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Cardiopulmonary Resuscitation in Adult Patients in Prone Position

Patients are often positioned in the prone position for surgeries on the back, for example, spine surgery as a necessary procedure for the conduct of surgery. Since the respiratory system function, the matching of ventilation and perfusion have been shown to be better in prone position, this position is also adopted in the ICU as a rescue maneuver in patients with severe acute respiratory distress syndrome. In both situations, the patients are already undergoing mechanical ventilation with their airway being secured with an endotracheal tube. Cardiac arrest can happen in these patients being managed in prone position. Effective external cardiac compressions (ECC) and early defibrillation are cornerstones for effective management of cardiac arrest. In the event of diagnosis of cardiac arrest, the usual response is to turn the patient supine as soon as possible and follow standard resuscitation measures. While it is easier resuscitating patients in the supine position, precious time may be lost before a patient can be turned prone.

Cardiopulmonary resuscitation (CPR) in prone position is more challenging as access to airway and veins is difficult. Turning a critically ill patient from prone to supine in an emergency may result in loss of airway, disconnection of vascular lines with resultant adverse situations. The patient may have ongoing bleeding and an unstable spine during surgery that compound the matter. Thus, it would be important to see whether CPR can be done in prone position, at least till the patient can be turned supine.

In this review, we will review the effects of ECC in prone position and the variations in defibrillation pads placement. We will then review some of the case reports of management of cardiac arrest in prone position and the lessons learnt from them. Finally, we will look at some of the preparatory measures and planning necessary to deal with such a difficult situation.

Kouwenhoven *et al*. in 1960 first described ECCs for cardiac resuscitation and proposed the "cardiac pump theory" according to which ECCs led to compression of the ventricles of the heart against the spine and reestablished circulation.[1] In 1980, Rudikoff *et al*. challenged this theory by proving that the changes in intrathoracic pressures (ITP) during compressions was the cause for the movement of blood and thus established the "thoracic pump theory."[2] A recent systematic review concluded that both mechanisms are operative during ECCs but which one dominates depends on the depth and site of the compressions and presence or absence of positive pressure ventilation.[3]

Mazer *et al*. proposed an explanation for the efficacy of prone CPR.[4] According to them, the force generated by ECC in prone position is greater as the costovertebral joints are more rigid and can easily transfer the force of compression without yielding. This results in greater change in the ITP and also more effective direct cardiac compression that providing better circulatory effects. Prone position provides airway patency naturally and the increased alteration in ITP allows ventilation. Gas exchange is also known to be better in prone position.

Mannequin and human studies have proven that ECC is more effective in prone position. Atkinson assessed the efficacy of prone CPR performed on mannequins and concluded that effective CPR (compressions with adequate depth) can be performed in prone position, but it requires additional instruction for the technique.[5] In a human study involving six patients who had sustained cardiac arrest and failed CPR for 30 min, Mazer *et al*. gave reverse CPR *(*prone CPR) for 15 min and supine CPR for 15 min. They found that prone CPR generates higher systolic blood pressure.[4] Similarly, Wei *et al*. also proved that prone CPR with back compressions produces adequate hemodynamic and ventilatory effects. They also opined that it is easier to learn and perform.[6] A recent study by Kwon *et al*. has shown that left ventricular cross-sectional area is maximum 0–2 vertebral segments below the inferior angle of scapula and compression at this site could give better results.[7]

Defibrillation is another important aspect of CPR for which the defibrillation pads can be attached in 3 different ways, namely, anterior-lateral, anterior-posterior, and apex posterior. The success rate of defibrillation is comparable in all these three locations. In the apex posterior position, which is most convenient for a prone patient, one of the pads is placed at the left 5th ICS in the midaxillary line and the other between the tip of right scapula and the spine.[8]

Tobias *et al*. reported a case of successful prone CPR where the efficacy of ECC was monitored by arterial blood pressure (ABP) and capnography.[9] Brown *et al*. reported a case of successful prone CPR and also did a systematic review of literature to identify 22 cases of cardiac arrest in prone position surgery.[10] The authors identified certain risk factors and events which led to cardiac arrest. The predisposing factors identified were undergoing complex spine or cranial surgeries, pediatric patients with congenital spine abnormalities and coexisting cardiorespiratory disease (e.g., Duchenne muscular dystrophy, Marfan syndrome, achondroplasia). The complications which led to the cardiac arrest were hemorrhagic shock, venous air embolism (VAE), oxygen bubble embolism (produced by hydrogen peroxide irrigation of wound), paradoxical air embolism, compression of trachea or tracheal tube due to extreme lordoscoliosis of the thoracic spine, dislodgement of

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the tracheal tube, arrhythmias due to brainstem stimulation or cervical cord manipulation, acute increase in intracranial pressure, and vasovagal shock. Beltran and Mashour reported 2 cases of unsuccessful attempt to resuscitate patients who had cardiac arrest in prone position and were managed after turning them supine.[11] The authors recommended that starting CPR in prone position minimizes interruption in ECCs and also provides access to surgical field to control any ongoing bleeding. Dooney[12] and Haffner *et al*.[13] have similarly reported cases of successful prone CPR. Gomes and Bersot described a case of cardiac arrest in a patient undergoing neurosurgery in the prone position.[14] Cardiac massage was promptly initiated in the prone position with rhythmic manual compression to the middle portion of the thoracic spine. They did not provide any counter pressure sternal support. The rate of compressions remained above 100/min, the $PetCO_2$ >15 mmHg, and diastolic blood pressure >30 mmHg.

Identifying patients at risk, careful positioning, invasive hemodynamic monitoring and attaching defibrillation pads before the surgery prepares us well to deal with an arrest in prone position. Patients undergoing complex spine and cranial surgeries and those with preexisting cardiorespiratory diseases and congenital/genetic deformities are the ones at risk for such an event. Invasive hemodynamic monitoring should include invasive ABP central venous pressure and if required transesophageal echocardiography as well (in surgeries at high risk for VAE. Capnography helps in early diagnosis of VAE and also in assessing effectiveness of ECC. In case of cardiac arrest, ECC should be started at the earliest without wasting time in turning the patient to supine position. The cause should be identified and treated appropriately. In case of dislodgement of the tracheal tube, supraglottic airways (especially PLMA, iGel) should be inserted as they do not require laryngoscopy and takes less time.

Prompt and appropriate CPR is vital in the event of cardiac arrest. When cardiac arrest occurs in prone position, it is probably prudent to start ECC in the prone position itself until arrangements can be made to turn the patient supine. Precious time thus gained may translate to well-maintained brain tissue resulting in return of spontaneous circulation with a meaningful outcome.

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