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Successful Cardiopulmonary Resuscitation of Two Patients in the Prone Position Using Reversed Precordial Compression

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Standard precordial cardiac massage was developed for cardiac arrest with the patient in the supine position. On rare occasions cardiac massage is required for patients in the prone position during anesthesia. These occurrences may be catastrophic. Resuming the supine position is usually recommended for effective cardiac massage. However, there are some drawbacks. Changing position is usually time-consuming and delays the initiation of cardiac massage. If intracranial or spinal cord surgery is in progress, moving the patient without proper protection into the supine position may injure the brain or spinal cord. To date we know of no previous report or description of cardiac massage for patients in whom cardiac arrest occurred while they were in the prone position. We therefore report the successful resuscitation of two patients while in the prone position who suffered cardiac arrest during posterior cranial fossa and cervical spine surgery. We call our resuscitation technique for these patients "the reverse precordial compression maneuver (reversed precordial compression)."

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CASE REPORTS

Case 1. A 14-yr-old girl who sustained an open occipital fracture in a motorcycle accident was scheduled for an emergency posterior fossa craniectomy. She had been unconscious after the accident. Neurologic examination revealed a Glasgow coma scale of 8. Her pupils were small and equal, and the light reflex was sluggish. Computerized tomographic scan of the head revealed a left intracerebellar hematoma measuring 3 × 3.5 cm, a reduction in size of both lateral ventricles, and a depressed occipital fracture. In the operating room she was monitored with electrocardiogram, pulse oximeter (Sp_{O_2}), direct radial arterial blood pressure, and central venous pressure *via* right internal jugular vein. Following induction of anesthesia, she was placed in the prone position with her head supported by a Mayfield head clamp. Anesthesia was maintained with oxygen–nitrous oxide–fentanyl.

The patient's vital signs were stable for 75 min (blood pressure = 90/

70 mmHg and heart rate = 104/min), when the transverse sinus was accidentally torn, resulting in rapid blood loss. Upon forceful retraction of brain during hemostasis, sudden severe bradycardia (30 beats/min) and hypotension (systolic pressure less than 50 mmHg) developed. Despite removal of the retractor and administration of atropine and epinephrine, idioventricular rhythm developed and blood pressure became unobtainable. Cardiac massage was begun. This was performed by the attending anesthesiologist's placing his left hand clenched into a fist under the sternum while compressing rhythmically the mid-thoracic spine using his right hand. Arterial systolic pressure as high as 160 mmHg was noted during the cardiac compression and was maintained at 100–120 mmHg throughout. Five minutes after institution of cardiac compression, sinus rhythm resumed with arterial systolic pressure maintained at 90–130 mmHg. The surgeon quickly repaired the tear of the transverse sinus and evacuated the hematoma. Arterial blood gases measured during and after the arrest were within normal limits.

This episode was likely caused by an acute compression of the brain stem, resembling uncal herniation, which led to a transient decompensation of vital center. The patient regained consciousness 2 days after the surgery and made an uneventful recovery.

Case 2. A 34-yr-old man sustained a compression fracture of the third cervical vertebrae with incomplete severance of the cervical spinal cord from a fall. The head and neck were immobilized with a halo device, and he was treated medically. However, due to progressive upper extremity and respiratory muscle weakness, he was brought to the operating room for an emergency decompression laminectomy 36 h later. Preoperative chest x-ray suggested aspiration pneumonia. Rales were heard bilaterally. Sp_{O_2} while breathing room air was 89%. Arterial blood pressure was monitored *via* right radial artery. Induction of general anesthesia was smooth and anesthesia was maintained with isoflurane–oxygen–fentanyl. After induction of anesthesia an arterial blood gas revealed a Pa_{O_2} of 125 mmHg and a Pa_{CO_2} of 34 mmHg. He was positioned prone, with his head supported by a Mayfield clamp. His vital signs were stable, maintaining an Sp_{O_2} of 92–95% and a PET_{CO_2} of 28 mmHg, although frequent endotracheal suction was required.

Ninety minutes after surgery was begun, a sudden increase in airway pressure and a decrease in tidal volume were noted. High-pitch noises were heard through both inspiratory and expiratory phases. Sp_{O_2} decreased to 30% and PET_{CO_2} increased to 78 mmHg. When the endotracheal tube was suctioned, severe bradycardia, hypotension, and ventricular fibrillation developed. Since resumption of the supine position was impossible, cardiac massage was begun immediately with the patient remaining in the prone position. The anesthesiologist placed one hand clenched into a fist under the patient's sternum while the surgeon compressed the thoracic supine between the scapulae. Arterial systolic pressure as high as 200 mmHg was noted during compression and was maintained at 120–130 mmHg throughout the resuscitation. We found that the suction catheter was unable to pass beyond the tip of the endotracheal tube. However, by forcing a pliable metal stylet through the tube it become possible to pass the obstruction. Airway pressure decreased, and the lung could be ventilated. Two minutes after regaining airway patency, the heart resumed sinus rhythm and arterial pressure was maintained at 120–140 mmHg systolic. Neither hypoxemia nor hypercapnia was noted after the arrest. Cardiac massage lasted 6 min.

Surgery was completed without further incident. The endotracheal tube was replaced at the end of surgery and was found to have a blood clot 3 cm in length at the tip of the endotracheal tube. The patient regained consciousness immediately after operation.

Discussion

Reversed precordial compression proved to be an acceptable method of cardiopulmonary resuscitation in these patients. To perform a reversed precordial compression, one hand is placed on the patient's back over the mid-thoracic spine and is used to compress the thorax rhythmically. The other hand, which should be clenched into a fist, is placed against the lower third of the sternum and remains there during the resuscitation. This serves as a counterforce to the compression of the thorax. This second hand should be supported by a rigid board placed under the chest or by several operating table sheets placed directly under the chest. The resuscitator can alternate hand positions during the resuscitation if the hands become tired. Although compression pressure was strong enough, neither rib fracture nor precordial ecchymosis occurred in either of our patients.

Despite the advantages over standard precordial compression with the patient prone, there are some limitations with reversed precordial compression. The clenching hand becomes tired rapidly because it supports in part the compression pressure and the weight of trunk. For the second patient, who weighed 72 kg (much more than the patient in case 1), the hands were alternated so frequently that an effective compression rhythm could hardly be maintained. For surgery involving the thoracic spine, direct compression from the back is not possible. For patients who have sternal deformities, this maneuver may not be effective. In addition, in patients who have substantial osteoporosis or bony deformities in whom spinal compression may be deleterious, this technique should be avoided.

To enhance its effectiveness, we performed the reversed precordial compression in a slightly different way in both of our two cases. Although the technique was designed originally to be performed by single resuscitator, when two persons are available (*e.g.*, anesthesiologist and surgeon) one can apply back compression (*e.g.*, the scrubbed surgeon if the back is covered by sterile drapes) while the other holds a fist under the chest. Alternatively, one may perform reversed precordial compression alone, while a second person administers resuscitative drugs. The two-person technique may offer additional benefits. When the thoracic spine has been exposed where direct compression is not possible, simultaneous compression over both scapulae may be an alternative way of generating compressing pressure (although we cannot at this time attest to the hemodynamic effectiveness of this modification). Furthermore, with the help of scrubbed surgeon, wound contamination is less likely during hasty resuscitation.

The force applied over the thoracic spine is transmitted *via* the thoracic cage to the precordial region. As elucidated by computerized tomography in normal healthy patients, the anatomic structures of the precordial region reduce the effectiveness of cardiac massage in patients in the prone position. Direct contact between sternum and

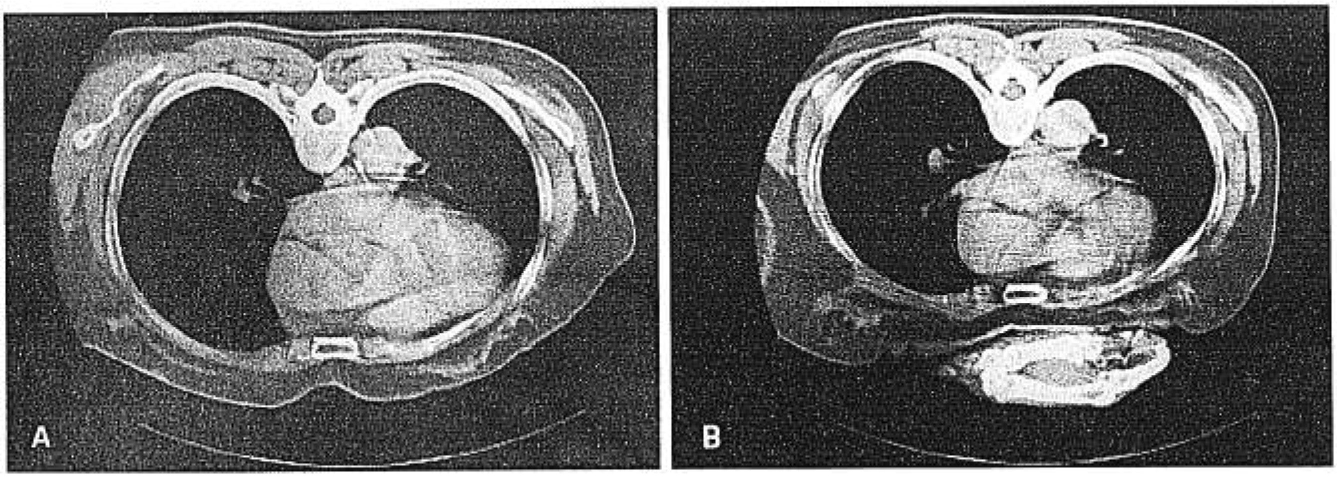

FIG. 1. Computerized tomographic (CT) scan of a woman's thoracic cage at T4 level in prone position. *A:* Contact area between chest and the bed is diffuse. Subcutaneous fat, breast, and pectoralis muscle are interposed between thoracic cage and the bed. The woman lies on a mattress, which is shaped by the curvature of a CT scan bed. *B:* With a fist under the sternum, contact area between the sternum and the bed is reduced. Both the metacarpal bones and the proximal phalanges of ring finger and index finger are also shown.

the bed is cushioned by the flattened shape of anterior thoracic cage, subcutaneous fat, breast, and pectoralis muscle (fig. 1A). With a fist between sternum and the bed, compression force applied from the back is more likely to focus pressure on the sternum (fig. 1B). Were it not for the fist under the precordium, the contact area would be much larger, and therefore a smaller compression pressure would be produced.

Performing cardiac massage in a patient in a position other than supine has not been documented in humans. However, according to the theories underlying cardiac and/or thoracic pump mechanisms, either intracardiac or intrathoracic pressure is generated by compressing the anteroposterior dimension of the thorax and outwardly displacing the ribs.[1,2] Maximal displacement of thoracic cage takes place at the sternum. The presumptive mechanism of reversed precordial compression is similar to standard precordial cardiac massage since the lower third of the sternum is chosen as the site for generation of maximal compression pressure. The major difference between conventional external cardiac massage and reversed precordial compression is the way force is generated over the sternum. Direct force is applied to the sternum in standard external cardiac massage, whereas in reversed precordial compression, indirect force is obtained. Further studies conducted in animals and humans illustrating the effectiveness of reversed precordial compression and comparing the efficacy of this technique to that of standard cardiac massage are needed before its definite role in clinical practice is recommended.

In our cases we found that reversed precordial compression was both effective and efficient. The advantages are the speed with which reversed precordial compression can be started and the avoidance of contamination or trauma to the surgical site that might occur when hastily turning a patient to the supine position. Reversed precordial compression may be considered as an alternative to standard precordial cardiac massage for the patient in the prone position.

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