EACTS

Guideline for resuscitation in cardiac arrest after cardiac surgery

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On behalf of the Clinical Guidelines Committee of the European Association of Cardio-Thoracic Surgery.

The Clinical Guidelines Committee of the European Association for Cardio-Thoracic Surgery provides this professional view on resuscitation in cardiac arrest after cardiac surgery. This document was created using a multimodal methodology for evidence generation including the extrapolation of existing guidelines from the International Liaison Committee On Resuscitation where possible, our own structured literature reviews on issues particular to cardiac surgery, an international survey on resuscitation hosted by CTSNet and manikin simulations of potential protocols.

The full protocol addresses many issues particular to our specialty including the timing of emergency resternotomy, the number of attempts at defibrillation before emergency resternotomy, the administration of adrenaline, ventilator, infusion and pacemaker settings, emergency resternotomy sets, the organisation and training of personnel involved in the emergency resternotomy, the use of the intra-aortic balloon pump, and cardiac arrests on the ward and in special circumstances.

This pocket guideline is an abbreviated version of the full guideline and is intended to be a quick reference guide after reading the full version.

You may obtain the full article for free at the website of the European Journal of Cardio-Thoracic Surgery www.ejcts.org or via www.ctsnet.org

For further information including courses or in-house training, sternotomy manikins, posters, training, videos and many other resources click on

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The guidelines will be presented in full at the EACTS conference in Vienna, including a live manikin reconstruction of the guidelines with six critical care staff-members and also accounts of the guideline in practice.

Please come to Hall E, Level 0, Austria Center, Tuesday 20th October 14:00 to 15:30.

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1. Proposed protocol for cardiac surgical patients in ICU

The proposed modification of the European Resuscitation Council advanced life support cardiac arrest algorithm to be applied in cardiac arrest after cardiac surgery is presented in figure 1. We recommend that this protocol be used in the ICU. It is not recommended for use outside of this setting. This protocol should be used in preference to the protocol currently recommended for patients with cardiac arrest which does not follow cardiac surgery. Major differences between the protocols are addressed in this document.

2. Cardioversion

Recommendations

In ventricular fibrillation, three sequential attempts at biphasic defibrillation should be made without intervening external cardiac massage.

If this fails, preparation should be made for emergency resternotomy.

One major change is the speed and vigour with which cardioversion is attempted. Before this guideline, a patient in ventricular fibrillation (VF) after cardiac surgery was to receive a single attempt at cardioversion followed immediately by cardiopulmonary resuscitation (CPR) including external cardiac massage (ECM) for 2 minutes. Thereafter, the rhythm is reassessed and CPR ceased if evidence of a cardiac output is found. Cardiac surgical patients are sufficiently different from other patients for us to recommend an important departure from this guideline. Firstly the cardiac surgical patient in ICU usually has continuous arterial line, central venous line, pulse oximetry and ECG monitoring. Thus the arrest will be immediately identified, making early cardioversion more likely to be successful in restoring cardiac output without any ECM. Secondly immediate ECM is unnecessary in certain cases, and its use after cardiac surgery should be minimised due to the risk of trauma to the surgical site. Thirdly, if cardioversion is unsuccessful, rapid resternotomy may be indicated. Thus 3 successive attempts at defibrillation will increase the likelihood of restoring cardiac output after a VF arrest while minimising the delay to chest reopening where indicated as well as reducing the risk of trauma to recently operated cardiac structures and suture lines. As recognition of VF is immediate, a prolonged period without cardiac output or CPR is unlikely, and the rationale for the traditional recommendation is less likely to be pertinent here.

3. Identification of arrest

Recommendations

If the ECG shows VF or asystole, call cardiac arrest immediately.

If the ECG is compatible with a cardiac output, feel for a central pulse for 10 seconds and look at all pressure traces. If arterial and other pressure waveforms are pulseless then call cardiac arrest immediately.

Patients in the ICU are highly monitored and often intubated and ventilated. A potential cardiac arrest is most likely therefore to be signalled by monitoring alarms. If there has been an arrhythmic arrest and the ECG is incompatible with an output (VF or asystole) then the diagnosis is straightforward and the arrest protocol can be initiated immediately without feeling for a pulse. An ECG lead displacement will cause a flat-line electrical trace with pulsatile pressure traces, and therefore will not simulate VF or asystole.

A kinked arterial line should not simulate an arrest as the CVP, PA, and pulse oximeter traces will all remain pulsetile and unchanged, whereas these will also flatten when arterial pressure is genuinely lost.

Sometimes there is a viable ECG and the arterial waveform has been gradually diminishing as the blood pressure falls. Assuming that the arterial line is functioning well (CVP, PA and oximetry trace amplitudes also diminishing) then immediate expert assistance should be sought, but cardiac arrest should not be called and the protocol not instituted until the arterial impulse is absent and all pressure waves become flat.

4. Basic life support: external cardiac massage

Recommendations

In an arrest after cardiac surgery, external cardiac massage can be deferred until initial defibrillation or pacing (as appropriate) have been attempted provided this can be done in less than 1 minute.

If you have witnessed the change of rhythm to VF or pulseless VT then ECM may be delayed until 3 shocks have been given if a defibrillator is rapidly available (within 1 minute). Otherwise, ECM should be immediately initiated by interlocking your fingers and applying pressure in the middle of the sternum with your arms straight to depress the sternum 4-5cm in depth. You should perform chest compressions at a rate of 100 beats per minute.

In the ICU setting you will be able to assess how effective your compressions are by looking at the arterial trace on the monitor. You should aim for the 'systolic' impulse over 60mmHg. If increasing the rate of compression improves the mean blood pressure on the monitoring screen then you should increase the rate of compression.

Inability to achieve an acceptable compression-generated blood pressure may indicate that the cause of the arrest warrants immediate emergency resternotomy (massive bleeding, tamponade or tension pneumothorax) and chest reopening should be expedited.

5. Airway management

Recommendations

Immediately turn the oxygen up to 100%

For ventilated patients, PEEP should be removed, and if you are happy to do so, the ventilator should be disconnected and a bag/valve used. Listen for breath sounds both sides and equal chest movement to identify a pneumothorax or a haemothorax if present.

If you suspect a tension pneumothorax, place a large bore needle into the 2nd intercostal space, anterior midclavicular line, followed either by a chest drain or opening of the pleura at resternotomy.

If you are happy with the airway and breathing, the patient may be reconnected to the ventilator.

Most patients will be intubated and ventilated. If you are the second person to attend the arrest then your most important role is immediately to increase the oxygen on the ventilator to 100%. After this, removing positive end-expiratory pressure (PEEP) is also recommended.

The following steps are useful in ensuring a satisfactory airway and ventilation:

- Check the position of the endotracheal tube.
- Listen for any air excursion around the tube, and that the cuff is inflated.
- Look at the chest for bilateral expansion.
- Feel the neck to see if the trachea is central.
- Listen with a stethoscope for bilateral air entry.
- Capnography may give valuable information.
- We recommend that the ventilator is disconnected and breaths are administered with a bag/valve connected to 100% oxygen. Bag/valve administration will allow a rough assessment of airway pressure and also more easily allow you to listen for breath sounds with a stethoscope.
- If your examination indicates that a tension pneumothorax is a possibility, you should immediately place a large bore cannula into the 2nd intercostal space, anterior mid-clavicular line.
- If you are unable to inflate the lungs with the bag/valve, and a sucker will not pass down the ET tube, then ET-tube occlusion or malpositioning should be suspected. The ET-tube should be immediately removed and a bag/valve/mask with airway adjuncts used to maintain the airway.

6. Infusions and syringe drivers

Recommendations

In an established cardiac arrest all infusions and syringe drivers should be stopped.

If there is concern about awareness then it is acceptable to continue the sedative infusions. Other infusions can be restarted as required by the clinical situation.

We found no cases of arrest after cardiac surgery being caused by incorrect administration of drugs by a syringe driver or infusion pump although theoretically cardiac arrest may result from this. In addition, inadvertent flushing of a vasodilator or residual drug in the lumen of a central line is a conceivable cause of arrest.

Conversely, during cardiac arrest it is unlikely that a drug running by infusion pre-arrest would assist the conduct of the cardiac arrest by continued administration. Sedatives and anaesthetic medications such as propofol are vasodilators and their cessation for a few minutes in the context of very low cerebral perfusion is unlikely to cause awareness. In addition, once stability has been achieved and adequate cerebral perfusion restored, recommencing this infusion will be straightforward. Thus during an arrest after cardiac surgery, stopping all the syringe drivers and infusions may be regarded as best practice.

7. Administration of adrenaline (epinephrine)

Recommendation

Neither adrenaline nor vasopressin should be given during the cardiac arrest unless directed by a senior clinician experienced in their use.

Evidence was sought for whether routine adrenaline administration may be either useful or potentially harmful for patients who arrest after cardiac surgery. This search is documented in the full guideline.
The 2005 European Resuscitation Council Guidelines and the American Heart Association guidelines state that for patients suffering a cardiac arrest with pulseless electrical activity (PEA) or asystole, 1 mg of adrenaline should be given as soon as intravascular access is achieved and for every 3–5 min or every other loop of the algorithm. For VF/VT, adrenaline should be given after the second failed shock. However, the ERC state that 'despite the widespread use of adrenaline during resuscitation, and several studies involving vasopressin, there is no placebo-controlled study that shows that the routine use of any vasopressor at any stage during human cardiac arrest increases survival to hospital discharge. Current evidence is insufficient to support or refute the routine use of any particular drug or sequence of drugs. Despite the lack of human data, the use of adrenaline is still recommended, based largely on animal data.'

In the cardiac surgical literature Webb in 2008 reported the case of a patient who lost cardiac output due to a tension pneumothorax. Adrenaline was administered after needle thoracocentesis failed to return spontaneous circulation. A chest drain restored cardiac output but extreme hypertension then caused massive blood loss and a PEA arrest. This case demonstrated the dangers of adrenaline administration when reversible causes exist in patients after cardiac surgery.

In summary, the European Resuscitation Council and the American Heart Association both recommend 1mg of adrenaline immediately in PEA/asystole or after the second failed shock in VF/VT. However, they acknowledge the weakness of the evidence behind this recommendation, based entirely on animal studies which have not been successfully replicated in humans, and grade such evidence as 'indeterminate'. When arrest follows cardiac surgery, the chances of rapidly restoring cardiac output are good, and routine use of adrenaline in the arrest may result in dangerous subsequent hypertension.

We therefore cannot recommend adrenaline be given routinely in all such cardiac arrests. We recommend that administration of adrenaline be delayed until reversible causes of arrest are excluded. We acknowledge that adrenaline may be useful in the impending arrest or peri-arrest situation and may also be safely used in smaller doses such as 100-300mcg boluses. However, once cardiac arrest has happened, we recommend that adrenaline is only administered by senior clinicians with experience of its routine use and it should not form part of the arrest protocol.

8. Cardiac arrest in patients with an intra-aortic balloon pump

Recommendations

In cardiac arrest with an IABP in place, it should be set to pressure trigger.

If there is a significant period without massage, triggering should be changed to internal at a rate of 100bpm until massage is recommenced.

Patients with an intra-aortic balloon pump (IABP) present special considerations. VF or asystolic arrest is normally easy to recognise, but in PEA or in asystole with an active pacemaker, the ECG may continue to trigger the IABP and the arterial waveform may remain pulsatile even in the absence of cardiac output. Cardiac arrest can be confirmed by the loss of the cardiac component of the IABP pressure trace and, more visibly, by the loss of pulsatility in other pressure waveforms such as CVP, PA and pulse oximetry, in which case cardiac arrest should be called.

In an arrest, ECG recordings are either absent or highly variable and subject to artefact from chest compression and other activity. ECG trigger for the IABP is therefore not helpful. Pressure trigger, however, will coordinate diastolic balloon inflation with cardiac compression and may help improve mean blood pressure including coronary artery perfusion pressure. Once cardiac arrest is established, the IABP should therefore be set to pressure trigger, with 1:1 counterpulsation at maximal augmentation. This will allow augmentation of cardiac massage and improved cardiopulmonary resuscitation, without interference from the ECG trace. If there is a period with no cardiac output and no cardiac massage, the IABP may be set to internal trigger at 100/minute.

9. Management of the cardiac arrest

We have identified 6 key roles in the cardiac arrest situation after cardiac surgery and evaluated them in manikin simulation. Training should be given in these 6 key roles. When the arrest occurs, each role should be assumed by appropriately trained individuals (figure 2)

1. **External cardiac massage**
   Once the arrest has been established one person is allocated to ECM. This should commence immediately at a rate of 100 beats per minute while looking at the arterial trace to assess effectiveness. The only exception to this is when immediate defibrillation or pacing is appropriate prior to ECM.
2. **Airway and breathing**
   The oxygen must be turned up to 100% and airway and breathing checked as per protocol, specifically to exclude pneumothorax, haemothorax or endotracheal tube problem.
3. **Defibrillation**
   The defibrillator should be connected and shocks administered if required. This person should also check the pacing, and if emergency resternotomy is being performed, should ensure that internal defibrillators are available and connected.
4. **Team leader**
   This senior person should conduct the arrest management, ensuring that the protocol is being followed and that there is a person allocated to each role.
5. **Drug administration**
   This person stops all infusions and syringe drivers and administers atropine, amiodarone and other drugs as appropriate.
6. **ICU co-ordinator**
   This role, by a senior member of ICU staff coordinates activity peripheral to the bedside. This includes preparing for potential resternotomy as soon as an arrest is called, managing the additional available personnel and calling for expert assistance if not immediately available while continually reporting progress to the team leader.

10. Ventricular fibrillation or pulseless ventricular tachycardia

10.1. The use of a precordial thump in cardiac arrest

Recommendations

A precordial thump may be performed if within 10 seconds of the onset of VF or pulseless VT.

This should not delay cardioversion by defibrillation.

We have found no documented papers reporting the success of a precordial thump in patients after cardiac surgery. However anecdotally we have heard reports of success with this intervention.

10.2. Immediate external cardiac massage versus immediate defibrillation or pacing

Evidence was sought for whether an initial period of ECM before defibrillation or pacing might benefit the patient or cause unnecessary harm. A search for the evidence on immediate versus delayed ECM is documented in the full guideline.

In 2005, the International Liaison Committee on Resuscitation (ILCOR) task force recommended that for out-of-hospital arrests, where the response time is more than 4-5 minutes, a 1.5-3 minute period of ECM may be of benefit. The task force also stated that there is no evidence to support or refute the use of CPR before defibrillation for in-hospital cardiac arrest. Experimental studies showed that defibrillation first is more effective than ECM first if the duration of untreated ventricular fibrillation is 5 minutes or less.

Bohrer *et al* in 1989 reported 3 patients who suffered a VF arrest after cardiac surgery. They all had brief periods of external CPR and died from massive haemorrhage resulting from mechanically induced disruption of vascular sutures lines. One patient had only 5 compressions before 1,500mls of blood suddenly came down the drains in 30 seconds.

Kempen *et al* 1999 reported a right ventricular tear secondary to external CPR in a patient who had cardiac arrest shortly after a right pneumonectomy. We also identified 5 case reports of cardiac damage due to ECM in the non-surgical literature. Several cohort studies report the results of cardiac arrest after cardiac surgery but none mention significant complications due to the external CPR.

We found no studies reporting cohorts of patients resuscitated primarily by external pacing or temporary wire pacing. As this intervention is no more invasive than defibrillation, guidance on its timing in relation to ECM in asystole will parallel the timing recommendation for defibrillation in VF. In both cases, delay in obtaining the equipment is an indication for immediate ECM.

In summary, most evidence supporting immediate CPR before defibrillation or pacing derives from out-of-hospital arrests. Survival after in-hospital arrest is favoured by immediate defibrillation. After cardiac surgery, ECM is associated with potentially fatal complications, and may not be necessary in situations where the arrest can be immediately reversed by defibrillation or pacing. We therefore recommend that if defibrillation or pacing (as appropriate) can be performed within 1 minute then it is acceptable to defer ECM until they have been attempted.

10.3. Number of attempts at defibrillation before resternotomy

Recommendations

In ventricular fibrillation or pulseless ventricular tachycardia 3 sequential shocks should be given without intervening CPR.

In VF or pulseless VT, emergency resternotomy should be performed after 3 failed attempts at defibrillation.

Evidence was sought for the optimal number of attempts at external defibrillation for VF before proceeding to emergency resternotomy. This search is documented in the full guideline.

Data was found to determine the potential success of each subsequent attempt at defibrillation. The sources of data on the number of shocks were wide-ranging and included papers on ICDs, electrophysiological studies, out-of-hospital arrests and animal studies. Furthermore, the rate of success of a second shock after 2 minutes of CPR has not been reported in any paper that we found as all were published prior to the guideline change of 2005. When data from all 15 papers were combined, the average success rate of sequential shocks declined from 78% for the first shock to 35% for the second shock and 14% for the third. Data on fourth shock success was only recorded in 1 paper. Thus the likelihood of successful cardioversion declines dramatically from first to second shock, and declines further from second to third shock. We conclude that proceeding to resternotomy after the third shock is preferable due to the minimal chance of fourth shock success and the desire to minimise the delay to emergency resternotomy.

10.4. Amiodarone

Recommendation

After 3 failed attempts at cardioversion for ventricular fibrillation/pulseless VT, a bolus of 300mg of intravenous amiodarone should be given via the central line.

Evidence was sought as to whether amiodarone or lidocaine may be useful if the patient is in VF and not responding to cardioversion. This search is documented in the full guideline.

According to both European and American 2005 resuscitation guidelines, no evidence is available that any antiarrhythmic drug given routinely during human cardiac arrest increases survival to hospital discharge. But in these guidelines there is consensus that *"amiodarone should be considered as the first line antiarrhythmic drug that should be given to patients with VF/pulseless VT that persists after 2 to 3 shocks plus adequate CPR and use of a vasopressor"*. It should be given as a bolus injection of 300 mg. A further dose of 150mg may be given for recurrent or refractory VF/VT followed by an infusion of 900mg over 24-hours. Lidocaine 1mg/kg may be used as an alternative but only if amiodarone is not available.

11. Cardiac arrest with "non-shockable" rhythm

Recommendations

For asystole or severe bradycardia, connect the epicardial pacing wires and set to DDD at 90bpm at the maximum atrial and ventricular output voltages.

If the rhythm is pulseless electrical activity and a pacemaker is connected and functioning, then briefly turn the pacemaker off to exclude underlying ventricular fibrillation.

11.1. Pacing

The initial arrest rhythm will be only amenable to defibrillation in 30-50% of patients. The remainder have other rhythms which cannot be treated by defibrillation. Of these, predominant rhythms that may be amenable to pacing are severe bradycardia or asystole (Figure 1).

If epicardial pacing wires are in place, they should be immediately connected to a pacemaker. This pacemaker should be set to DDD at a rate of 90 beats per minute. The atrial and ventricular output should be set to maximum. If this fails to restore cardiac output, or if there is delay in obtaining pacing equipment beyond 1 minute, basic life support must be commenced immediately.

In the absence of epicardial pacing wires, pacing can be achieved using external pacing pads. No studies have reported successful use after cardiac surgery but this does not exclude it as a possible intervention if suspicion that the arrest is due to nothing more than extreme bradyarrhythmia. We have included this intervention lower down in the protocol, after ECM has been commenced, due to the additional complexity in setting up external pacing and clinicians' unfamiliarity with this intervention that we have observed in our manikin simulations even after training.

If the pacemaker is connected and functioning before the arrest, and the patient has arrested with an ECG showing PEA at a rate that looks like a paced rhythm, the pacemaker spikes on the monitor may disguise underlying VF. We recommend that in this situation it is worth turning off the pacemaker to exclude underlying VF.

11.2. Atropine

Recommendation

For patients with asystole or extreme bradycardia atropine should be given via the central line at a dose of 3mg.

Despite widespread use of atropine in all cardiac arrest protocols, its benefit is not well established. Five prospective non-randomised controlled trials in non-cardiac surgical patients have failed to establish a survival benefit for in-hospital or out-of-hospital cardiac arrest.

We were unable to find any further evidence in favour of atropine in the cardiac surgical literature. However, atropine is a relatively benign drug with few side-effects and thus in the context of asystole or extreme bradycardia without a viable arterial blood pressure we continue to recommend 3mg of atropine administered as a single dose via the central line as soon as a non-VF/VT arrest has been identified.

11.3. Emergency resternotomy after non-VF/VT arrest

Recommendation

In non-shockable cardiac arrest which does not resolve after atropine and pacing, emergency resternotomy should be immediately performed.

In non-cardiac surgical patients, non-VF/VT arrests are associated with a poorer outcome. The ERC guidelines ask clinicians to consider the following as causes of the arrest: hypoxia, hypovolaemia, hypo/hyperkalaemia, hypothermia, tension pneumothorax, thromboembolism, tamponade and toxins, the so called 4 'H's and 4 'T's.

In contrast, cardiac surgical patients who have a non-VF/VT arrest with this rhythm may have tamponade, tension pneumothorax or severe hypovolaemia. Prompt treatment is associated with an excellent outcome. Thus delays to resternotomy should be minimised.

After connecting the pacemaker and administrating atropine, there should be no delay to the decision to perform emergency resternotomy. If each of the 4 'H's and 4 'T's are considered in turn it is apparent that none of these should delay resternotomy. Reversible causes of hypoxia should already have been addressed as part of the basic life support protocol already described. Hypovolaemia which causes arrest will inevitably require a resternotomy to stem the bleeding. Hypo/hyperkalaemia are unlikely causes of arrest after cardiac surgery as serum potassium is regularly monitored but if this is the cause of the arrest, a prolonged period of CPR may be needed which will be better performed by internal massage. Hypothermia causing arrest is unlikely and may require active rewarming on bypass as passive rewarming would already have been used in the ICU prior to the arrest. Tension pneumothorax should be identified by the assessment of the airway and breathing during basic life support and treated by drainage. If undetected clinically, it will be promptly relieved by emergency resternotomy. Tamponade requires resternotomy and is the commonest cause of non-VF/VT arrest after cardiac surgery. Toxins are unlikely and cessation of infusions may be all that can be done unless clinical suspicion regarding a specific drug are raised. Finally thromboembolic and mechanical obstruction such as a pulmonary embolus or obstructed valve, will be difficult to treat other than with emergency resternotomy.

Thus prompt resternotomy should be performed if there is a non-VF/VT cardiac arrest which does not resolve with atropine and epicardial pacing.

12. Conduct of emergency resternotomy

12.1. Internal versus external cardiac massage

Recommendation

Internal cardiac massage is superior to external cardiac massage. In patients with a recent sternotomy in whom resuscitative efforts are likely to last more than 5-10 minutes, emergency resternotomy is indicated in order to perform internal cardiac massage even if a reversible cause from resternotomy seems unlikely.

ILCOR provided a systematic review of the topic as part of the worksheet review process. They found four human studies, with two in cardiac surgery and two in out-of-hospital cardiac arrest and 18 animal studies. They report benefits of internal cardiac massage including better coronary perfusion pressure, increased return of spontaneous circulation, superior organ blood flow and better survival rates as compared to ECM. They recommend that open-chest CPR should be considered for cardiac arrest in the early postoperative phase after cardiothoracic surgery or when the chest or abdomen is already open.

We support this intervention if simple resuscitative efforts such as defibrillation, pacing or atropine fail, in order to improve significantly the quality of cardiopulmonary resuscitation.

12.2. The emergency resternotomy set

Recommendations

A small emergency resternotomy set should be available in every ICU, containing only the instruments necessary to perform the resternotomy. This should include a disposable scalpel attached to the outside of the set, an all-in-one drape, a wire cutter, a heavy needle holder and a single piece sternal retractor.

This should be in addition to a full cardiac surgery sternotomy set which need not be opened until after the emergency resternotomy has been performed.

These sets should be clearly marked and checked regularly.

If a resternotomy is to be performed rapidly, ICU staff must be trained in this multi-personnel procedure. One reason for delay in emergency resternotomy is the preparation of a standard sternotomy instrument set which may contain over 30 items of equipment, although only 5 items are essential: an all-in-one sterile thoracic drape, a scalpel, a wire cutter, a heavy needle holder, and a single piece sternal retractor. A Jankauer sucker may be useful and can be connected to the bedside suction point. Larger sets may confuse staff unaccustomed to assisting in theatres and thus cause delay. In addition, when the theatre team arrives, the full thoracic instrument set may have been partially desterilised when opened by the ICU staff in the emergency and have to be replaced.

We recommend every cardiac surgery ICU be equipped with a small emergency resternotomy set with the disposable scalpel taped to the top (figure 3). Once the chest has been opened, this set can be discarded and a full set opened in a more measured fashion.

12.2. Preparation for emergency resternotomy

Recommendations

Two to three staff members should put on a gown and gloves as soon as a cardiac arrest is called, and prepare the emergency resternotomy set.

Hand washing is not necessary prior to closed-sleeve donning of gloves.

Emergency resternotomy is a multi-practitioner procedure which should ideally be rapidly performed with full aseptic technique. Cardiac arrests in the ICU are often promptly attended by more staff members than needed simply to manage basic life support, defibrillation, airway, and decision making. Therefore additional staff should immediately prepare for resternotomy as soon as cardiac arrest is confirmed, because 20-50% of cardiac arrests after cardiac surgery result in emergency resternotomy. The minor potential waste in re-sterilising equipment if not needed is more than compensated for by the benefits gained from early resternotomy when needed.

Two or three staff members should gown and glove as soon a cardiac arrest is called. Hand washing is time-consuming in an emergency situation and incomplete drying of the hands will slow the donning of gloves. Hand washing is not necessary if an aseptic closed-sleeve technique in donning gown and gloves is used.

11.3. Personnel performing emergency resternotomy

Emergency resternotomy may be required in 0.8-2.7% of all patients undergoing cardiac surgery. A cardiac surgeon at registrar (resident) level or above is normally available. However, there may be situations where a surgeon is either unavailable or unable to attend immediately. As resternotomy is often an integral part of successful resuscitation after cardiac surgery, it is beneficial for all personnel who participate in resuscitation in this setting to be aware of the technique of emergency resternotomy and to have practised it. This ensures better assistance for the surgeon and, in the unlikely situation that resternotomy is required and a surgeon is not immediately available, resternotomy by another member staff may be life-saving.

11.4. Emergency resternotomy

- Don a gown and gloves in a sterile fashion using the closed glove technique. ECM must continue until you are ready to apply the all-in-one sterile thoracic drape.
- When ready, ask the person performing ECM to stand aside after removing the sternal dressing.
- Apply the thoracic drape ensuring that the whole bed is covered.
- If an all-in-one sterile drape is used (as recommended) then there is no need to prepare the skin with antiseptic, as there is a clear adhesive plastic window in the drape to cover the skin. This will not stick if a skin preparation is used (skin preparation only sterilises the skin as it dries which requires several minutes).
- Recommence ECM (changeover from non-sterile ECM to sterile ECM should take no more than 10 seconds).
- When equipment is ready (figure 3), cease ECM and use the scalpel to cut the sternotomy incision, including all sutures deeply down to the sternal wires.

- Cut all the sternal wires with the wire cutters and pull them out with the heavy needle holder. The sternal edges will separate a little and tamponade, if present, may be relieved at this point. This is significantly faster if one person cuts the wires with the wire cutter and a second assistant removes the wires with the heavy needle holder.
- Use suction to clear excessive blood or clot.
- Place the retractor between the sternal edges and open the sternum. If cardiac output is restored then you have successfully treated the cardiac arrest and should wait for expert assistance.
- If there is no cardiac output, carefully identify the position of any grafts and then perform internal cardiac massage and internal defibrillation if required.

11.5. Method of internal cardiac massage

This is potentially dangerous and personnel who may be required to perform this must have had prior training to do this safely. Risks to the patient include avulsion of a bypass graft, with the left internal mammary artery being at particular risk. If you are inexperienced you should not rush to perform internal cardiac massage once the chest is open. It is more important carefully to remove any clot and identify structures at risk such as grafts prior to placing your hands around the heart.

Single hand techniques may disrupt the right ventricle especially if it is thin or distended. There are several methods of internal massage and if you are experienced then you may use the technique that is most suitable for the particular scenario. In our view the safest method for people who do not routinely handle the heart is the two-hand technique.

Before attempting internal massage, inspect the heart to locate the internal mammary and any other grafts, carefully removing any blood clots. Pass the right hand over the apex of the heart (minimising the likelihood of avulsing any grafts, as grafts are rarely placed near the apex). The right hand is then further advanced round the apex to the back of the heart, palm up and hand flat. The left hand is then placed flat onto the anterior surface of the heart and the two hands squeezed together. Flat palms and straight fingers are important to avoid an unequal distribution of pressure onto the heart, thereby minimising the chance of trauma. If there is a mitral valve replacement or repair, care should be taken not to lift the apex by the right hand, as this can cause a posterior ventricular rupture. Squeeze your hands together at a rate of 100 per minute and look at the arterial trace to verify adequate internal massage. You should try to obtain a systolic impulse of more than 60mmHg.

12. Cardiac arrest protocol and emergency resternotomy outside the ICU

Recommendations

This guideline should not be followed outside of the ICU. The 2005 European Resuscitation Council guidelines should be applied.

Local protocols for emergency resternotomy outside of the ICU should be drawn up and practised.

Emergency resternotomy outside of the ICU is associated with a poor survival although occasional patients do survive. Postoperative wards may not only care for patients after cardiac surgery, but may also have thoracic surgical or medical patients.

It is important that members of a resuscitation team use the same resuscitation protocol. The guideline presented here is not appropriate for patients who have not recently undergone cardiac surgery via sternotomy. Together with the fact that emergency resternotomy is less effective outside ICU, we recommend that this guideline is not used on the ward and the ERC guidelines should be used. However arrangements should be made locally for experienced cardiac surgical personnel to be immediately available to attend an arrest on the ward.

13. How long after cardiac surgery is emergency resternotomy no longer indicated?

Recommendations

Emergency resternotomy should form an integral part of the cardiac arrest protocol up to the 10th post-operative day.

Beyond the 10th post-operative day, a senior clinician should decide whether emergency resternotomy should still be performed.

Emergency resternotomy for internal cardiac massage should still be considered in preference to prolonged external cardiac massage even if a surgically reversible cause for the arrest is not suspected.

As the patient recovers from cardiac surgery, the chance of a cardiac arrest occurring due to a cause that can be corrected by emergency resternotomy is reduced. Tamponade, graft occlusion and life-threatening arrhythmias mostly occur in the hours after cardiac surgery. However delayed tamponade may still occur later, possibly in association with pacing wire removal or overanticoagulation. In addition, when cardiac arrest occurs several days after cardiac surgery, internal cardiac massage remains a superior method of resuscitation compared to ECM . Thus, even if a reversible cause such as tamponade is not suspected, emergency resternotomy is preferable to prolonged ECM. However, this must be balanced with the danger of resternotomy once adhesions have started to form. It is the opinion of the committee that adhesions would be unlikely to be present until at least 10 days post-operatively. Therefore emergency resternotomy should form a standard part of the arrest protocol up to the 10th post-operative day. Thereafter emergency resternotomy should be considered but a senior clinician should make the decision as to whether the resternotomy is performed, balancing the risks of damage to increasingly adherent mediastinal structures with the likely chances of a successful outcome to the arrest with emergency resternotomy.

14. Special considerations

There are many special considerations within cardiac surgery related to the specific operative procedures. The cases below serve as examples and every clinician should consider whether the patient that they are returning to the ICU may present a particular challenge should cardiac arrest occur, and if so, this should be clearly documented and discussed with the ICU staff.

14.1. Transplant patients

Patients undergoing heart, heart-lung or double lung transplant via a sternotomy may be resuscitated using these guidelines. Patients having a transplant procedure via a clam-shell incision or bilateral thoracotomy incisions should have an emergency re-thoracotomy through the previous particular incision using the same indications in this guideline. Only a surgeon experienced in this particular approach should perform this procedure. Atropine will be ineffective for patients after operations involving a cardiac transplant and therefore this may be omitted from the non-VF/VT protocol.

14.2. Paediatric patients

The only reported series that we identified sets the incidence of cardiac arrest at 4% after cardiac surgery in children. The success of resuscitation is similar to adult patients and the causes are also similar although 11% suffered a respiratory arrest in this series. This guideline should be read together with the ERC guidelines on paediatric cardiac arrest. Paediatric cardiac surgery ICUs may use this protocol but it must be noted that ***none of the drug dosages are intended for use in children and all dosages must be corrected for body weight or surface area as is the usual practice for drug administration in paediatrics.***

14.3. 'Open chest' patients

Occasionally a patient after a high-risk operation will be returned to the ICU with the sternum 'open'. The heart may be surrounded by gauze packs, especially if bleeding has been difficult to control. Such patients are at high risk for cardiac arrest. The surgeon should hand over specific guidelines for their care should a cardiac arrest occur. However we recommend that they be cared for using this guideline. ECM should be performed at the midpoint of the chest, over the packs, and the arterial pressure trace should be observed to assess the effectiveness of external massage. If emergency resternotomy is then indicated, full aseptic technique should be used, and this will be easier as sternal wires will not need to be removed. In particular the packs may contribute to cardiac compression, inducing an element of tamponade and thus should be carefully removed, making sure that no grafts are adherent to them if present.

14.4. Patients with a cardiac assist device

All clinicians caring for these patients should have full training in the procedures for equipment failure and the 'cardiac arrest' situation. The guidelines presented in this document do not apply to these patients. They are highly complicated due to the fact that an 'arrest' may be due to mechanical failure and in this situation ECM is not appropriate. A protocol for resuscitation and back-up support must be established and rehearsed.

14.5. Patients undergoing non-sternotomy cardiac surgery

Some cardiac operations avoid a full sternotomy. This may range from a partial sternotomy, port-access surgery with a mini-thoracotomy, minimally invasive coronary artery bypass (MIDCAB) to TECAB (totally endoscopic coronary artery bypass). It is appropriate to follow this guideline and it is important that the ICU has only one protocol for the initial management of a cardiac arrest.

The operating surgeon should however ensure that the staff members are fully aware of how an emergency reopening should be performed should cardiac arrest occur and emergency reopening be indicated. In these cases it is acceptable for the operating surgeon to indicate that a reopening should not occur unless a senior surgeon familiar with the particular operation is present. This should be discussed with the ICU on admission from theatres.

It should be noted that internal cardiac massage is difficult to perform from a right thoracotomy such as that used in port-access mitral surgery, and therefore it is likely that in the event of a cardiac arrest, these patients should receive a sternotomy by an experienced surgeon rather than rethoracotomy. A sternal saw should therefore be immediately available on the ICU for these patients.
Similarly a patient undergoing coronary artery bypass grafting via a MIDCAB incision should probably undergo a sternotomy rather than extending the incision laterally in an arrest. The sternotomy allows full access to the heart and is most familiar to the attending surgeon and team. It should be noted that the LIMA may not have been fully harvested from the chest wall, and extra care should be taken if internal massage or cardiac manipulation is required.

15. Guideline implementation

The transition phase of modifying resuscitation guidelines in the ICU represents a time of high risk to both patients and staff. In particular, there are clear dangers in changing from a single-shock protocol followed by cardiac massage to a 3-sequential shock protocol. The change should be discussed in advance as a unit, and ideally training given in advance of practice change. Training resources are available (www.csu-als.com) together with specialist resternotomy manikins, but equally it is hoped that this guideline is sufficiently comprehensive that it may be taken into the ICU and after local discussion and practice, the guideline may be implemented without any further specialist equipment or assistance.

This is an interim guideline prior to full discussion with the International Liaison Committee On Resuscitation who will be updating all resuscitation guidelines in 2010. Thus it is possible that substantial updates will be available at that time.

Figure 1: EACTS guideline for resuscitation of a patient who arrests after cardiac surgery.

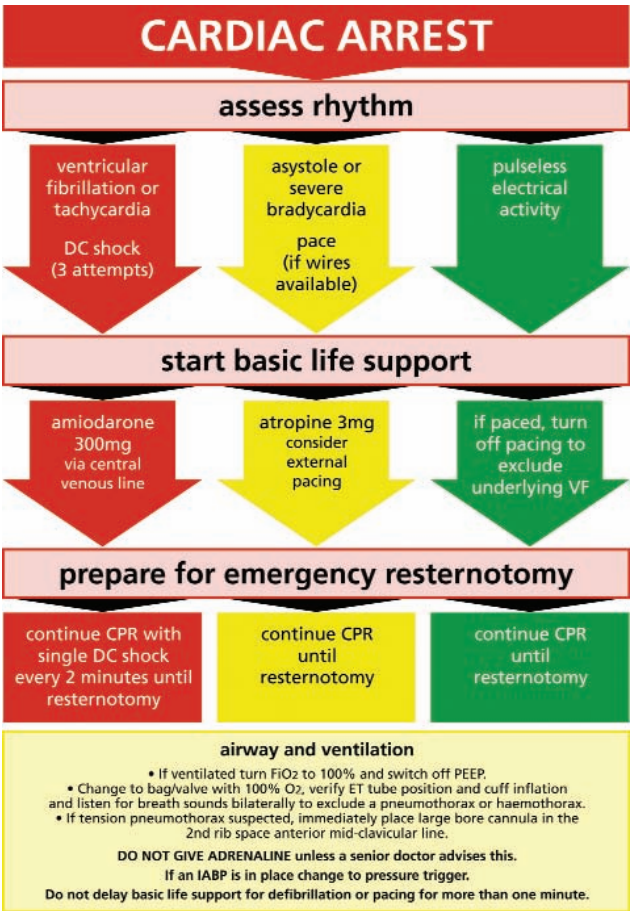
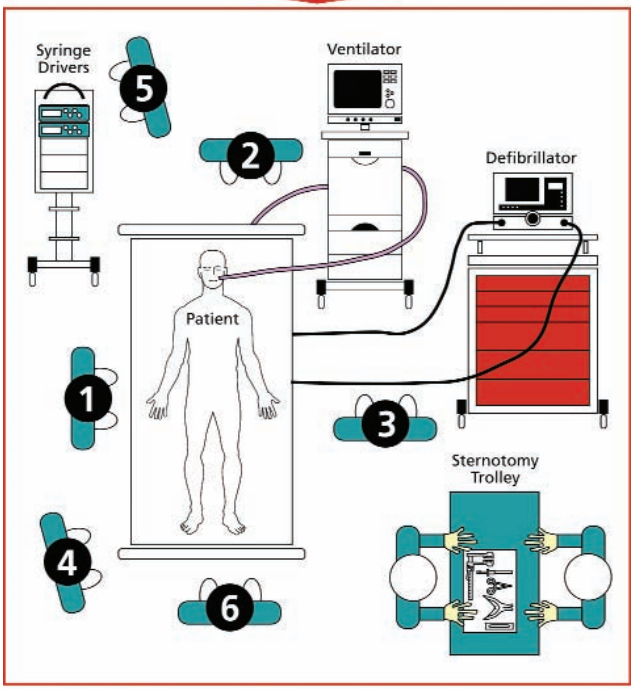


Figure 2 : Six key roles in the cardiac arrest

Figure 2. Six key roles in the cardiac arrest



Six key roles in the cardiac arrest:

1. External cardiac massage
2. Airway and breathing
3. Defibrillation
4. Team leader
5. Drugs and syringe drivers
6. ICU co-ordinator

Figure 3. Small resternotomy set packed with scalpel on top (above) and opened (below)

For a full presentation on the guideline for resuscitation in cardiac arrest after cardiac surgery given by the authors come to :

Hall E, Level 0, Austria Center, tuesday 20th October 14:00 to 15:30

This presentation will feature :

14:00-14:30: The guidelines presented with their rationale and reasons for making these final recommendations

14:30-15:00: Live manikin simulation of the protocols in action : 6 nurses and resuscitation officers from the UK will perform a live demonstration on the resternotomy manikin to highlight the advantages of the new protocol

15:00-15:30: Structured panel discussion, featuring descriptions from 2 nurses of their experience in having to perform emergency resternotomy without a surgeon present, an account of how Papworth has adopted these guidelines from their resuscitation officer, The UK national perspective from the SCTS nurse representative, and views from the anaesthetists and surgeon's point of view.

CARDIAC ARRESTS

assess rhythm

ventricular fibrillation or tachycardia	asystole or severe bradycardia	pulseless electrical activity
DC shock (3 attempts)	pace (if wires available)	

start basic life support

amiodarone 300mg via central venous line	atropine 3mg consider external pacing	if paced, turn off pacing to exclude underlying VF

prepare for emergency resternotomy

continue CPR with single DC shock every 2 minutes until resternotomy	continue CPR until resternotomy	continue CPR until resternotomy

airway and ventilation

- If ventilated turn FiO_2 to 100% and switch off PEEP.
- Change to bag/valve with 100% O_2, verify ET tube position and cuff inflation and listen for breath sounds bilaterally to exclude a pneumothorax or haemothorax.
- If tension pneumothorax suspected, immediately place large bore cannula in the 2nd rib space anterior mid-clavicular line.

DO NOT GIVE ADRENALINE unless a senior doctor advises this.

If an IABP is in place change to pressure trigger.

Do not delay basic life support for defibrillation or pacing for more than one minute.