactive calculators available online: www.euroscore.org and http://riskcalc.sts.org/stswebriskcalc/. EuroSCORE II also offers a smartphone 'app' for use at the bedside.

Age

There is an increased risk above the age of 60 years.

Gender

Females have a higher operative mortality than males, possibly because of smaller coronary artery size, smaller blood volume predisposing to risks associated with perioperative anaemia and transfusion, although the definitive reason for the difference is unknown.

Left Ventricular Function

As estimated by echocardiography or angiography, LV function is a good measure of cardiac status, but determination can be operator dependent and it is difficult to produce an accurate and reproducible percentage ejection fraction. Thus, LV function is generally classified as 'good', 'moderate' or 'poor'; EuroSCORE II has an additional category of 'very poor'.

Type of Surgery

General cardiac risk models take into account patients that undergo different surgeries – the risk for coronary artery bypass graft (CABG) surgery is less than for valve surgery, which in turn is less than that for surgery of the thoracic aorta. Combined procedures like valve with CABG carry a higher risk than single procedures.

Extent of Cardiac Disease

The severity of coronary disease is subjective and therefore not included in surgical risk scores. The Syntax score allows for a measure of the severity of disease, but is time consuming and partly subjective. Left main stem disease may be associated with more risk. Objective measures of cardiac disease include recent myocardial infarction (MI), unstable angina and mechanical complications of MI such as acute rupture of the mitral valve or ventricular septum.

Repeat Operation

Previous cardiac surgery (or previous sternotomy) increases difficulty of access and prolongs operative time. These patients therefore carry an increased risk of bleeding as well as possibly having more advanced disease than those undergoing their first cardiac procedure.

Lung Disease

The presence of chronic pulmonary disease such as chronic obstructive pulmonary disease (COPD) has a large impact on how a patient is managed in anaesthetic and ventilatory terms. After cardiac surgery, patients with concurrent lung disease are more likely to require extended ventilation and to develop pulmonary complications, such as chest infections. Lung function is difficult to quantify with a single test and severity is based partly on subjective judgements. However, chronic pulmonary disease is taken into account in the EuroSCORE and STS.

Renal Disease

Renal dysfunction, as evidenced by dependence on dialysis, increases mortality by as much as 40%, but the spectrum of renal failure is wide and difficult to quantify. Creatinine levels are easy to measure, but are not always an accurate measure of true kidney function. The original EuroSCORE uses grossly deranged serum creatinine (>200 μmol/l) as a measure of significant renal impairment. Other scores use dialysis dependence. The best measure is probably creatinine clearance (CC), and this now features in EuroSCORE II, where the categories of renal dysfunction have expanded into four: normal function (CC > 85 ml/minute), moderate (CC 50–85 ml/minute), severe (CC <50 ml/minute) and on dialysis (regardless of CC). Interestingly, patients with severe dysfunction but not on dialysis yet fare worst.

Other Risk Factors

These include peripheral vascular disease, neurological dysfunction, degree of urgency, diabetes, hypertension and degree of pulmonary hypertension. In addition, various scoring systems give weight to the type of operation performed.

Postoperative Models

These models benefit from information that is only available after the completion of the operation, such as the physiological parameters on admission to critical care. Many have been devised for critically ill patients outside the cardiac surgical specialty, but have been used and validated in cardiac surgery. The most well-known models are the Acute Physiology and Chronic Health Evaluation (APACHE) and the Sequential Organ Failure Assessment (SOFA) (Table 1). The APACHE score is used on admission to critical care to assess the risk of in-hospital death, whereas the SOFA was developed to quantify the severity of a patient's illness using the degree of organ dysfunction at any one time. The BRiSc score is specifically aimed at predicting patients likely to bleed excessively after heart surgery.

Postoperative Model Risk Factors

Postoperative risk scores look at each organ system systematically and score according to derangement of function. Basically, the more organ dysfunction, the poorer the prognosis.

Respiratory

Oxygenation and the requirement for ventilatory support are used as measures of respiratory function.

Circulatory

Most scores which are applied postoperatively use mean arterial pressure as an easily measured and monitored parameter. However, whereas APACHE concentrates on derangement of normal physiology, SOFA concentrates on the need for (and level of) inotropic support.

Neurological

Trends are more useful than a snapshot at a particular point in time, but the Glasgow Coma Scale is easily measured and provides an easily reproducible measure of neurological status.

Renal

As preoperatively, the mainstay of renal function is serum creatinine level as it is easily measured and a relatively inexpensive test; this variable can be used to monitor changes in renal function and to compare current with preoperative function.

Gastrointestinal/Hepatic

Both APACHE and SOFA use bilirubin levels as a measure of liver function. APACHE is used more widely in general critical care units and includes many more variables, such as amylase, albumin (as a rough measure of nutritional status) and other liver function tests. The APACHE score also contains variables to measure metabolic function and septic status. These criteria are less relevant in cardiac surgery.

Thoracic Surgery

Risk modelling is not as developed in thoracic surgery, although recently some attempts have been made to produce models for predicting mortality after lung resection. The most important risk factors associated with a poor outcome are age (older people do less well) and how much functioning lung remains long after the resection (the more, the better).

Learning Points

- Many models help to predict the outcome of cardiac surgery, and these can be applied before or after the operation.
- Preoperative models help in the decision making, consent and assessment of clinical performance.
- Postoperative models can help to plan resource use and provide information to relatives.
- Models devised specifically for mortality have also been found to be useful in predicting major morbidity, resource use and long-term outcomes.
- No amount of risk modelling can predict with certainty which patient will live and which will die and they should be used as an adjunct rather than as a replacement for sound clinical judgement.

Table 1 Postoperative cardiac surgery risk assessment scores

Organ system	SOFA	APACHE
Respiratory	Oxygenation (PaO_2/FiO_2)	Respiratory rate non-ventilated
	Respiratory support	PaO_2 with FiO_2 1.0
		$PaCO_2$
Coagulation/haematological	WCC	WCC
		Haematocrit
		Platelet count
		Prothrombin time
Circulatory	Mean arterial pressure	Mean arterial pressure
	Dopamine dose	Heart rate ventricular response
	Adrenaline dose	Central venous pressure
	Norepinephrine dose	Evidence of acute MI
	Dobutamine use	Arrhythmia
		Serum lactate
		Arterial pH
Neurological	Glasgow Coma Scale	Glasgow Coma Scale
Renal	Creatinine	Creatinine
	Urine ouput/24 hour	Urine output/24 hour
		Blood urea nitrogen
Gastrointestinal/hepatic	Bilirubin	Amylase
		Albumin
		Bilirubin
		Alkaline phosphatase
		Liver enzymes
		Anergy by skin testing
Septic		Cerebrospinal fluid positive culture
		Blood culture positive
		Fungal culture positive
		Rectal temperature
Metabolic		Calcium level
		Glucose
		Sodium
		Potassium
		Bicarbonate
		Serum osmolarity

Abbreviations: APACHE, Acute Physiology and Chronic Health Evaluation; FiO_2, fraction of inspired oxygen; MI, myocardial infarction; $PaCO_2$, partial pressure of carbon dioxide in arterial blood; PaO_2, partial pressure of oxygen in arterial blood; SOFA, Sequential Organ Failure Assessment; WCC, white cell count.

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Abbreviations

AC	Assist-Control ventilation
ACBT	Active Cycle of Breathing Technique
ACEI	Angiotensin Converting Enzyme Inhibitor
ACLS	Advanced Cardiac Life Support
ACT	Activated Clotting Time
AD	Advanced Directive
AEDs	Automated External Defibrillators
AEG	Atrial Electrocardiogram
AEP	Auditory Evoked Potentials
AF	Atrial Fibrillation
AFE	Amniotic Fluid Embolism
AKI	Acute Kidney Injury
ALG	Anti-human Lymphocyte Globulin
ALS	Advanced Life Support
AMP	Adenosine Monophosphate
APACHE	Acute Physiology and Chronic Health Evaluation
APRV	Airway Pressure Release Ventilation
aPTT	Activated Partial Thromboplastin Time
AR	Aortic Regurgitation
ARB	Angiotensin Receptor Blockers
ARDS	Acute Respiratory Distress Syndrome
ARF	Acute Respiratory Failure
ASD	Atrial Septal Defect
ATG	Anti-human Thymocyte Globulin
ATLS	Advanced Trauma Life Support
AVNRT	Atrioventricular Node Re-entrant Tachycardia
AVSD	Atrioventricular Septal Defect
BAL	Bronchoalveolar Lavage
BALF	Bronchoalveolar Lavage Fluid
BIPAP	Biphasic or Bilevel Positive Airway Pressure
BIPDs	Bilateral Independent PDs
BIS	Bispectral Index
BiVAD	Bilateral Ventricular Assist Device
BLS	Basic Life Support
BLUE	Bedside Lung Ultrasound in Emergency
BNP	B-type Natriuretic Peptide
BPF	Bronchopleural Fistula
BPS	Behavioural Pain Scale
BTC	Bridge to Candidacy
BTS	British Thoracic Society
BTT	Bridge to Transplant
BURP	Backwards, Upwards and Rightward Pressure on the thyroid cartilage
CABG	Coronary Artery Bypass Grafting
CAM-ICU	Confusion Assessment Method for the ICU
CAP	Community Acquired Pneumonia
CC	Creatinine Clearance
CCA	Critical Care Area
CCS	Canadian Cardiovascular Society
ccTGA	Congenitally Corrected Transposition of the Great Arteries
CCU	Coronary Care Unit
CDC	Centers for Disease Control
cEEG	Continuous Electroencephalography
CF	Cystic Fibrosis
CHD	Congenital Heart Disease
CHF	Congestive Heart Failure
CICO	'Can't Intubate, Can't Oxygenate'
CIN	Contrast Induced Nephropathy
CI	Cardiac Index
CIS	Clinical Information Systems
CK	Creatinine Kinase
CKD	Chronic Kidney Disease
CLABSI	Central Line Associated Bloodstream Infections
CLAD	Chronic Lung Allograft Dysfunction
CMR	Cardiac Magnetic Resonance
CMV	Continuous Mandatory Ventilation
CMV	Cytomegalovirus
CNI	Calcineurin Inhibitors
CO	Cardiac Output

Abbreviations

COAD	Chronic Obstructive Airways Disease, same as COPD
COPD	Chronic Obstructive Pulmonary Disease
CP	Constrictive Pericarditis
CPAP	Constant Positive Airway Pressure
CPAx	Chelsea Critical Care Physical Assessment Tool
CPB	Cardiopulmonary Bypass
CPE	Carbapenemase Producing Enterobacteriaceae
CPOT	Critical Care Pain Observation Tool
CPP	Cerebral Perfusion Pressure
CRP	C-Reactive Protein
CT	Computerised Tomography
CTCA	Computerised Tomography Coronary Angiogram
CTEPH	Chronic Thromboembolic Pulmonary Hypertension
CV	Stroke Volume
CVC	Central Venous Catheter
CVD	Cardiovascular Disease
CVP	Central Venous Pressure
CXR	Chest X-Ray
DAG	1,2-Diacylglycerol
DBD	Donation after Brain Death
DBexs	Deep Breathing Exercises
DCD	Donation after Circulatory Death
DD	Diastolic Dysfunction
DNAR	Do Not Attempt Resuscitation Order
DOLS	Deprivation of Liberty Safeguards
DSI	Daily Sedation Interruption
DT	Destination Therapy
DTI	Direct Thrombin Inhibitor
DVT	Deep Venous Thrombosis
EACA	Epsilon Aminocaproic Acid
ECC	Emergency Cardiovascular Care
$ECCO_2R$	Extracorporeal Carbon Dioxide Removal
ECG	Electrocardiography
ECLS	Extracorporeal Life Support
ECMO	Extracorporeal Membrane Oxygenation
ECPR	Extracorporeal Cardiopulmonary Resuscitation
EDA	End-Diastolic Area
EEG	Electroencephalography
EF	Ejection Fraction
ELISA	Enzyme-Linked Immunosorbent Assay
ELSO	Extracorporeal Life Support Organisation
EMR	Electronic Medical Records
ERP	Enhanced Recovery Programmes
ESBL	Extended Spectrum Beta-Lactamases
ESG	Endovascular stent graft
ETT	Endotracheal Tube
EVLWI	Extravascular Lung Water Index
EWMA	Exponentially Weighted Moving Average
EWS	Early Warning Scores
FAC	Fractional Area Change
FALLS	Fluid Administration Limited by Lung Sonography
FAM	Functional Assessment Measure
FB	Flexible Bronchoscopy
FBC	Full Blood Count
FDO_2	Fraction of Oxygen Delivered
FEV1	Forced Expiratory Volume for 1 second
FFP	Fresh Frozen Plasma
FIM	Functional Independence Measure
FIRDA	Frontal IRDA
FOUR	Full Outline of Unresponsiveness
FRC	Function of Residual Capacity
FS	Fraction of Shortening
FVC	Forced Vital Capacity
GBS	Guillain–Barré Syndrome
GCS	Glasgow Coma Score
GEDVI	Global End-Diastolic Volume Index
GICS	Gastrointestinal Complication Score
GPCR	G Protein Coupled Receptors
GUCH	Grown-Up Congenital Heart disease
HD	Haemodialysis
HDF	Haemodiafiltration
HDU	High Dependency Unit
HES	Hydroxyethil Starch
HF	Haemofiltration
HFV	High Frequency Ventilation
HIT	Heparin Induced Thrombocytopenia
HIV	Human Immunodeficiency Virus
HLHS	Hypoplastic Left Heart Syndrome
HOCM	Hypertrophic Obstructive Cardiomyopathy
HSV	Herpes Simplex Virus
HTEA	High Thoracic Epidural Analgesia
IABP	Intra-aortic Balloon Pump
ICD	Implantable Cardioverter-Defibrillators
ICP	Intracranial Pressure

ICSD	Intensive Care Delirium Screening Checklist
ICU-AW	Intensive Care Unit Acquired Weakness
IE	Infective Endocarditis
IJV	Internal Jugular Vein
IMCA	Independent Mental Capacity Advocate
IMV	Invasive Mechanical Ventilation
INR	International Normalised Ratio
INTERMACS	Interagency Registry for Mechanically Assisted Circulatory Support
IPF	Idiopathic Pulmonary Fibrosis
IR	Interventional Radiology
IRDA	Intermittent Rhythmic Delta Activity
IRV	Inversed Ratio Ventilation
IS	Incentive Spirometry
ISHLT	International Society for Heart and Lung Transplantation
ITBVI	Intrathoracic Blood Volume Index
IUGR	Intrauterine Growth Retardation
IVC	Inferior Vena Cava
IVS	Interventricular Septum
JET	Junctional Ectopic Tachycardia
LAD	Left Anterior Descending artery
LAS	Lateral Amiotrophic Sclerosis
LBBB	Left Bundle Branch Block
LCx	Left Circumflex Artery
LMA	Laryngeal Mask Airway
LMCA	Left Main Coronary Artery
LMWH	Low Molecular Weight Heparin
LTACH	Long-Term Acute Care Hospitals
LV	Left Ventricle
LVAD	Left Ventricular Assist Device
LVEDV	Left Ventricular End-Diastolic Volume
LVESV	Left Ventricular End-Systolic Volume
LVOT	Left Ventricular Outflow Tract
LVOTO	Left Ventricular Outflow Tract Obstruction
LVSF	Left Ventricular Systolic Function
MACE	Major Adverse Cardiac Events
MALDI TOF MS	Matrix Assisted Laser Desorption/ Ionisation Time-of-Flight Mass Spectrometry
MAO	Monoamine Oxydase
MAP	Mean Arterial Pressure
MCCD	Mechanical Chest Compression Devices
MCFP	Mean Circulatory Filling Pressure
MDR	Multidrug Resistance
MDT	Multidisciplinary Team
MET	Medical Emergency Teams
MHI	Manual Hyperinflation
MI	Myocardial Infarction
MIC	Minimum Inhibitory Concentration
MMF	Mycophenolate Mofetil
MMV	Mandatory Minute Ventilation
mPAP	Mean Pulmonary Arterial Pressure
MR	Mitral Regurgitation
MRSA	Methicillin Resistant *Staphylococcus aureus*
MSE	Myoclonic Status Epilepticus
MSSA	Methicillin-Sensitive *Staphylococcus aureus*
mTOR	Mammalian Target of Rapamicin Inhibitors
MUST	Malnutrition Universal Screening Tool
MV	Mitral Valve
NAAT	Nucleic Acid-Based Amplification Technologies
NAP4	Fourth National Audit Project
NAVA	Neurally Adjusted Ventilatory Assist
NCS	Non-convulsive Seizures
NCSE	Non-convulsive Status Epilepticus
NHSBT	National Health Service Blood and Transfusion
NI	Narcotrend Index
NICE	National Institute for Clinical Excellence
NIPPV	Non-invasive Positive Pressure Ventilation
NIRS	Near Infrared Spectroscopy
NIV	Non-invasive Ventilation
NMDA	*N*-Acetyl-D-Aspartate receptor
NOAC	Newer Oral Anticoagulants
NRS	Nutritional Risk Screening
NVE	Native Valve Endocarditis
NYHA	New York Heart Association
OD	Optical Density
OHCA	Out-of-Hospital Cardiac Arrest
OIRDA	Occipital IRDA
OpCAB	Off pump Coronary Artery Bypass
PAC	Pulmonary Artery Catheter
PAH	Pulmonary Arterial Hypertension
PAP	Pulmonary Arterial Pressure
PAWP	Pulmonary Arterial Wedge Pressure
PBM	Patient Blood Management
PBW	Predicted Body Weight
PCAS	Post-Cardiac Arrest Syndrome
PCI	Percutaneous Coronary Intervention

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Abbreviations

PCP	*Pneumocystis jirovecii Carinii Pneumonia*
PCR	Polymerase Chain Reaction
PCT	Procalcitonin
PCWP	Pulmonary Capillary Wedge Pressure
PD	Peritoneal Dialysis
PDA	Posterior Descending Artery
PDE	Phosphodiesterase Inhibitors
PDR	Posterior Dominant Rhythm
PDs	Periodic Discharges
PE	Pulmonary Embolism
PEA	Pulmonary Endarterectomy
PEEP	Positive End Expiratory Pressure
PF	Pulmonary Fibrosis
PF4	Platelet Factor 4
PFIT	Physical Functional Intensive Care Test
PGD	Primary Graft Dysfunction
PH	Pulmonary Hypertension, same as PAH
PKC	Protein Kinase C
PLC	Phospholipase C
PPCs	Postoperative Pulmonary Complications
PPCI	Primary Percutaneous Coronary Intervention
PPCM	Peripartum Cardiomyopathy
PPHN	Persistent Pulmonary Hypertension of the Newborn
PPV	Pulse Pressure Variation
PRC	Post-resuscitation Care
PRES	Posterior Reversible Encephalopathy Syndrome
PRVC	Pressure Regulated Volume Controlled Ventilation
PSI	Patient State Index
PT	Prothrombin Time
PTE	Pulmonary Thromboendarterectomy, same as PEA
PTLD	Post-transplantation Lymphoproliferative Disorder
PVE	Prosthetic Valve Endocarditis
PVR	Pulmonary Vascular Resistance
RAP	Right Atrial Pressure
RASS	Richmond Agitation Sedation Scale
RBBB	Right Bundle Branch Block
RCM	Restrictive Cardiomyopathy
RCT	Randomised Controlled Trial
ROC	Receiver Operating Characteristic
ROSC	Return of Spontaneous Circulation
ROTEM	Rotational Thromboelastometry
RRT	Renal Replacement Therapy
RV	Right Ventricle
RVP	Right Ventricular Pressure
RVAD	Right Ventricular Assist Device
RWMA	Regional Wall Motion Abnormalities
SACP	Selective Antegrade Cerebral Perfusion
SAH	Subarachnoid Haemorrhage
SAM	Systolic Anterior Motion
SAS	Sedation Agitation Scale
SDD	Selective Digestive Decontamination
SE	Status Epilepticus
SGA	Subjective Global Assessment
SIMV	Synchronised Intermittent Mandatory Ventilation
SLED	Slow Low-Efficiency Dialysis
SMR	Standardised Mortality Ratio
SOFA	Sepsis Related Organ Failure Assessment
SR	Sarcoplasmic Reticulum
SRA	Serotonin Release Assay
SSEP	Somatosensory Evoked Potentials
SSRI	Selective Serotonin Reuptake Inhibitor
SVC	Superior Vena Cava
SVCS	Superior Vena Cava Syndrome
SVR	Systemic Vascular Resistance
TAA	Thoracic Aortic Aneurysm
TAH	Total Artificial Heart
TAPSE	Tricuspid Annular Plane Systolic Excursion
TAPVD	Total Anomalous Pulmonary Venous Drainage
TCPC	Total Cavopulmonary Connection
TEG	Thromboelastography
TETS	Transcutaneous Energy Transfer Systems
TEVAR	Thoracic Endovascular Aortic Repair
TGA	Transposition of the Great Arteries
TnC	Troponin C
TNF	Tumour Necrosis Factor
TOE	Transoesophageal Echocardiography
TOF	Tetralogy of Fallot
TPG	Transpulmonary Gradient
TR	Tricuspid Regurgitation
TRALI	Transfusion Related Lung Injury
TTE	Transthoracic Echocardiography or Thoracic Expansion Exercises as TTEs
TTM	Targeted Temperature Management
TXA	Tranexamic Acid

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URR	Urea Reduction Ratio
VALI	Ventilator Associated Lung Injury
VAP	Ventilator Associated Pneumonia
VATS	Video Assisted Thoracic Surgery
VF	Ventricular Fibrillation
VHI	Ventilator Hyperinflation
VRE	Vancomycin Resistant Enterococci
VSD	Ventricular Septal Defect
VT	Ventricular Tachycardia
VTI	Velocity-Time Integral
VTM	Viral Transport Media
vWF	von Willebrand Factor
WCRS	Withdrawal of Cardiorespiratory Supports
WOB	Work of Breathing
WPW	Wolff–Parkinson–White syndrome