Cardiac Arrest in the Operating Room

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Introduction

The purpose of this lecture is to discuss the incidence, causes, treatment and outcome of unexpected cardiac arrest in the operating room.

Some people hold the opinion that if anaesthesiology was entirely safe, without the risk of cardiac arrest, it might not have developed as an independent medical speciality [1]. Fortunately the incidence of cardiac arrest and death attributable to anaesthesia is very low, but both outcomes are regarded by anaesthesiologists as a perioperative catastrophe [2]. Management of sudden cardiac arrest in both the hospital setting and the non-hospital setting is governed by clear evidence-based guidelines. However, neither current nor previously published resuscitation guidelines [3] have specifically addressed intraoperative cardiac arrest, which, ideally, should also be managed according to its own corresponding evidence-based principles although the low rate of anaesthesia related cardiac arrest makes it difficult to conduct controlled studies on this subject. This may explain why intraoperative cardiac arrest has not been included so far in the guideline evaluation process undertaken by the International Liaison Committee on Resuscitation (ILCOR) (www.ilcor.org).

In the past our efforts to limit the number of fatal events occurring during anaesthesia have focused on drugs, equipment, monitoring and anaesthetic techniques. Nowadays organizational and human factors are known to play a major role [4,5,6]. We are currently being asked to anaesthetise and manage patients with numerous comorbidities who present a significant risk of cardiac arrest both during anaesthesia and in the perioperative period. Fortunately, our operating theatres are equipped with advanced anaesthesia monitoring equipment, modern drugs and life support systems, which ensure more effective recognition and management of high risk patients.

Defining cardiac arrest in the operating room

There is no uniformly accepted definition of anaesthesia-related cardiac arrest nor is it clear what we should classify as cardiac arrest in the operation room. Should this definition include an episode of ventricular fibrillation (VF) occurs which is successfully treated with defibrillation after 10 seconds, or only to those situations where chest compression is required to support circulation? Perioperative cardiac arrest may occur at the point of receiving premedication, during anaesthesia or in the postoperative period. However, for the sake of clarity we will focus on cases of cardiac arrest that may occur or have occurred to the patient in the operating room, from the moment of the induction of anaesthesia right up until the end of the surgical procedure. Our definition of a cardiac arrest in the operating room encompasses the need for chest compressions or open-chest cardiac massage (the latter is not discussed in this lecture).

Incidence of cardiac arrest during anaesthesia and survival rate

Only a few studies have attempted to determine the incidence of cardiac arrest during anaesthesia and the factors associated with survival. The reported incidence of unexpected cardiac arrest during anaesthesia varies considerably. Although it is relatively rare it is probably underreported. At present cardiac arrest during anaesthesia in developed countries occurs in between 0.2 and 1.1 cases per 10,000 anaesthetised adults, at a rate 1.4 to 2.9 per 10,000 cases for paediatric patients and even more frequently for neonates [1,4,5,7]. The incidence of cardiac arrest as a direct consequence of general anaesthesia has declined significantly since the 1980’s, when the overall rate was almost 20 cases per 10,000 anaesthetics [8]. Cardiac arrest during regional anaesthesia and monitored anaesthesia care has been reported to occur at 1.5 and 0.7 per 10,000 cases respectively [7], although it might be as high as 2.73 per 10,000 [9]. This figure...
has remained relatively stable during the last two decades. A recent study from the University of Pittsburgh showed that intraoperative cardiac arrest requiring chest compression occurs in 1.1 per 10,000 in patients receiving general anaesthesia [10]. Hence this complication is classified as very rare on an anaesthesia-related morbidity scale [11]. The reported survival rate after intraoperative cardiac arrest is 34.5% [7] and is higher than the 15-20% overall survival rate reported after in-hospital cardiac arrest [12]. Intensive Care National Audit data from the UK [13] indicate a 43.9% survival rate up to discharge from hospital for patients after a perioperative cardiac arrest. In cases where cardiac arrest is solely attributable to anaesthesia the outcome is even more favourable when about 70-80% patients survive [1,4,14]. These differences are probably due to various definitions of cardiac arrest in relation to the time or type of event, the case mix, country or region and the definition of cardiac arrest associated with anaesthesia. The surgical population has changed dramatically over the past 25 years: patients are older, sicker and surgical procedures have themselves become more complex – all these factors have also contributed to the problem [5].

**Causes of cardiac arrest in the operating room**

Numerous factors are associated with perioperative cardiac arrest and in general they represent a combination of preoperative factors, the surgical procedure, intraoperative management and anaesthesia techniques [5,15]. The majority of cardiac arrests in the operating room are multifactorial in origin and may be ascribed to the patient’s pre-existing condition, an inadequate risk estimate, a failure in monitoring, inappropriate patient management or human error. A review of the causes of intraoperative cardiac arrest by the Mayo Clinic [7] recorded blood loss, cardiac complications and drug- or hypoxia-inducing factors brought on by airway loss or ventilation failure. The highest mortality rate occurred from cardiac arrest resulting from profound bleeding. Here the survival rate was just 10%. A relatively recent study [9] listed the following as causes of intraoperative cardiac arrest: intraoperative haemorrhage, end-stage organ failure, thromboembolic events, cardiac events (myocardial infarction), sepsis and, (in one case only) anaesthesia. Contrary to studies on out-of-hospital cardiac arrest, in the case of anaesthesia-induced cardiac arrest the rhythm associated with the best chance of survival up to the time of a patient’s discharge from hospital is asystole [7]. Of the 2,211 recorded anaesthesia-related deaths in the United States reported during the period 1999-2005, 46.6% were attributable to an overdose of anaesthetic drugs, 42.5% to adverse effects from anaesthetics used for therapeutic purposes, 3.6% to complications arising from anaesthesia during pregnancy, labour and puerperium and 7.3% to other complications of anaesthesia [16].

**Prevention, pre-cardiac arrest issues, general principles of management**

Patients in the operating room are monitored extensively and, as a consequence, there should be no delay in diagnosing a cardiac arrest. However, this may not always be the case - recent data highlight delays of 2 minutes or more in identifying the need for and initiation of defibrillation in the operating room [17]. A high-risk patient will often receive invasive blood pressure monitoring, which is invaluable in the event of a cardiac arrest. If there is a strong possibility of a cardiac arrest, it may be advisable to apply self-adhesive defibrillation patches before the induction of anaesthesia. Asystole and ventricular fibrillation (VF) should be detected in the operating room immediately. However, the onset of pulseless electrical activity (PEA) might not be so obvious and capnography, pulse oximetry and pulse check or arterial line analysis may be required to establish a diagnosis. Failure to rescue a deteriorating patient is the most common ‘cause’ of cardiac arrest in the operating room, but in most cases such failure to rescue tends to be due to the serious condition of the patients despite the timely recognition of the problem and provision of maximum support.
A patient can deteriorate within minutes or hours in the intraoperative setting, and effective monitoring and correction of physiological variables (hypovolemia, hypoxemia, hypercarbia, dysrhythmias, heart pump failure) and surgical intervention are the key to intraoperative prevention and treatment. To prevent a cardiac arrest an anaesthesiologist needs to control all the factors that affect cardiac output, including preload, afterload and contractility, as well as ventilation, avoiding auto-PEEP and gas trapping in patients with obstructive lung diseases [6]. It is important to recognize when a patient is compromised or that a crisis situation has developed and to ensure timely and appropriate action with a positive therapeutic response. A typical example in a case of prolonged hypotension with systolic pressure of less than 90 mmHg. Undiagnosed hypotension may progress to shock. Recognizing when to start cardiopulmonary resuscitation (CPR) in the operating room may be even more difficult than might appear outside the operating room for a variety of reasons: false alarms from monitoring systems, ECG lead disconnections, hypotension and bradycardia are common occurrences in the operating room and might be overlooked. Finally, achieving optimal monitoring might not be possible for some patients – for example in cases of morbid obesity.

**Patients in crisis in the operating room**

In the event of a cardiac arrest we should follow the advanced life support (ALS) algorithm [3]. However, this algorithm is based on scientific and treatment recommendations applicable to out-of-hospital and in-hospital cardiac arrest scenarios. Cardiac arrest in the operating room differs substantially from these cases and there is a deficit of scientific knowledge in this area and the anaesthesia-centred ALS algorithm (A-ACLS) should be applied in these situations [6].

**Which patients are more prone to cardiac arrest during the perioperative period?**

The following factors are associated with increased perioperative complications: male gender, chronic heart failure, hypotension (systolic blood pressure less than 90 mmHg), chronic obstructive lung disease, renal failure, cancer and major surgery [18]. The most important intervention that may improve cardiac arrest survival in every scenario, including in the operating room, is high quality cardiopulmonary resuscitation immediately after cardiac arrest. The current resuscitation guidelines [3] available online (www.erc.edu) emphasise high quality cardiopulmonary resuscitation with 30 compressions (at least 100 but no more than 120 per minute) with 2 ventilations and early defibrillation for a shockable rhythm (CPR and AED) as a sine qua non condition of successful advanced life support (ALS) which should be initiated immediately after a cardiac arrest is confirmed. In the operating room we should start chest compressions when we observe a non-shockable pulseless rhythm on ECG, a loss of pulse for more than 10 seconds, a loss of ETCO2, and a loss of arterial catheter tracing.

**How should the quality of cardiopulmonary resuscitation be monitored in the operating room?**

A pulse check on the femoral artery or carotid artery alone is unreliable and gives no information on the quality of CPR. A number of new defibrillators may provide feedback on the quality of compressions [3]. However, as anaesthesiologists we are experts in using end-tidal CO2 monitoring, which is a very good parameter for monitoring the quality of resuscitation. If we are able to compress the chest with a displayed ETCO2 value of about 20 mmHg or more, the probability of a return to spontaneous circulation (ROSC) is much higher than in situations when compressions resulted in an ETCO2 of about 10 mmHg or less. If an arterial line is in place, a relaxation (diastolic) pressure of 40 mmHg is also associated with a higher rate of ROSC [6]. A central venous pressure (CVP) line may be helpful in estimating coronary perfusion pressure (CPP), (CPP = diastolic arterial catheter pressure minus CVP). A CPP value above 15 mmHg is associated with an increased rate of ROSC. Special attention should be paid to the ventilation and respiratory rate, which should not be more than 10 breaths/min with an inspiratory time of one second, and the tidal volume limited to “chest rise” (approximately 500 ml in an average 70 kg adult). We should provide ventilation with great caution, avoiding hyperventilation especially in low flow states. There are many possible ways of controlling the quality of resuscitation in the operating room. As Andrea Gabrielli said: “we have plenty of fancy tools in the operating room, so use them!” Central venous saturation (ScvO2) and/or echocardiography are also possible adjuncts.
Bradycardia and non-shockable rhythm in the operating room

Symptomatic bradycardia evolving into non-shockable cardiac arrest is the most common cardiac arrest scenario in the perioperative setting. We should ensure adequate oxygenation (check pulse oximetry if possible), exclude auto-PEEP and initiate CPR, as otherwise drugs used to assist resuscitation will not reach the heart in a timely fashion. Atropine, epinephrine, transthoracic, transvenous (or oesophageal if indicated) pacing may be of value. Checking ETCO₂, plethysmograph, or arterial catheter tracing may help control the pacing and quality of resuscitation if an arterial pulse is not detectable. The classical mnemonic approach (4Hs and 4Ts) used to ensure consideration has been given to a differential diagnosis of non-shockable cardiac arrest [3] in the perioperative setting should include additional Hs’ and Ts’ such as Hypervagal reactivity and malignant Hyperthermia as well as Q-T prolongation and pulmonary Hypertension [6].

Symptomatic tachycardia, pulseless shockable arrest (VT, VF, Torsades des Pointes) in the operating room

In cases of symptomatic tachycardia the general approach should focus on diagnosing the underlying rhythm and ensuring immediate cardioversion (in general with a ventricular rate > 150 bpm) whenever it is indicated for the anaesthetised patient. We should be prepared for external pacing in patients who are being cardioverted, as some will convert to a bradycardia. Pharmacological treatment of symptomatic tachycardia in the operating room employs either adenosine or amiodarone as the drugs of choice in many situations. Current guidelines are available for pulseless shockable arrest [3,6]. The following are useful websites: www.erc.edu, www.escardio.org. It should be remembered that antiarrhythmic drugs can also be proarrhythmic.

There are numerous reported causes of cardiac arrest in the operating room [15], including gas embolism, acute hyperkalaemia, complications of central venous lines and malignant hyperthermia some of which will be discussed in more details below.

Anaphylaxis in the operating room

The estimated incidence of intraoperative anaphylaxis is between 1 in 3,500 and 1 in 13,000 cases (www.reses.org.uk/reaction.pdf) and the main causes of anaphylactic shock are as follows: intravenous contrast, beta lactam antibiotics, latex exposure, and non-depolarizing neuromuscular blockers. Surgery should be interrupted if possible, the airway secured and the patient supported with 100% oxygen, fluids and vasopressors (epinephrine, vasopressin). H1 and H2 blockers and steroids might also be indicated although there is less evidence for this approach. A tryptase level obtained from a blood sample can be used to confirm the diagnosis retrospectively. When a cardiac arrest occurs (no pulse for 10 seconds) CPR should be initiated and 1mg epinephrine administered intravenously and subsequently repeated every 3-5 minutes or followed by vasopressin 40 U. Auto-PEEP needs to be ruled out and tension pneumothorax considered if the cardiac arrest is preceded by severe bronchospasm [6].

Local anaesthetic toxicity

The risk of local anaesthetic toxicity is difficult to predict [15]. Among the amide group of local anaesthetics, bupivacaine is the most potent and well described myocardial depressant which is also most frequently associated with cardiac arrest. Early central nervous system manifestations of local anaesthetic toxicity, such as a metallic taste in the mouth, a ringing in the ears, dysphagia, confusion and premature ventricular contractions, should not be overlooked. Treatment should focus on discontinuing local anaesthetics, tracheal intubation and ventilation with 100% oxygen, with use of transcutaneous or intravenous pacemakers prior to cardiac arrest. If local anaesthetic toxicity is strongly suspected, epinephrine should be avoided as it can worsen the outcome [6,20]. When a cardiac arrest occurs immediate chest compression should be commenced. Specific treatment with an intravenous infusion of 20% Intralipid, firstly as an intravenous loading dose of 1.5ml/kg, followed by an infusion rate or repeated boluses should be commenced. It is recommended that a maximum cumulative dose of 12ml/kg should not be exceeded. However the exact regimen is currently a matter of debate [20]. In patients without immediate ROSC, sodium bicarbonate (to maintain a pH greater than 7.25) and prolonged CPR for at least 60 minutes should be continued [6]. Details: www.lipidrescue.org, www.aagbi.org/publications/guidelines/docs/latoxicity07.pdf
Neuraxial anaesthesia and cardiac arrest

The pathophysiology of cardiac arrest associated with neuraxial anaesthesia remains unclear but at the same time it is an important and unpredictable cause of morbidity and mortality in the perioperative period. The overall incidence of cardiac arrest during neuraxial anaesthesia is 1.8 cases per 10,000 patients with more cardiac arrests occurring with spinal (2.9 per 10,000) than other (0.9 per 10,000) techniques [19]. In the peri-arrest period the suggested treatment algorithm consists of discontinuation of the anaesthetic or sedation, applying immediate tracheal intubation and ventilation with 100% oxygen, effective treatment of bradycardia (atropine, pacing) and hypotension (epinephrine, vasopressin). If cardiac arrest occurs, immediate CPR should be initiated, epinephrine in escalating doses and/or alternative drugs should be considered and prolonged CPR maintained and monitoring used to confirm its effectiveness.

Key learning points

• Unexpected cardiac arrest in the operating room is a rare event but should be anticipated, immediately recognized and treated effectively.
• There are plenty of devices to monitor the effectiveness of resuscitation, among which arterial and central venous lines as well as capnography and echocardiography are of special importance for monitoring the quality of resuscitation in the operating room.
• Whenever resuscitation efforts in the operating room are seen to be having a positive response, aggressive and prolonged treatment should be considered.
• Anaesthesia related cardiac arrest is associated with a relatively favourable outcome, which should be registered, monitored and audited regularly.
• Anaesthesia–Centred Advanced Life Support algorithms should be developed for the operating room based on science and treatment recommendations.
References