Cardiopulmonary resuscitation in the prone position: a systematic review of case series/reports

Reanimação cardiopulmonar em posição prona: uma revisão sistemática de séries/relatos de casos

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Date of first submission: March 22, 2022
Last received: March 28, 2023
Accepted: June 6, 2023

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Abstract

Introduction: The prone position is frequently adopted for surgical or critically ill patients in intensive care. Cardiorespiratory arrest in these patients may pose an operational challenge, in which delays resulting from mobilization to the supine position culminate in worse outcomes. **Objective:** To provide clinical insight based on the synthesis of evidence from reports or case series on reverse cardiopulmonary resuscitation (reverse CPR) in surgical patients or invasive ventilatory support in severe acute respiratory distress syndrome. **Methods:** This is a systematic review of reports or case series in PubMed, Scopus, Embase, and Google Scholar databases, in addition to a search of the gray literature. Case reports published in any language, reporting at least one case of prone cardiopulmonary resuscitation in patients of any age and in any care context, were considered eligible. **Results:** Thirteen studies of fourteen cases of successful reverse resuscitation were retrieved. Three patients died within 30 days, while the others survived without complications or neurological sequelae. **Conclusion:** Despite limited evidence to support clinical decision-making, prone resuscitation appears to be a feasible alternative in exceptional circumstances, where patient mobilization may result in additional harm, delay or interrupt advanced life support (compressions, high-quality early chest surgery, and defibrillation) or incur occupational risks to the health team.

Keywords: Cardiopulmonary arrest. Cardiopulmonary resuscitation. Case reports. Evidence-based clinical practice. Prone position.

Resumo

Introdução: *A posição prona é um procedimento frequente de cuidados intensivos para pacientes cirúrgicos ou doentes graves. A ocorrência de parada cardiorrespiratória nestes pacientes pode representar um desafio operacional, no qual atrasos relacionados à mobilização para decúbito dorsal implicam em piores desfechos.* ***Objetivo:*** *Oferecer um* insight *clínico a partir da síntese das evidências oriundas de relatos ou séries de casos sobre a utilização de reanimação cardiopulmonar reversa em pacientes cirúrgicos ou em suporte ventilatório invasivo na síndrome do desconforto respiratório agudo grave.* ***Métodos:*** *Trata-se de uma revisão sistemática de relatos ou séries de casos conduzida nas bases de dados PubMed, Scopus, Embase e Google Scholar, além de busca na literatura cinzenta. Foram considerados elegíveis relatos de caso publicados em qualquer idioma, que reportaram pelo menos um caso de reanimação cardiopulmonar em posição prona em pacientes de qualquer idade e em qualquer contexto de atendimento.* ***Resultados:*** *Foram recuperados treze estudos que relataram quatorze casos de reanimação reversa bem-sucedidos. Três pacientes faleceram em um intervalo de 30 dias, enquanto os demais sobreviveram sem complicações ou sequelas neurológicas.* ***Conclusão:*** *Apesar de evidências limitadas para suportar a tomada de decisão clínica, a reanimação em posição prona parece ser uma alternativa factível em circunstâncias excepcionais, nas quais a mobilização do paciente pode resultar em dano adicional, atrasar ou interromper o suporte avançado de vida (compressões torácicas precoces de alta qualidade e a desfibrilação) ou, ainda, incorrer em riscos ocupacionais à equipe de saúde.*

Palavras-chave: *Parada cardiorrespiratória. Reanimação cardiopulmonar. Relatos de casos. Prática clínica baseada em evidências. Decúbito ventral.*

Introduction

The prone position is commonly used for surgical procedures that require access to posterior anatomical structures of the brain, neck, and spine, as well as the retroperitoneum and upper urinary tract or other posterior structures.[1,2] It is also used in intensive care patients with severe acute respiratory distress syndrome (ARDS) on invasive ventilatory support, considered an established evidence-based practice in these cases.[3,4]

Patients managed in the prone position, either due to acute respiratory failure or during surgery, may suffer cardiac arrest. They may present with hemodynamic instability due to the severity of the underlying disease and multiple organ failure or acute clinical deterioration induced by drugs or vasovagal stimulation, with subsequent cardiac arrest.[5-7]

When patients suffer cardiac arrest in the prone position, options include placing them in the supine position before initiating cardiopulmonary resuscitation (CPR) or performing CPR in the prone position.[8] In the event of cardiac arrest in the prone position, changing to the supine position may not be feasible or promptly executable, i.e., it is not possible to safely and quickly turn the patient.[9] Changing to the supine position may require five or six professionals experienced in performing the procedure and take up to five minutes to complete.[10] This delay in initiating CPR can be harmful to the patient, increasing the time without blood flow to the brain and coronary arteries,[11] negatively impacting survival and functional prognoses.

Factors such as spinal instability, open surgical wounds, the presence of surgical instruments, the risk of adverse events such as the loss of ventilatory prosthesis or vascular lines, the need for Covid-19-related personal protective equipment and limited staff preclude performing decubitus changes and may result in a delay in resuscitation. In these circumstances, CPR, including electrical therapy (defibrillation), can be performed with the patient in ventral decubitus.[10,12,13]

The main goals of initiating prone CPR, also known as reverse CPR, are to shorten the no flow time of blood to the heart or brain and apply defibrillation early (when indicated), factors that contribute to decreasing mortality and mitigating neurologic outcomes in survivors.[14]

There are a limited number of observational studies and case reports comparing prone versus supine CPR and/or defibrillation.[15] There is also a scarcity of data supporting the adoption of prone CPR as a protocol practice. This is due to the lack of information on the clinical implications of the intervention, such as survival with favorable neurologic outcomes, rate of cardiac arrest, resuscitation time, use of defibrillation, patient characteristics, and occurrence of adverse effects.

Given the above, this study aims to provide clinical insight based on synthesized case reports or case series on the use of reverse CPR in surgical patients or those on invasive ventilatory support in severe ARDS.

Methods

This systematic review of case reports is in line with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[16] Systematic reviews are routinely used to synthesize current science and assess the strength of the evidence and the resulting quality of the recommendations. Case series can be included in systematic effectiveness reviews, particularly in the absence of experimental designs such as randomized controlled trials and analytical observational studies. This methodological design contributes to a better understanding of the topic and identifying knowledge gaps in a rare clinical event or new intervention.[17]

This study asks the following research question: what is the available scientific evidence in case reports and case series on resuscitation in the prone position for return of spontaneous circulation (ROSC), survival, favorable neurologic outcome, and occurrence of adverse events?

A systematic search was performed in PubMed/MEDLINE, SCOPUS, and EMBASE (Excerpta Medica dataBASE) databases. A manual search of the grey literature was also conducted in Google Scholar, OpenGrey, and Grey Literature Report, as well as complementary consultation of the reference lists of the included studies.

The theoretical framework was based on the following descriptors and respective synonyms, combined using the Boolean operators AND and OR: (Cardiac Arrest) OR (Heart Arrest) OR (Cardiopulmonary Arrest) OR (CPR) AND (Cardio Pulmonary Resuscitation) AND (Prone Position) OR (Reverse CPR) OR (Prone CPR).

Eligibility criteria included case reports or case series; patients of any age; patients previously in the prone position (surgical procedures or ventilatory support); resuscitated in the prone position; and available data on survival and neurologic prognosis. There were no restrictions on language or year of publication. Patients who suffered intraoperative cardiac arrest or those under intensive care were considered a subgroup.

Exclusion criteria were studies that used other methodological designs; reports in which the patient was repositioned to dorsal decubitus during CPR; and studies with incomplete data.

All retrieved citations were screened and assessed for eligibility by two independent reviewers. The screening process comprised two stages: (i) evaluation of the titles and abstracts and (ii) reading in full and assessment of the complete article

Data from the articles that met the inclusion criteria in the second stage were collected, organized in a standardized table and presented in a narrative summary including authorship and year of publication; indication of prone position; age; sex; cardiac arrest rhythm; resuscitation time until ROSC; use of defibrillation (in the case of shockable rhythms); survival; neurologic outcome; clinical repercussions; and occurrence of adverse events.

The risk of bias in case reports was assessed by applying the Critical Appraisal Checklist for Case Reports from the Joanna Briggs Institute Reviewers' Manual.[18] The critical appraisal tool considers demographic characteristics; patient history; clearly described clinical cases; description of the intervention; outcome; adverse events; and implications for practice.

Results

The search strategy resulted in 29 eligible studies. After evaluation by two reviewers, 14 studies were considered for inclusion in the present review (Figure 1). The Kappa index for analysis of inter-reviewer agreement was 1.0 (95% CI; 0.60-1.00; $p \leq 0.001$).

Tables 1 - 3 present a summary of the relevant information from the studies. Table 1 lists the selected studies with their respective references and summarizes the information related to case reports of reverse resuscitation, while Table 3 contains the critical appraisal of case reports.

Fourteen studies reported 15 cases of reverse resuscitation with ROSC by manual cardiac compressions in the posterior region or defibrillation. One study did not report cardiac compressions performed in the prone position, but describes the application of early defibrillation after cardiac arrest in monomorphic ventricular tachycardia, resulting in immediate ROSC.[19] The reports ranged from children under one-year-old to adults aged over 80 years.

Most of the studies identified cases of cardiorespiratory arrest in hemodynamically stable (surgical) patients and not as a result of clinical degeneration and multiple organ failure in critically ill patients. Only one study reported a patient in intensive care.[20]

The prevalent cardiac arrest rhythm was asystole,[20-25] followed by pulseless electrical activity (PEA),[26-29] ventricular fibrillation (VF),[29,30] eand pulseless ventricular tachycardia (PVT).[12] Two cases did not specify the mechanism of cardiac arrest.[19,31] Among the studies that reported the occurrence of shockable rhythms (VF/PVT), one described the non-use of defibrillation.[29]

Return of spontaneous circulation was achieved in all patients. Among the fifteen cases reported, three patients died in less than 30 days.[21,30,31] The remaining articles describe the clinical evolution of patients with no neurological complications secondary to cardiac arrest. No adverse events due to resuscitation in the prone position were reported. A critical evaluation of the case reports shows that most studies provided detailed information.

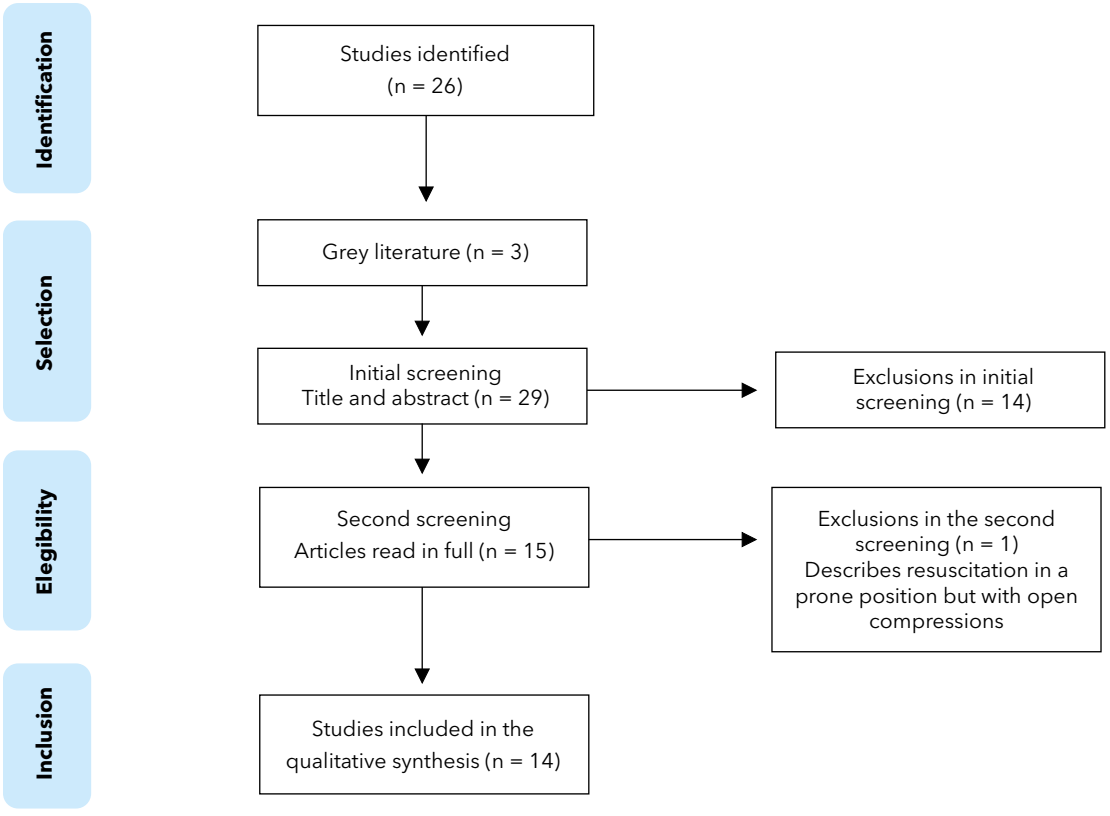

Figure 1 - Flowchart of study identification, assessment, exclusion, and inclusion.

Discussion

Effective external cardiac compressions and early defibrillation are the gold standard of care for cardiac arrest.[32] The typical approach for ventral decubitus cardiac arrest is to return the patient to a supine position as soon as possible and follow standard resuscitation measures. Although resuscitation is easier in dorsal decubitus, the postural change wastes valuable time and shifting a critically ill patient from prone to supine during an emergency may result in adverse situations, contributing to a worse prognosis.[7,33] The effectiveness of reverse CPR is related to the greater force generated by external cardiac compression in the prone position, since the costovertebral joints are stiffer and favor the transfer of the compression force. This results in more effective direct cardiac compression, thereby providing better hemodynamic effects. The prone position also allows greater airway permeability, enhancing perfusion and oxygenation.[6,11] Reverse CPR generates greater venous return and higher coronary perfusion pressure when compared to the supine position.[34,35]

Table 1 - Narrative summary: general study data

Authors/Year	Country	Title	Journal
Al. Harbi et al. (2020)[26]	Saudi Arabia	Prone cardiopulmonary resuscitation in elderly undergoing posterior spinal fusion with laminectomy	Saudi J Anaesth
Burki et al. (2017)[31]	Pakistan	CPR in prone position during neurosurgery	Anaesth Pain & Intensive Care
Kaur et al. (2016)[21]	India	Cardiac arrest in prone position: When da I make my patient supine?	Anesth Analg
Chauhan et al. (2016)[22]	India	Asystole during lumbar discectomy: a case report	J Clin Anesth
Gomes et al. (2012)[27]	Brazil	Cardiopulmonary resuscitation in the prone position	Open J Anesthesiol
Dooney (2010)[23]	Australia	Prone CPR for transient asystole during lumbosacral spinal surgery	Anaesth Intensive Care
Haffner et al. (2010)[19]	Germany	Successful cardiopulmonary resuscitation in prone position	Anaesthesist
Brown et al. (2001)[12]	United Kingdom	Cardiac arrest during surgery and ventilation in the prone position: a case report and systematic review	Resuscitation
Miranda et al. (2001)[30]	United Kingdom	Successful defibrillation in the prone position	Br J Anaesth.
Dequin et al. (1996)[20]	France	Cardiopulmonary resuscitation in the prone position: Kouwenhoven revisited	Intensive Care Med
Kelleher et al. (1995)[24]	United Kingdom	Cardiac arrest and resuscitation of a 6-month-old achondroplastic baby undergoing neurosurgery in the prone position	Anaesthesia
Tobias et al. (1994)[25]	United States	Cardiopulmonary resuscitation in the prone position	J Pediatr Surg
Loewenthal et al. 1993)[28]	France	Efficacy of external cardiac massage in a patient in the prone position	Ann Fr Anesth Reanim
Sun et al. (1992)[29]	Taiwan	Successful cardiopulmonary resuscitation of two patients in the prone position using reversed precordial compression	Anesthesiology

Table 2 - Narrative overview: clinical study data

Reference	Gender	Age	Indication for the prone position	Defibrillation	Return of spontaneous circulation	Rhythm	Duration (min)
Al. Harbi et al.[26]	Male	80 years	Posterior spinal fusion with laminectomy	No	Yes	Pulseless electrical activity	Unspecified
Burki et al.[31]	Female	6 years	Tumor excision	No	Yes	Unspecified	20 minutes
Kaur et al.[21]	Female	14 years	Correction of spinal deformity	No	Yes	Asystole	4 minutes
Chauhan et al.[22]	Male	49 years	Lumbar discectomy	No	Yes	Asystole	Between 15 and 20 seconds
Gomes et al.[27]	Female	77 years	Tumor excision	No	Yes	Pulseless electrical activity	2 minutes
Dooney[23]	Male	43 years	Lumbar discectomy	No	Yes	Asystole	Unspecified
Haffner et al.[19]	Male	81 years	Emergency craniotomy after cerebellar hemorrhage	No	Yes	Unspecified	5 minutes
Brown et al.[12]	Female	60 years	Thoracic spine decompression	Shock application (200 Joules)	Yes	Pulseless ventricular tachycardia	Unspecified
Miranda et al.[30]	Female	39 years	Thoracic vertebral tumor resection	Shock application (200 Joules)	Yes	Ventricular fibrillation	Unspecified
Dequin et al.[20]	Female	48 years	Acute Respiratory Distress Syndrome	No	Yes	Asystole	5 minutes
Kelleher et al.[24]	Female	6 months	Craniectomy	No	Yes	Asystole	2 episodes: 7 and 4 minutes
Tobias et al.[25]	Male	12 years	Spinal arthrodesis	No	Yes	Asystole	7 minutes
Loewenthal et al.[28]	Female	53 years	Tumor excision	No	Yes	Pulseless electrical activity	3 minutes
Sun et al.[29] (Case 1)	Female	14 years	Craniectomy	No	Yes	Pulseless electrical activity	5 minutes
Sun et al.[29] (Case 2)	Male	34 years	Decompressive laminectomy of cervical spine	No	Yes	Ventricular fibrillation	6 minutes

Table 3 - JBI Critical Appraisal evaluation

Reference	Demographic characteristics	Clinical history	Clinical condition	Diagnostic tests	Intervention / Treatment	Post-intervention conditions	Adverse events	Lessons learned
Al. Harbi et al.[26]	Yes	Yes	Yes	Yes	Unclear	Yes	No	Yes
Burki et al.[31]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Kaur et al.[21]	Yes	Unclear	Unclear	No	Unclear	Unclear	Unclear	No
Chauhan et al.[22]	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	Yes
Gomes et al.[27]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dooney[23]	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	Yes
Haffner et al.[19]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Brown et al.[12]	Yes	No	Yes	Yes	Yes	Yes	Yes	No
Miranda et al.[30]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dequin et al.[20]	Yes	No	Yes	Yes	Unclear	Yes	Yes	Yes
Kelleher et al.[24]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Tobias et al.[25]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Loewenthal et al.[28]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sun et al.[29]	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	Yes

Note: JBI = Joanna Briggs Institute Reviewer.

In regard to the appropriate region to apply resuscitation compressions in the prone position, one study showed that the cross-sectional area of the left ventricle is located at most 0 to 2 vertebral segments below the inferior angle of the scapula, meaning that compression in this location may produce better results.[13] A number of methods can be used to perform chest compressions in the prone position, including placing the hands on the scapulae and the thoracic spine, with or without counterpressure on the sternum.[12] Counterpressure, where the closed fist is positioned between the sternum and the bedside, can optimize resuscitation maneuvers.[23] Sternal counterpressure can increase the effectiveness of chest compressions. The same compression rate (100-120/min) and depth (5-6 cm) as conventional chest compression should be used.[36]

In young children, compressions are performed using the fingers of one hand on the thoracic spine.[24] In the neurosurgical approach, where the surgical wound and/or instruments prevent access the patient to apply compressions, the surgeon can perform a posterior left thoracotomy and direct cardiac compression.[37]

Another key aspect of conducting CPR is the application of defibrillation in the event of VF or PVT rhythms. For patients in the prone position in cardiac arrest by VF/PVT, defibrillation must be performed in this position because changing decubitus wastes time and reduces the likelihood of successful defibrillation.[9,30,38] To apply electrical therapy in the prone position, one of the defibrillator pads is placed in the left fifth intercostal space at the mid-axillary line, while the other is positioned between the tip of the right scapula and the spine.[39] Another technique involves placing one electrode at the left lower sternal border and the other posteriorly below the scapula.[40,41]

The probability of successful defibrillation and survival after hospital discharge is directly related to the time between the onset of ventricular fibrillation and administration of the first shock.[42] A simulation study reported 22 seconds for applying the first defibrillation in prone patients, compared with an average of 108 ± 61 seconds when the patient was mobilized in the supine position before defibrillation.[43]

Wei et al.[35] compared the effectiveness of supine and prone cardiac compressions in 11 patients who had

suffered cardiopulmonary collapse. The mean systolic blood pressure obtained was 79.4 (± 20.3) mm/Hg, while diastolic pressure was 16.7 (± 10.3) mm/Hg for prone resuscitation. On the other hand, precordial compressions resulted in a mean systolic arterial pressure of 55.4 (± 20.3) mm/Hg and diastolic pressure of 13.0 (± 6.7) mm/Hg, demonstrating that reverse resuscitation enables adequate circulatory support.

In a similar study, patients who suffered cardiac arrest without ROSC after 30 minutes of conventional resuscitation received an additional 15 minutes of reverse resuscitation.[7] Systolic blood pressure increased significantly, from 48 mm/Hg during standard resuscitation to 72 mm/Hg during reverse resuscitation (23 ± 14 mm/Hg). The results were also higher for mean arterial pressure (14 ± 11 mm/Hg) and diastolic arterial pressure (10 ± 12 mm/Hg). However, despite the increase in pressures, no patient experienced ROSC.[7]

In a clinical simulation with a Laerdal Resusci Anne mannequin, a study conducted with thirty-six nurses showed that appropriate training in reverse CPR, considering the performance of compressions with adequate depth, produced favorable results and adequate hemodynamic and ventilatory effects.[44]

Additionally, capnography ($ETCO_2$) is recommended to determine the effectiveness of chest compressions and CPR duration and confirm the correct position of the orotracheal tube.[45] Invasive blood pressure and continuous $ETCO_2$ monitoring may be helpful to determine if compressions in the prone position are generating adequate perfusion, which may indicate the ideal moment to place the patient in dorsal decubitus.[32]

Another relevant aspect concerns training professionals to use reverse CPR algorithms.[46,47] Familiarizing the teams with the technical aspects of applying compressions and defibrillation to the patient in the prone position may contribute to better compliance rates.[5,22,48]

Conclusion

Despite limited evidence to support clinical decision-making, reverse CPR may be a feasible alternative in exceptional circumstances when the time required and technical complexity of moving to supine could cause delays, interruption of advanced life support or risks to the healthcare team.

It is important to note that early high-quality chest compressions and immediate defibrillation are critical to patient survival and neurologic outcomes. These measures can be readily implemented with the patient in ventral decubitus. It is essential for teams caring for surgical or intensive care patients to be trained to recognize cardiac arrest in the prone position and immediately initiate reverse resuscitation.

Given the relevance of the issue, further research with an appropriate design and greater methodological rigor (adequate power and sample size) is needed to provide evidence for developing clinical protocols to guide care in situations requiring CPR in the prone position. The Critical Appraisal Checklist for Case Reports is recommended for standardizing case reports on reverse CPR.

Authors' contributions

MMD was responsible for project conception, writing, and revision of the article: PKH for the methodological framework, search strategy, narrative synthesis, and JBI Tools; and JLSA for results and discussion, translations, gray literature search, and review. SOI supervised the project, provided academic and financial support, and conducted the final review.

References

1. St-Arnaud A, Paquin MJ. Safe positioning for neurosurgical patients. AORN J. 2008;87(6):1156-68. DOI

2. Anez C, Becerra-Bolaños Á, Vives-Lopez A, Rodríguez-Pérez A. Cardiopulmonary resuscitation in the prone position in the operating room or in the Intensive Care Unit: A Systematic Review. Anesth Analg. 2021;132(2):285-92. DOI

3. Scholten EL, Beitler JR, Prisk GK, Malhotra A. Treatment of ARDS with prone positioning. Chest. 2017;151(1):215-24. DOI

4. Nanjangud P, Nileshwar A. Cardiopulmonary resuscitation in adult patients in prone position. Indian J Respir Care. 2017; 6(2):791-2. DOI

5. Chowdhury T, Petropolis A, Cappellani RB. Cardiac emergencies in neurosurgical patients. Biomed Res Int. 2015; 2015: 751320. DOI

6. Mazer SP, Weisfeldt M, Bai D, Cardinale C, Arora R, Ma C, et al. Reverse CPR: A pilot study of CPR in the prone position. Resuscitation. 2003;57(3):279-85. DOI

7. Ludwin K, Szarpak L, Ruetzler K, Smereka J, Böttiger BW, Jaguszewski M, et al. Cardiopulmonary Resuscitation in the Prone Position: A Good Option for Patients With COVID-19. Anesth Analg. 2020;131(3):e172-3. DOI

8. McCraw C, Baber C, Williamson AH, Zhang Y, Sinit RS, Alway AD et al. Prone Cardiopulmonary Resuscitation (CPR) protocol: a single-center experience at implementation and review of literature. Cureus. 2022;14(9):e29604. DOI

9. Barker J, Koeckerling D, West R. A need for prone position CPR guidance for intubated and non-intubated patients during the COVID-19 pandemic. Resuscitation.2020;151:135-6. DOI

10. Mędrzycka-Dąbrowska W, Lewandowska K, Ślęzak D, Dąbrowski S. Prone ventilation of critically ill adults with COVID-19: how to perform CPR in cardiac arrest? Crit Care. 2020;24(1):258. DOI

11. Bhatia N, Yaddanapudi S, Aditya AS. Prone cardiopulmonary resuscitation: Relevance in current times. J Anaesthesiol Clin Pharmacol. 2022;38(Suppl 1):S8-12. DOI

12. Brown J, Rogers J, Soar J. Cardiac arrest during surgery and ventilation in the prone position: a case report and systematic review. Resuscitation. 2001;50(2):233-8. DOI

13. Kwon MJ, Kim EH, Song IK, Lee JH, Kim HS, Kim JT. Optimizing prone cardiopulmonary resuscitation: identifying the vertebral level correlating with the largest left ventricle cross-sectional area via computed tomography scan. Anesth Analg. 2017;124(2):520-3. DOI

14. Moscarelli A, Iozzo P, Ippolito M, Catalisano G, Gregoretti C, Giarratano A, et al. Cardiopulmonary resuscitation in prone position: A scoping review. Am J Emerg Med. 2020;38(11):2416-24. DOI

15. Hsu CH, Considine J, Pawar RD, Cellini J, Schexnayder SM, Soar J, et al. Cardiopulmonary resuscitation and defibrillation for cardiac arrest when patients are in the prone position: A systematic review. Resusc Plus. 2021;8:100186. DOI

16. Moher D, Shamseer L, Clarke M, Ghersi D, Liberati A, Petticrew M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. Syst Rev. 2015;4(1):1. DOI

17. Munn Z, Barker TH, Moola S, Tufanaru C, Stern C, McArthur A, et al. Methodological quality of case series studies: an introduction to the JBI critical appraisal tool. JBI Evid Synth. 2020;18(10):2127-33. DOI

18. The Joanna Briggs Institute. Joanna Briggs Institute Reviewers' Manual: 2016 edition. JBI Critical Appraisal Checklist for Case Reports. Australia: The Joanna Briggs Institute; 2016.

19. Haffner E, Sostarich AM, Fösel T. Successful cardiopulmonary resuscitation in prone position. Anaesthesist. 2010;59 (12):1099-101. DOI

20. Dequin PF, Hazouard E, Legras A, Lanotte R, Perrotin D. Cardiopulmonary resuscitation in the prone position: Kouwenhoven revisited. Intensive Care Med. 1996;22(11):1272. DOI

21. Kaur J, Kane D, Shinde S, Donge V. Cardiac arrest in prone position; When do I make my patient supine? Anesth Analg. 2016;123(Suppl 3):47. Full text link

22. Chauhan V, Tiwari A, Rath GP, Banik S. Asystole during lumbar discectomy: a case report. J Clin Anesth. 2016;31:265-6. DOI

23. Dooney N. Prone CPR for transient asystole during lumbosacral spinal surgery. Anaesth Intensive Care. 2010;38 (1):212-3. Full text link

24. Kelleher A, Mackersie A. Cardiac arrest and resuscitation of a 6-month-old achondroplastic baby undergoing neurosurgery in the prone position. Anaesthesia. 1995;50(4):348-50. DOI

25. Tobias JD, Mencio GA, Atwood R, Gurwitz GS. Cardiopulmonary resuscitation in the prone position. J Pediatr Surg. 1994;29(12):1537-8. DOI

26. Al Harbi MK, Alattas KA, Alnajar M, Albuthi MF. Prone cardiopulmonary resuscitation in elderly undergoing posterior spinal fusion with laminectomy. Saudi J Anaesth. 2020;14(1): 123-6. DOI

27. Gomes DS, Bersot CDA. Cardiopulmonary resuscitation in the prone position. Open J Anesthesiol. 2012;2(5):199-201. DOI

28. Loewenthal A, De Albuquerque AM, Lehmann-Meurice C, Otteni JC. Efficacy of external cardiac massage in a patient in the prone position. Ann Fr Anesth Reanim. 1993;12(6):587-9. DOI

29. Sun WZ, Huang FY, Kung KL, Fan SZ, Chen TL. Successful cardiopulmonary resuscitation of two patients in the prone position using reversed precordial compression. Anesthesiology. 1992;77(1):202-4. DOI

30. Miranda CC, Newton MC. Successful defibrillation in the prone position. Br J Anaesth. 2001;87(6):937-8. DOI

31. Burki AM, Mahboob S, Fatima T. CPR in prone position during neurosurgery. Anaesth Pain Intensive Care. 2017;21(2):275-8. Full text link

32. Wyckoff MH, Singletary EM, Soar J, Olasveengen TM, Greif R, Liley HG, et al. 2021 International consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations. Resuscitation. 2021;169:229-311. DOI

33. Bhatnagar V, Jinjil K, Dwivedi D, Verma R, Tandon U. Cardiopulmonary resuscitation: unusual techniques for unusual situations. J Emerg Trauma Shock. 2018;11(1):31-7. DOI

34. Stewart JA. Resuscitating an idea: prone CPR. Resuscitation. 2002;54(3):231-6. DOI

35. Wei J, Tung D, Sue SH, Wu SV, Chuang YC, Chang CY. Cardiopulmonary resuscitation in prone position: a simplified method for outpatients. J Chin Med Assoc. 2006;69(5):202-6. DOI

36. Bersot CDA, Pereira JEG, Aslanidis T. Cardiopulmonary resuscitation in prone position in critically ill patients with SARS-CoV-2 infection. Greek e J Perioper Med. 2020;19(b):13-20. Full text link

37. Reid JM, Appleton PJ. A case of ventricular fibrillation in the prone position during back stabilisation surgery in a boy with Duchenne's muscular dystrophy. Anaesthesia. 1999;54(4):364-7. DOI

38. Douma MJ, MacKenzie E, Loch T, Tan MC, Anderson D, Picard C, et al. Prone cardiopulmonary resuscitation: A scoping and expanded grey literature review for the COVID-19 pandemic. Resuscitation. 2020;155:103-11. DOI

39. Link MS, Atkins DL, Passman RS, Halperin HR, Samson RA, White RD, et al. Part 6: electrical therapies: automated external defibrillators, defibrillation, cardioversion, and pacing. Circulation. 2010;122(18 Suppl 3):S706-19. DOI

40. Walsh SJ, Bedi A. Successful defibrillation in the prone position. Br J Anaesth. 2002;89(5):799. DOI

41. Theodoros A. Alternative positions for cardiopulmonary resuscitation. Op Sci J Clin Med. 2017;5(4):21-4. Full text link

42. Kang JY, Kim YJ, Shin YJ, Huh JW, Hong SB, Kim WY. Association between time to defibrillation and neurologic outcome in patients with in-hospital cardiac arrest. Am J Med Sci. 2019;358(2):143-8. DOI

43. Tofil NM, Dollar J, Zinkan L, Youngblood AQ, Peterson DT, White ML, et al. Performance of anesthesia residents during a simulated prone ventricular fibrillation arrest in an anesthetized pediatric patient. Paediatr Anaesth. 2014;24(9):940-4. DOI

44. Atkinson MC. The efficacy of cardiopulmonary resuscitation in the prone position. Crit Care Resusc. 2000;2(3):188-90. Full text link

45. Kodali BS, Urman RD. Capnography during cardiopulmonary resuscitation: Current evidence and future directions. J Emerg Trauma Shock. 2014;7(4):332-40. DOI

46. Peixoto E, Batista REA, Okuno MFP, Baptista RCN, Campanharo CRV, Lopes JL. Effectiveness of chest compressions skill training in the prone position: comparison of two methods. Eur Heart J. 2021;42(Suppl 1):ehab724.1505. DOI

47. Sinha T, Stinehart K, Moorer C, Spitzer C. Cardiopulmonary arrest and resuscitation in the prone patient: an adult simulation case for internal medicine residents. MedEdPORTAL. 2021;17:11081. DOI

48. Simón CA, López AV, Pérez AR. Reanimación cardiopulmonar básica en decúbito prono: ¿una revolución necesaria? Emergencias. 2021;33(1):65-7. Full text link