

Prone cardiopulmonary resuscitation: Relevance in current times

Nidhi Bhatia, Sandhya Yaddanapudi, Ashish S. Aditya

Department of Anaesthesia and Intensive Care, Postgraduate Institute of Medical Education and Research (PGIMER), Chandigarh, India

Abstract

The most common and recommended position for performing cardiopulmonary resuscitation (CPR) is the supine position. However, clinicians may encounter situations when patients suffer cardiac arrest in prone position. Prone CPR has been described previously in a number of settings, most commonly intraoperative. In the current COVID-19 era, with more patients being nursed in prone position, an increase in the incidence of cardiac arrests requiring prone CPR is expected. Hence most of the resuscitation guidelines have made prone CPR a vital component of their recommendations. To date, most of our health-care workers have limited knowledge about prone resuscitation and the literature surrounding it. Nonetheless, with the current evidence at hand, it seems to be a reliable method of providing resuscitation and all health-care workers should be well versed with it. Thus, the goal of this narrative review is to try and fill the gaps in our knowledge about prone CPR. Literature search was done on PubMed, Medline, EMBASE using keywords 'CPR', 'Resuscitation', 'Prone Position', 'Prone', 'Prone CPR'.

Keywords: Cardiopulmonary resuscitation, prone cardiac arrest, prone CPR

Introduction

The most common and recommended position for performing cardiopulmonary resuscitation (CPR) is the supine position.^[1] However, clinicians may encounter situations when patients suffer cardiac arrest in prone position. This may occur in out-of-the hospital arrests with the patients lying face-down, or more commonly within the hospital during prone surgeries, like spine surgeries, neurosurgeries and retroperitoneal surgeries.^[1] Since long there has been a debate over whether to turn the patients' supine before initiating resuscitation or to initiate CPR in the prone position. A number of questions regarding the effectiveness and technique of prone CPR remain unanswered. This is mainly due to the fact that prone cardiac arrests have been relatively uncommon and mostly encountered intraoperatively. However, in recent times, prone

mechanical ventilation has become a widely accepted treatment modality for patients with severe acute respiratory distress syndrome requiring intensive care management.^[2] Moreover, since the onset of COVID-19 pandemic, prone positioning and/or prone ventilation has become one of the vital forms of treatment in patients suffering from this disease. Hence the issue of prone resuscitation has become especially important and relevant in current times.^[1] To date, most of our health care workers (HCWs) have limited knowledge about prone resuscitation and the literature surrounding it. The goal of this review is to try and fill the gaps in our knowledge about prone CPR.

For the purpose of this review we searched PubMed, Medline, EMBASE for clinical studies, including original articles, reviews, case reports and case series on CPR in prone position. We also searched for articles on manikin studies in prone

Address for correspondence: Dr. Nidhi Bhatia,
Department of Anaesthesia and Intensive Care, Postgraduate Institute of Medical Education and Research (PGIMER), Chandigarh, India.
E-mail: nidhi.bhatia75@gmail.com

Access this article online

Quick Response Code:	Website: https://journals.lww.com/joacp
	DOI: 10.4103/joacp.joacp_421_21

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How to cite this article: Bhatia N, Yaddanapudi S, Aditya AS. Prone cardiopulmonary resuscitation: Relevance in current times. *J Anaesthesiol Clin Pharmacol* 2022;38:S8-12.

Submitted: 24-Aug-2021

Revised: 28-Sep-2021

Accepted: 24-Oct-2021

Published: 30-Jun-2022

CPR. For the purpose of this search, we included keywords ‘CPR’, ‘Resuscitation’, ‘Prone Position’, ‘Prone’, ‘Prone CPR’. We excluded abstracts and conference proceedings.

Why Must We Know Prone CPR?

Since the onset of COVID-19 pandemic, there has been an increase in the number of critically ill patients being ventilated in prone position. Hence HCWs may encounter more patients sustaining cardiopulmonary arrest while in prone position. Immediately turning a prone patient supine, for performing CPR, can be detrimental for patients as well as staff members. Turning a mechanically ventilated patient supine, especially if obese, requires extra staff members and additional time. It has been suggested that a minimum of four and probably up to six staff members may be required to safely turn the patient supine and thus it may take as long as five minutes before conventional CPR can be started, thus increasing the no-flow time to the brain.^[3,4] This delay in initiating CPR can be extremely detrimental for the patient. In addition, there is a risk of disconnection of vascular lines and ventilator tubing as well as endotracheal tube dislodgement.^[3,4] Thus, it is important that all frontline clinicians are well-versed with the technique of prone CPR.^[1]

Evidence at Hand

Prone CPR was first reported in 1989 by McNeil.^[5] So, the concept of prone CPR is not new, but over the last three decades since it was first reported, there have only been case reports/case series that have described prone CPR [Table 1].^[6-20] In majority of these reports, cardiac arrest occurred intraoperatively, with the patients undergoing either spine surgery or posterior craniotomy. A number of these arrests occurred in children, with the youngest patient being 6 months old.^[14] The most common cause of arrest in these reported cases was venous air embolism. Other causes were cardiac decompensation, hemorrhagic shock, endotracheal tube obstruction, excessive parasympathetic stimulation and cardiac tamponade. In most of the cases that have been reported in the past, the most common initial rhythm at the time of arrest was pulseless electrical activity (PEA), followed by asystole. In majority of these cases prone CPR was successful with 80% of the patients being associated with post-resuscitation survival. Arterial blood pressure waveform, end-tidal carbon dioxide monitoring and pulse palpation were used to evaluate the quality of prone compressions. Though most of our knowledge about prone CPR is from case reports/series, however, there have been a few original research studies on prone CPR as well [Table 1].^[3,21-23] Mazer et al.^[21] conducted a feasibility study in six ICU patients and

evaluated the blood pressures during prone versus supine CPR. Similarly, Wei et al.^[22] studied the tidal volumes and blood pressures generated during prone CPR in cadavers and healthy volunteers respectively. A prone compression quality study was conducted in manikins by Atkinson^[3] to assess the quality of compressions administered by staff nurses during prone resuscitation. With the idea of identifying the ideal prone compression hand position, Kwon et al.,^[23] in 2017, conducted a retrospective analysis of chest computed tomography (CT) scans of 100 patients in prone position.

Optimum Technique of Prone CPR

The steps of CPR in prone position remain the same as in supine position. The main difference lies in the position of the hands for providing prone compressions. Most of our evidence guiding optimum hand position for chest compressions in prone position comes from case reports.^[24] Sun et al.^[17] in 1992 were the first to report cases of successful prone CPR in patients undergoing neurosurgery in prone position. They called their technique ‘reversed precordial compression’ and recommended placing one hand on the patient’s back over the mid-thoracic spine, while the other hand was placed against the lower one-third of the sternum. Alternatively, the authors recommended using a two-person technique, wherein one person can apply back compressions with two hands and the other holds a fist under the chest. With a fist between the sternum and the bed, compression force applied from the back was more likely to focus pressure on the sternum and serve as a counterforce to the compression of the thorax.^[17] Following this, in 1994, Tobias et al.^[19] reported a successful resuscitation of a 12-year old child who suffered a cardiac arrest while undergoing spinal fusion surgery to treat progressive scoliosis. The arrest occurred intraoperatively, four hours into the procedure. The surgeon performed prone chest compressions with both the hands over the two scapulae, at the mid-thoracic level, on either side of the surgical incision. As the front of the patient’s thorax was supported on a frame, counter-pressure from under the sternum, as reported by Sun et al.,^[17] was not considered necessary. Kelleher and Mackerse^[14] described cardiac arrest following venous air embolism in a 6-month-old child with achondroplasia and congenital cervical cord compression who underwent foramen magnum decompression. Successful prone CPR was done in the infant using fingers of one hand over the thoracic spine at the level of the scapula. Dequin et al.,^[10] suggested trying the ‘reversed precordial compression’, as described by Sun et al.,^[17] when cardiac arrest occurred in prone position, provided its efficacy was proved by a capnograph or an arterial catheter. de Souza Gomes and Bersot^[25] suggested prone compressions at the level of mid-thoracic spine, in the

Table 1: Literature evidence of prone cardiopulmonary resuscitation

Original Studies	Type of Study
Atkinson, 2000 ^[3]	Feasibility Trial
Mazer <i>et al.</i> , 2003 ^[21]	Pilot feasibility study
Wei <i>et al.</i> , 2006 ^[22]	Study on cadavers and healthy volunteers
Kwon <i>et al.</i> , 2017 ^[23]	Retrospective Analysis
Case Studies	Type of Surgery/Intervention
Sun <i>et al.</i> , 1992 ^[17]	Case Study of Two patients: - Posterior fossa Craniectomy -Decompression laminectomy
Tobias <i>et al.</i> , 1994 ^[19]	Spinal fusion
Gueugniaud <i>et al.</i> , 1995 ^[12]	Scoliosis correction surgery
Kelleher and Mackersie, 1995 ^[14]	Foramen Magnum Decompression
Dequin <i>et al.</i> , 1996 ^[10]	Prone ICU ventilation in patient with pneumonia
Woo-Ming, 1996 ^[20]	Case series of children with respiratory pathology
Sutherland and Winter, 1997 ^[18]	Case Study of two patients undergoing posterior spinal fusion
Dooney, 2010 ^[11]	lumbosacral spinal surgery
Cho <i>et al.</i> , 2012 ^[9]	scoliosis correction surgery
Chauhan <i>et al.</i> , 2016 ^[8]	lumbar discectomy
Burki <i>et al.</i> , 2017 ^[7]	Posterior cranial fossa surgery
Kaloria <i>et al.</i> , 2017 ^[13]	Bony Spur Removal in a Child of Split Cord Malformation
Mayorga-Buiza <i>et al.</i> , 2018 ^[15]	Posterior fossa tumour excision
Mishra <i>et al.</i> , 2019 ^[16]	Laminectomy and Tumour Excision
Al Harbi <i>et al.</i> , 2020 ^[6]	posterior spinal fusion with laminectomy

absence of sternal pressure. More recently, Kwon *et al.*^[23] retrospectively reviewed computed tomography images of 100 patients to determine the optimal hand position while performing prone compressions, and defined it as a region that correlates with the largest left ventricular (LV) area. The authors reported that in at least 86% of the patients, the largest LV cross-sectional area was located 0 to 2 vertebral segments below the line crossing the inferior angles of the scapula. However, the authors also suggested that further studies were required to determine the quality of compressions at this location. The current American Heart Association CPR guidelines recommend placing hands in the midline over the thoracic spine, at the level of T7/10 vertebral bodies.^[26]

Defibrillator pad positions in prone position

Defibrillator pads should be located to allow sufficient energy to pass through the myocardium. The various positions that have been recommended include the antero-posterior position, left and right mid-axillary lines and the postero-lateral (one slightly posterior to the left mid-axillary line and the other inferior to the right scapula) position.^[24,26,27]

Is prone CPR effective?

The most important question that currently needs to be addressed is that how effective prone CPR is and what is the survival rate of patients who are resuscitated in prone position. There are a number of ethical concerns that are associated with human studies evaluating the efficacy of resuscitation in prone position. However, there are a few studies suggesting

that as compared to supine position, CPR in prone position generates higher blood pressures.^[21,22,28] The quality of chest compressions has been assessed by invasive blood pressure monitoring, pulse palpation and end-tidal carbon dioxide. In 2003, a pilot feasibility study was conducted in six adult ICU patients in whom a prolonged (for 45 minutes), standard CPR had failed and the patients were then turned prone for resuscitation.^[21] Prone CPR resulted in a significant improvement in both systolic (23 ± 14 mmHg, $P < 0.05$) and mean arterial blood pressure (14 ± 11 mmHg, $P < 0.05$). However, as expected, given the studies' design, none of the patients had a return of spontaneous circulation. With the aim of ascertaining the effectiveness of prone CPR, a manikin study was conducted by Atkinson^[3]. The authors enrolled 36 registered nurses who volunteered to perform CPR on a Laerdal Resusci-Annie® manikin turned to the prone position. The authors found that of the 3376 chest compressions done by the nursing staff, 34.6% had a compression depth of 4-5 cm and were effective. Forty two percent of the nurses were able to perform adequate CPR throughout the cycle. Wei *et al.*,^[22] measured the blood pressures and tidal volumes generated during prone CPR in cadavers and volunteers respectively. The authors found that prone CPR generated greater systolic (79.4 ± 20.3 mmHg) and diastolic pressures (16.7 ± 10.3 mmHg) as compared to resuscitation in supine position (55.4 ± 20.3 mmHg/ 13.0 ± 6.7 mmHg). Prone compressions in healthy volunteers generated a tidal volume of 399 ± 110 ml. Previous case reports have suggested

that prone CPR may generate an end-tidal CO₂ of 18-33 mm of Hg.^[11,12,29]

Do patients survive if resuscitated prone?

There is very little evidence evaluating long term outcome of patients resuscitated prone. Most of the previous case reports/case series have reported good survival to hospital discharge, with patients having complete neurologic recovery as well.^[12,19,27,30] However there are no randomized controlled trials on this and most of the current evidence we have comes from case reports and nonrandomized studies. Nonetheless prone CPR maybe a viable option in patients who cannot immediately be turned supine.^[4]

What do resuscitation guidelines recommend?

Since the onset of COVID-19 pandemic, knowing and performing prone CPR has become vital. Most of the current guidelines have now incorporated prone CPR in their recommendations. For COVID-19 patients who are in prone position without an advanced airway, the American Heart Association (AHA) recommends placing and resuscitating patients in supine position. They further recommend that *'Although the effectiveness of CPR in the prone position is not completely known, for those patients who are in the prone position with an advanced airway, it may be reasonable to avoid turning the patient to the supine position, unless able to do so without risk of equipment disconnections and aerosolization'*. AHA recommends providing prone CPR by placing the hands over the thoracic spine at the level of T7/T10 vertebral bodies, with the defibrillator pads in the anterior-posterior position.^[26] The UK Resuscitation council also recommends initiating prone CPR without turning the patient supine and monitoring the efficacy of compressions with end-tidal carbon dioxide and arterial pressure waveform.^[1] The Intensive Care Society and Faculty of Intensive Care Medicine recommend prone compressions using two hands placed over the mid-thoracic spine located between the two scapulae, with a counter-pressure that maybe applied by a second person. For defibrillation, they recommend placing the pads either in postero-lateral or in bi-axillary positions.^[24] The European Resuscitation Council, in addition to compressing between the two scapulae at a depth of 5-6 cm, recommends turning the patient supine if the compressions are ineffective, as indicated by an arterial diastolic pressure less than 25 mmHg. They also recommend turning the patient supine if the patient requires some airway intervention or there is no return of spontaneous circulation in a few minutes.^[31] A recent joint position statement from Brazilian societies of cardiology, intensive care medicine, anesthesiology and emergency medicine also recommends that patients should be turned supine as soon as possible and also suggested that CPR effectiveness should be monitored

using diastolic pressure (>20 mmHg) and partial pressure of end-tidal carbon dioxide partial (EtCO₂ > 10 mmHg).^[32]

Conclusions

Prone CPR has been described previously in a number of settings, most commonly intraoperative. Most of the evidence is from case series as well as non-randomized trials. In the current COVID-19 era, with more patients being nursed in prone position, an increase in the incidence of cardiac arrests requiring prone CPR is expected. Hence most of the resuscitation guidelines have made prone CPR a vital component of their recommendations. Though conventional supine CPR remains the 'gold-standard', however prone CPR can be of help in cases where there is delay/inability in turning the patient supine. Thus, despite the existence of knowledge gaps, with the current evidence at hand, 'prone CPR' seems to be a reliable method of providing CPR in prone position and all health care workers should be well versed with it.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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