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USE OF MECHANICAL PRONATION BEDS IN ACUTE RESPIRATORY DISTRESS SYNDROME IN THE INTENSIVE CARE UNIT: AN INTEGRATIVE REVIEW OF THE LITERATURE

by

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B.S.N. University of Central Florida, 1978

A thesis submitted in partial fulfillment of the requirements
for the Honors in the Major Program in Nursing
in the College of Nursing
and in the Burnett Honors College
at the University of Central Florida
Orlando, Florida

Spring Term
2021

ABSTRACT

The increasing rate of Acute Respiratory Distress Syndrome (ARDS) reinforces the need for additional resources to assist clinical staff with an individual's care and recovery. Pronation therapy involves physically rotating an individual from the posterior position to the prone position. Pronation therapy has successfully been used for individuals diagnosed with ARDS in Intensive Care Units for decades. However, manual pronation maneuvers by staff members poses risks for those who are critically ill and risk of physical injury to caregivers. Mechanical pronation beds have revolutionized the art of pronation therapy, minimizing risks, and decreasing possibility of kinking or pulling out life supporting lines.

The methodology for this thesis included searching electronic database of research and clinical peer reviewed journals. Search terms included the keywords: Rotopron* OR "Rotoprone therapy" OR "rotation* bed" AND ARDS or "acute respiratory distress syndrome" OR "acute respiratory failure". Inclusion criteria included articles published in English between 2005–present.

A table of evidence was being developed to summarize key points from each reviewed article. The articles were individually critiqued. Synthesis of the findings were discussed to identify consistent and inconsistent findings, along with gaps in the literature. Preliminary literature analysis suggests research is needed regarding standardization of mechanical pronation procedures along with staff education.

DEDICATION

To my significant other, Andrew Tullo, if it were not for you encouraging me to be the best version of myself every day, I would not be where I am today.

To my family who motivate me to reach for the stars no matter what I do.

Thank you for your ongoing support and encouragement.

I love you

ACKNOWLEDGEMENTS

It is a genuine pleasure to express my deepest appreciation to my thesis committee chair, Dr. Angeline Bushy. Thank you for always challenging me to dive into the literature further and explore topics that interest me. Your dedication to working with me through all the changes and challenges of this project has helped me to a very great extent to accomplish this task.

I would like to thank my honors undergraduate thesis coordinator and committee member, Dr. Leslee D'Amato-Kubiet for your encouragement and ongoing support. Your knowledge and guidance throughout this project have been significant in my success not only this project but with the nursing program experience.

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INTRODUCTION

Acute Respiratory Distress Syndrome (ARDS), in the United States ranges from 64.2 to 78.9 cases/100,000 person-years (Diamond, Peniston Feliciano, et al., 2020). ARDS presents as a condition in which fluid accumulation in the lungs impairs gas exchange resulting in low blood oxygen. The mortality rate of ARDS indicates a need for immediate intervention. The mortality rate of ARDS is commensurate to the severity of the symptoms; the rate ranging from 27%, 32%, and 45% for mild, moderate, and severe disease, respectively (Diamond, Peniston Feliciano, et al., 2020). Individuals with moderate to severe ARDS are not able to be repositioned due to the unstable severity of acute pulmonary conditions effecting ventilation and perfusion gradients. A specialty bed designed to maximize positioning in people with lung dysfunction can improve oxygenation to the body.

Mechanical pronation beds have impacted the care of individuals admitted to acute care facilities with ARDS and acute lung injury. The bed can slowly tilt the patient to a prone position using a touchscreen at the foot of the bed. A tube management system is used to manage endotracheal tubes, IVs, and other equipment to prevent tangles, and kinks, or unintentional disconnections of necessary devices. The use of the mechanical pronation bed, if used correctly by properly trained individuals, can decrease mortality in people with ARDS. Automated devices relieve the stress in health care providers caused by manually turning people who are intubated.

Recent SARS-CoV-2 virus spread in the US has increased the demand for specialty care for those who are acutely affected. Equipment to assist health care providers to care for people suffering from the respiratory effects of COVID-19 includes specialty beds that can place people in the prone position with minimal risk or negative effects on the staff and the individual.

Although beds used for prone positioning are beneficial to improving outcomes in ARDS, the use of specialty beds in people with COVID-19 and associated ease of use and provider confidence with prone positioning beds in the critical care setting is poorly understood.

PROBLEM STATEMENT

Examine the use of mechanical pronation beds to assist recovery of individuals diagnosed with ARDS and use of mechanical pronation beds in ICU settings.

PURPOSE

The purpose of this integrative literature review is to examine the effectiveness of mechanical pronation beds in the ICU with individuals developing ARDS.

BACKGROUND

Pronation Defined

The prone position is a body position where the individual is lying flat on their abdomen, or anterior, side with their head to the side. Opposite of prone is supine, where the individual is lying flat on the back, or posterior, side down.

Importance

Pronation therapy is indicated when a person needs additional help with lung expansion due to decreased oxygenation. Pronation therapy is accomplished by turning an individual from their back or side, onto the abdomen. The prone position allows for increased oxygenation since the heart rests on the sternum, allowing for greater expansion in the bronchioles and upper lobes of the lungs (See Appendices: Figure 1: Supine vs. prone pressure from the heart). Pronation mechanically realigns the position of the lungs and allows for improvement in the shape of lung inflation (Mentzelopoulos, Roussos, et al., 2005). Individuals benefit from receiving 4-8-hour intervals of pronation therapy each day, or as much as they can tolerate.

ICU Complications

The Intensive Care Unit is designed for critically ill people who need specialized care. Conditions most often seen in the ICU include stroke, heart attack, multi-organ failure, trauma, sepsis, and traumatic brain injury. Other complications such as those from surgery, pneumonia, diabetes management, viruses or cancer can also lead a person to seeking care within the ICU. Due to the risk factors of decreased mobility and impaired ability to swallow, the commonality of all these conditions is that respiratory complications that can occur within each. Common respiratory complications include several types of pneumonia, aspiration pneumonia being most common, and ARDS.

ARDS Defined

ARDS is not a disease process in and of itself, instead it is a classification of an individual's respiratory condition or respiratory failure. ARDS is diagnosed secondary to a larger disease process such as a bacterial or viral infection or lung injury. Fully treating a patient with ARDS involves treating the underlying disease process. In a study of 10 cases of H5N1 infection in Vietnam, while ARDS was not explicitly mentioned, the researchers found severe respiratory failure was present in 9 of 10 cases, bilateral pulmonary infiltrates were often noted. The mortality rate was at 80%, indicating that the criteria for ARDS may have existed in many of the patients (Torsten, Santiago, et al., 2006). The study illustrates the significance of identifying patients who develop ARDS; then, rapidly treating them as critical pulmonary cases. Pulmonary infiltrates and decreased lung function commonly found in ARDS signifies a decrease in gas exchange and decreased oxygenation to the brain, kidneys, heart, and other vital organs.

Currently associated with the COVID-19 pandemic, United States Intensive Care Units are confronted with a large influx of people who require treatment for ARDS. Most often, ARDS presents with shortness of breath, cyanosis, decreased blood oxygen, crackles in the lungs, severe fatigue and altered mental state. This condition is associated with complications of pneumonia, aspiration of smoke, vomit or fluid, severe chest injury, sepsis, or coronavirus (e.g., Covid-19). A substantial number of individuals diagnosed with coronavirus develop respiratory failure and

ARDS, with 17%– 30% of patients requiring admission to an intensive care unit; and, often with a 21-day mortality of 3.6% (Torsten, Santiago, et al., 2006).

Assessment

Assessment of a person with ARDS includes auscultation of lung fields, frequent vital signs, and chest radiograph (X-ray) to visualize infiltrates or effusions, laboratory studies to monitor fluid and electrolyte imbalances due to immobility. Full body skin assessments should be conducted because individuals who are intubated in the ICU are immobile and at a higher risk for pressure ulcers. While the patient is in the prone position, additional pressure is placed on the forehead, cheeks, chin, and anterior surfaces; areas not routinely subjected to weight from bodily forces. The additional pressure can result in the development of pressure ulcers and sores even on surfaces like the forehead, cheeks and chin (Kim and Mullins, 2016).

Diagnostics

A hallmark diagnostic for ARDS on an X-ray is the presence of multi focal ground glass opacities. Diagnostics confirming the level of ARDS include PaO2 to FiO2 ratio (P/F) and Oxygenation index (OI) (Harding, et al., 2020). PaO2 is an ABG measurement of the arterial partial pressure of oxygen. These diagnostic measurements will be discussed throughout the results section and review of the literature.

FiO2 is the fraction of inspired oxygen which is determined by the level of oxygen an individual is requiring, for example, room air is 21% FiO2. The average individual has a P/F ratio of 400-500 whereas somebody with mild ARDS has a P/F ratio of 200-300, moderate ARDS is identified as a P/F of 100-200 and severe is classified as less than 100 (Harding, et al., 2020). A ratio of less than 80 indicates the need for extracorporeal membrane oxygenation (ECMO) referral to maintain adequate oxygenation (See Appendices: Figure 2: Levels of ARDS severity, mortality rate and common treatments).

OI is determined by the equation [FiO2 x mean airway pressure (MAP) x 100]/PaO2. This measurement gives a more precise idea of how much oxygen is being used within the body and can indicate the level of hypoxic respiratory failure. The levels of severity are as follows: mild is between 0 and 15, moderate is between 15 and 25, severe is between 25 and 40 and very severe is anything greater than 40 (Muniraman et al., 2019) (See Appendices: Figure 2: Levels of ARDS severity, mortality rate and common treatments).

Manual Pronation

Manual pronation is the process of turning a patient from the supine to the prone position. This process usually involves several nursing staff (3-5 people) and a respiratory therapist to manage the EndoTracheal Tube (ETT). Pillows and sheets which will end up below the person who is being pronated are placed on top of the individual, accordingly, taking care to not care the person's face. The edges of the sheets on top of the individual are rolled in a jelly-roll fashion to keep the person secure. The individual is turned onto their side and a safety check is performed to ensure there is enough slack in all lines. The airway manager or respiratory therapist checks the ETT connection and makes sure there is enough slack for the rest of the turn. Once safety checks are performed, the individual is turned the rest of the way into the prone position.

Mechanical Pronation

Mechanical pronation beds are specialty acute care beds designed to turn the individual to a prone position with slow gentle movement. People with ARDS who are unstable with aortic rupture, unstable vitals, prominent external fixation, or obesity in many instances are unable to be placed in a prone position. A mechanical kinetic bed allows for a safer and gentle repositioning' using air filled modular inflatables, allowing an increased number of patients can be treated in prone position (Baacke, Neubert, et al., 2002). The kinetic mechanical bed has built in spaces for ventilation equipment management and IV management. The fasteners securing the patient into the bed assures a safe and smooth transition from supine to prone with fewer medical staff than manual pronation positioning. The bed has safeguards in place to remind healthcare providers of essential safety measures while the individual is prepared but before pronation repositioning begins (Anthony, 2019).

Risk of Injury

Since manual pronation therapy involves caregivers physically turning an individual from supine to prone and visa-versa, physical injury of the nursing staff can incur as well as increasing the risk for patients falling or dropping to the floor. Among physical injury within the nursing field, back injury is the most common. Not only can the nurse be injured during this process, but the patient can be too. Tubing can be caught on surfaces and parts of the bed creating associated risks factors. Manual pronation has an associated risk of both unintentional extubation and dislodgement of lines. Mechanical pronation devices have tube management systems at both ends of the bed which create less movement of the tubing around the bed during pronation (Anthony, 2019) (Refer to Appendices: Figure 3: Mechanical pronation bed with tube management system at head of bed). This decreases the risks of unintentional extubation and line dislodgement.

METHODOLOGY

An electronic database for systematic reviews and clinical journals was used to review the available literature on use of mechanical pronation beds in ARDS in the Intensive Care Unit (ICU). The databases used include CINAHL Plus with Full Text with 4 results and MEDLINE with 2 results. The search was conducted using the following keywords: rotopron* OR "rotation* bed" OR "prone oscillating bed" OR "kinetic therapy bed" AND ARDS OR "acute respiratory distress syndrome”. The search was limited to articles published from 2007 to present with full text in English. Duplicate articles were removed, resulting in 6 articles for review. (See Appendices: Figure 7: Methodology)

A table of evidence summarizes articles falling withing the researcher’s inclusion and exclusion criteria. The articles collected will be individually critiqued and analyzed. Inconsistent and consistent findings and gaps within the literature will be collected and discussed (See Appendices: Table 1: Table of Evidence).

LITERATURE REVIEW OR RESULTS

Six total studies were identified meeting inclusion and exclusion criteria related to mechanical pronation therapy used for ARDS in the ICU. These studies were included in the literature review. Included in the articles were two case studies, one of which was written by a critical care nurse on the nurse's perspective on mechanical pronation therapy. Two other articles measured the oxygenation improvement of the participants by oxygenation index (OI). The final two articles measured the oxygenation improvement of their participants by PaO2/FiO2 (P/F) ratio. All six studies include quantitative data. After careful review of the literature some consistent findings, inconsistent findings and gaps in literature were found.

Consistent Findings

All six articles consistently reported that pronation therapy in the treatment of ARDS can be a beneficial plan of care for ARDS. Comparison between mechanical pronation and manual pronation was also discussed within the articles and expressed the benefits of mechanical pronation for individuals who cannot be pronated manually safely. Berry (2015) and Cater, et al. (2020) discussed the nursing risks of manual pronation and the benefits of mechanical pronation as an alternative. Through each of the studies, results trended quickly toward recovery of hypoxic respiratory failure (See Appendices: Figure 4: PaO2/FiO2 ratio changes with mechanical pronation). In the study by Bajwa, et al. (2010) (N=17) the mean PaO2 to FiO2 ratio before pronation therapy was 89 +/- 33 and quickly rose to 224 +/- 92 after prone positioning was initiated. The individuals' changes in P/F ratios in this study are illustrated in Appendices: Figure 5: "Automated prone positioning and axial rotation in critically ill, nontrauma patients with acute respiratory distress syndrome (ARDS)" results. A study of 9 individuals in Toronto, Canada showed similar improvement scores by using measurements of oxygenation index (supine: 23.6 vs. prone: 16.5, p=0.13) (Badani, et.al., 2017). Berry (2015) analyzed a case study where the individual improved from a P/F ratio of 84 to a ratio of 143 on day 3 of pronation. The individual in Berry's study was extubated 12 days following intubation, was transferred to rehabilitation for 30 days, then discharged with no outstanding mental of physical deficits. In a study by Cater et al. (2020) using mechanical pronation therapy for pediatrics individuals (N=12) with ARDS a statistically significant improvement in oxygenation after prone positioning was apparent. The median starting OI of the participants was 29.7 and decreased to under 10 by the 48-hour mark. Data were collected every 6 hours and is illustrated in Appendices: Figure 6 "The use of a kinetic therapy rotational bed in pediatric acute respiratory distress syndrome: A case series" results. All six articles expressed increased oxygenation perfusion and improved health in individuals who received mechanical pronation therapy.

Inconsistent Findings

The main inconsistency was the method of and type of the study. Berry (2015) and Lehr (2020) discussed a case study where they reflected on the care of one individual receiving mechanical pronation therapy. Cater, et al. (2020) and Badani, et al. (2017) measured results by the oxygenation index and the other two pieces of literature measured the results by means of PaO2 to FiO2 ratios. Inconsistencies also include the adjunctive therapies used with each participant such as the use of high frequency oscillator ventilation in one third of the individuals in the study by Bajwa, et al. (2010). The differences in therapies cannot be avoided in such research but are a possible contributing factor to the effectiveness of mechanical pronation and the results of the study. The study by Davis, et al. (2007) was retrospective in nature and pulled data from the trauma registry whereas other studies were limited to one facility. The use of multiple facilities in studies provided a larger population of participants.

Berry (2015) analyzed the nurse's perspective on mechanical pronation beds in the ICU setting which was different than the rest. The author identified concerns regarding staff education and comfort level when using the specialty bed. He also described two instances in his case report where re-pronation was not accomplished very proficiently. The individual being pronated was returned to the supine position emergently as ventilator alarms were sounding to assess for ETT dislodgement. The individual did not tolerate the cycle back to supine and desaturated to SaO2 of 25% before being returned to the prone position. The urgency of the environment and the lack of familiarity with the bed menu controls created increasing anxiety among the staff (Berry, 2015). Berry had also made note of the multiple safety checks on the bed, which make urgently repositioning somebody from prone to supine (or visa versa) cumbersome.

The retrospective study by Cater et al. contained cases ranging from January 1st, 2016 to December 31st, 2019 making the data points the longest of all studies evaluated within this review. The dilemma with using data from such a wide date range is that other therapies used, and the experience of the staff involved may have seen changes. The training in healthcare staff, the doctors' course of treatment and the mechanical beds used at different facilities can also impact results.

Gaps in the Literature

Berry (2015) talked about nurse education level and experience with mechanical and manual pronation beds. The same article described what went well in the study and what did not go well, which gave insight on the ease of using mechanical beds and the challenges. Only two of the six studies, Bajwa, et al. (2010) and Cater, et al. (2020), included a chart or table showing the progression/degression of ARDS in the form of OI or P/F ratios throughout the course of several days. Badani, et al. (2017) had no baseline hemodynamics listed in the article despite stating that they recorded the baseline hemodynamics. The benefits of quick and simplified pronation of patients in emergency situations was not discussed by any of the authors. Staff comfort level working with mechanical pronation equipment. There is a lack of large studies with the use of mechanical pronation devices for individuals diagnosed with ARDS secondary to COVID-19. More studies involving pediatric individuals are needed as well as studies related to nutrition management related to ARDS.

DISCUSSION

The studies examined in this literature review can offer insight into the use of mechanical pronation beds to treat ARDS in the ICU. Research findings suggest mechanical beds provide a safer means of pronation therapy for both the patient and the healthcare workers. Pronation therapy is indisputably an effective method of therapy for individuals with ARDS. Mechanical beds make pronation more readily accessible to transition individuals with severe ARDS from supine to prone position. Healthcare professionals' safety when using mechanical pronation devices is not consistent among ICUs nor is the staff training to operate the machinery. One of the articles by Berry (2015) made it clear that for staff who are unfamiliar with the equipment, it is difficult to quickly turn a patient when not tolerating either being prone or supine. The machine has safety measure which make the transition longer than what is ideal, so it is important to anticipate the patient's needs prior to needing to emergently act.

Beginning Pronation Therapy

The transition of care for an individual with ARDS who is progressively declining is crucial for saving the integrity of the lungs and other organs. A study by Elharrar, et al. (2020) collected data on the effects of awake pronation during the peak of the 2020 COVID-19 pandemic. During this study 24 individuals who had ARDS secondary to COVID-19 laid in the prone position for as long as they could tolerate to avoid potential progression of ARDS leading to intubation. This study found that six of the 24 patients responded to pronation therapy. Only three of these six were persistent responders after resupination. The oxygenation was measured by PaO2 levels and due to the small sample size and the small group of responders, no significant beneficial data came from the study. Further studies in awake pronation are necessary to determine if there is a statistical significance in awake pronation vs. pronation after intubation.

Duration of Pronation

Among the six studies I analyzed in this literature review, duration of pronation ranged from 3 hours and 15-minute cycles (Davis, et al., 2007) to 12-hour cycles (Berry, 2015). The ideal therapeutic length of pronation therapy is still undetermined. Many institutions suggest pronation as long as the patient can tolerate followed by a shorter period of supination. Others have a set rotation they chose to use for effective therapy such as prone positioning for 3 hours and 15-minutes followed by 45-minutes in the supine position to allow for daily care. The results of the studies in this literature review showed no significant difference between studies which chose to pronate the individual for 3 hour and 15- minute period compared to those who chose to pronate for 12-hours. Further research involving length of pronation would provide an answer to this conundrum of deciding how long is long enough to see results.

Barriers to Access

Among mechanical pronation therapy there are several barriers to accessing a device to pronate individuals who would not otherwise tolerate manual pronation. One of the main barriers is the cost of the device itself. A mechanical pronation specialty bed costs the hospital around $1000 per day of use. Some community hospitals may find this bed to be cost prohibitive due to the lower available funding for such an expensive item. Training of healthcare staff also plays into the cost of implementing a new device, especially a device where thorough training it crucial for its success and the individual's safety and outcome. Although most major areas have adequate access to acquiring a specialty bed, availability of such devices in rural areas may also be a barrier for implementation and use.

IMPLICATIONS FOR NURSING

Implications for nursing practice, education and research will be discussed, along with study limitations.

Education

Nurses need to stay up to date with the newest research to practice effectively and ensure the best outcomes for their client. Continuous education for nursing staff working within a facility with access to mechanical pronation beds is beneficial due to the complex nature of the machinery. Background knowledge of manual pronation may also be useful prior to training an individual with mechanical pronation beds. The emergency functions and the time it takes to complete safety checks should be known to all individuals involved in the patient's care.

Practice

The findings synthesized in this review of the literature can have various implications to the practice of nursing. As pronation therapy becomes more commonly used due to the COVID-19 pandemic, education and practice using pronation devices safely and efficiently should be implemented with all ICU staff. The outcome of the individuals receiving pronation therapy is the measured factor regarding nursing practice with pronation therapy. Were they injured during pronation? Did their outcome improve due to pronation? As a nurse, you must know the contraindications to prone positioning such as facial or pelvic fractures, spinal instability, pregnancy, open chest or unstable chest wall or presence of chest tubes and uncontrolled intracranial pressure (Malhotra, 2020).

Policy

Hospital policies and guidelines require nurses to receive general training on the operations of the mechanical pronation bed at their facility. The training must be completed prior to operating the bed with a patient. Specific contraindication, indications for pronation and indications for returning an individual to either the supine or prone position are set by the hospital or the physician.

Recommendations for Research

All six articles recommended future research into the effectiveness of mechanical pronation beds to treat ARDS. Larger studies would be warranted due to the small sample sizes among the articles I analyzed. The largest study size consisted of 44 patients, but only 13 received pronation therapy. The impact on mortality was discussed in most of the studies and should also be researched further. Another aspect unknown to researchers today is the effectiveness of early pronation and the ideal therapeutic duration of pronation. Accessibility as a limiting factor must also be discussed due to it's potential commonality. Furthermore, research of mechanical pronation therapy during ECMO should be further employed.

Limitations

The studies included in this literature review had several limitations. Using general keyword searches, such as pronation, prone therapy and ARDS provided numerous articles. When using further search criteria to narrow the studies to those which contained mechanical pronation equipment, the number of articles greatly diminished. Filtering by recent publication dates, the language to include only the English language and filtering out all material which are not full text articles left me with six articles. The articles included in this review were analyzed after resulting from the keyword search to determine whether they met the inclusion criteria. All six articles met the inclusion criteria, however, the different measurements used within the articles proved difficult to compare. One article did not provide baseline date to compare with the results stated within the article and with other similar research.

Small sample sizes were consistent with each article, providing varied data. A larger population provides stronger, more accurate data and gives a basis to be able to identify any outliers in the study. Larger population sizes have been used in studies on the effectiveness of manual pronation therapy and should be replicated with mechanical pronation beds to determine effectiveness of using a specialty bed compared to manual pronation.

CONCLUSION

Emergent pronation has been used effectively to rescue individuals whose airway is not being effectively maintained otherwise. This integrative review of the literature focused on using mechanical pronation therapy using mechanical pronation beds with individuals diagnosed with ARDS. The mortality rate of ARDS is high, however pronation therapy can improve oxygenation related to hypoxic injury. Combined with treatment to target the underlying cause, pronation therapy can be beneficial in maintaining adequate perfusion of the lungs and other organs.

APPENDIX A: TABLE 1: TABLE OF EVIDENCE

TABLE OF EVIDENCE

Reference Article	Population	Study Design	Intervention Details	Outcome Measures	Results/Key Findings	Relevance/ Implications
Changes in Hemodynamic and Gas Exchange Parameters With the Use of the Rotoprone Bed in Patients With Severe ARDS (Badani, et al., 2017)	9	Seminal trial with retrospective clinical analysis. A paired 2-tailed t-test was used for statistical analysis.	Baseline hemodynamic data was collected 4 hours prior to pronation. Nine individuals in the ICU diagnosed with ARDS received pronation therapy using the Rotoprone bed.	Oxygenation index was measured before pronation and at the end of the study. Dead space fraction was also measured throughout this trial.	The study indicated significant improvement in oxygenation using oxygenation index (supine:23.6 vs. prone: 16.5, p=0.13). The study indicated no significant change in dead space fraction (supine: 0.33 vs. prone: 0.31).	Individuals who received pronation therapy using the Rotoprone bed had significantly better oxygenation index results compared to those who laid supine in this trial.
Automated prone positioning and axial rotation in critically ill, nontrauma patients with acute respiratory distress syndrome (ARDS) (Bajwa, et al., 2010)	17	Retrospective clinical analysis	Individuals were placed in the prone position using an automated bed with axial rotation. Participants stayed in the	P/F ratio was recorded prior to starting pronation. PaCO2 based on type of ARDS (pulmonary or extrapulmonary) was also recorded.	16/17 individuals had an improvement in P/F ratio after mechanical pronation therapy The mean P/F ratio prior to pronation was 89	The mean P/F ratio increased by over 250%. The starting P/F ratio was low indicating most participants had very severe cases of ARDS.

Reference Article	Population	Study Design	Intervention Details	Outcome Measures	Results/Key Findings	Relevance/ Implications
			prone position for at least 4-5 hours with 1-2 hour periods where they were turned back to the supine position.		+/- 33 and improved to 224 +/- 92 (P<0.001) 11 (65%) individuals died in the ICU.	The improvement of the P/F ratio provides evidence that mechanical pronation provided beneficial increased oxygenation in 16 of the 17 participants. The researchers found the device easy and versatile to use once trained.
Pronation Therapy Case Report Nurse's Perspective and Lessons Learned (Berry, 2015)	1	Case Study (Nurse's perspective)	The individual was mechanically pronated for 2 hours before being placed back in a supine position. Supine positioning was not tolerated and they were	P/F ratio was calculated upon admission. FiO2 was weaned twice. Once after the second round of prone positioning and again at the end of pronation therapy.	P/F ratio began at 84 and quickly increased to 143 by the end of pronation therapy. FiO2 weaning was also an indicator for recovery in this case. FiO2 began at 1.0 and was weaned	The longer periods of prone positioning were beneficial for this individual. The author recommended a "prone kit" so that equipment for mechanical pronation is easy

Reference Article	Population	Study Design	Intervention Details	Outcome Measures	Results/Key Findings	Relevance/ Implications
			returned to the prone position. 7.5 hours later the individual was turned back to the supine position and, again, did not tolerate it. In total, this individual spent 36 hours prone and 9 hours supine.		down to 0.6.	to access and all in the same place. Confidence level of health care providers working with the new equipment was said to be low and further education would be ideal.
The Use of a Kinetic Therapy Rotational Bed in Pediatric Acute Respiratory Distress Syndrome: A Case Series (Cater, et al., 2020)	12	Retrospective Case Series	Individuals diagnosed with ARDS were placed cycled through the prone position for 16 hours (or as long as tolerated) and placed supine for 8 hours. Two of the participants had moderate ARDS.	Oxygen Index (OI) was measured and recorded as supporting data	This study showed a statistically significant improvement in oxygenation of individuals after prone positioning from a median OI of 29.7 to under 10. There was 1 mortality among the 12 participants.	Considering the decrease of OI in these participants, the mechanical pronation was therapeutic in helping increase oxygenation. Nursing care of arterial lines to ensure no accidental removal or malfunction do

Reference Article	Population	Study Design	Intervention Details	Outcome Measures	Results/Key Findings	Relevance/ Implications
			10 of the participants had severe ARDS. Participants were on the rotational bed for a median of 65 1/2 hours.		Three of the 12 arterial lines had malfunctioned due to unknown causes. Tracheostomy tubes were required for three of the 12 individuals for chronic respiratory support upon discharge home.	not occur is important.
Prone Ventilation in Trauma or Surgical Patients with Acute Lung Injury and Adult Respiratory Distress Syndrome: is it Beneficial? (Davis et al., 2007)	61	Retrospective Review	44 individuals were placed in the supine position. 13 individuals were placed in the prone position. 4 of the individuals who were originally placed supine were changed to prone positioning.	PaO2/FiO2 (P/F) ratio and oxygen requirements were both measured prior to positional therapy.	The prone group's average P/F ratio began at 153 and reached 243 by day 5. The supine group's average P/F ratio began at 149 and reached 200 by day 5. Between the 4 individuals who	Significantly less mortality in the prone position group (8%) compared to the supine position group (41%). Individuals in the prone group ended up having better P/F ratios by day 5 compared to the supine group (243

Reference Article	Population	Study Design	Intervention Details	Outcome Measures	Results/Key Findings	Relevance/ Implications
			Individuals who received pronation therapy were cycled through being placed prone for 3 hours and 15 minutes, then places supine for 45 minutes. Average amount of prone positioning per day was between 4 and 8 hours.		began in the supine group and ended up being treated in the prone group the P/F ratio began at165 and reached 238 by day 5.	compared to 200). Average time on the ventilator was substantially less in the prone group (13.6 day vs. 24.2 days). Average hospital stay duration indicated a shorter recovery time in the prone group (22 days vs. 40 days).
Successful use of an automated proning system to achieve prone positioning in a patient with severe ARDS requiring veno-venous ECMO (Lehr, 2020)	1	Case Report	The individual in this case report was a 48-year-old female with a BMI of 51, symptoms of ARDS and an order for ECMO. Mechanical pronation using the Rotoprone Therapy System	P/F ratio was identified upon admission and prior to pronation therapy.	On arrival, the individual's P/F ratio was 64. Upon pronation therapy, her P/F ratio increased to 250. After pronation therapy for 7 days, on day 8, she was returned to the	The combination of ECMO and mechanical pronation in this case report

Reference Article	Population	Study Design	Intervention Details	Outcome Measures	Results/Key Findings	Relevance/ Implications
			was initiated while on ECMO. The prone position was maintained for 12 hours each day through a 4 series cycle.		supine position for the remainder of her ICU stay. ECMO cannulas were removed on day 13. The individual was discharged and transferred to rehabilitation on day 41.	

APPENDIX B: FIGURES

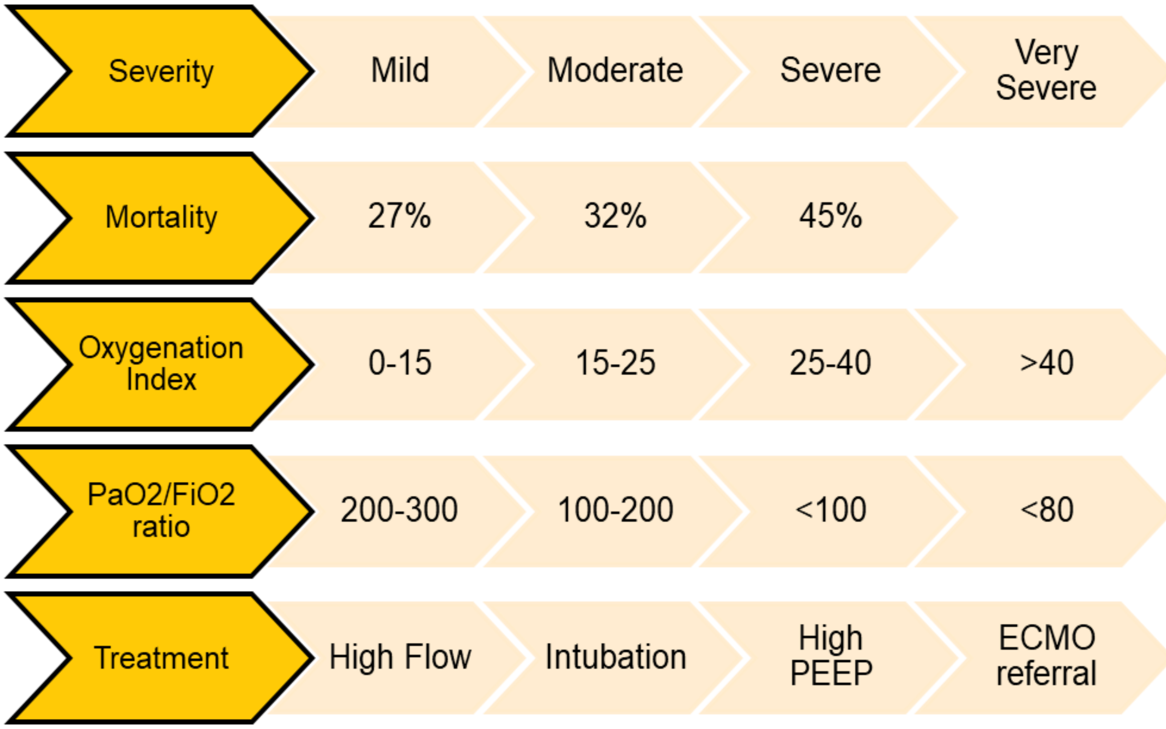
Figure 1

Supine vs. prone pressure from the heart

Note. From "Efficacy of prone position in acute respiratory distress syndrome patients: A pathophysiology-based review," by Koulouras, V., Papathanakos, G., Papathanasiou, A., & Nakos, G. (2016). World Journal of Critical Care Medicine, 5(2), 121–136. (https://doi.org/10.5492/wjccm.v5.i2.121). Copyright 2016 by Baishideng Publishing Group Inc.

Figure 2

Levels of ARDS severity, mortality rate and common treatments



Note. Adapted from:
Harding, M., Kwong, J., Roberts, D., Hagler, D., & Reinisch, C. (2020). *Lewis's medical-surgical nursing: assessment and management of clinical problems*. Elsevier.
and
Muniraman, H. K., Song, A. Y., Ramanathan, R., Fletcher, K. L., Kibe, R., Ding, L., Biniwale, M. (2019). Evaluation of oxygen saturation index compared with oxygenation index in neonates with hypoxemic respiratory failure. *JAMA Network Open*, *2*(3). (https://doi.org/10.1001/jamanetworkopen.2019.1179)

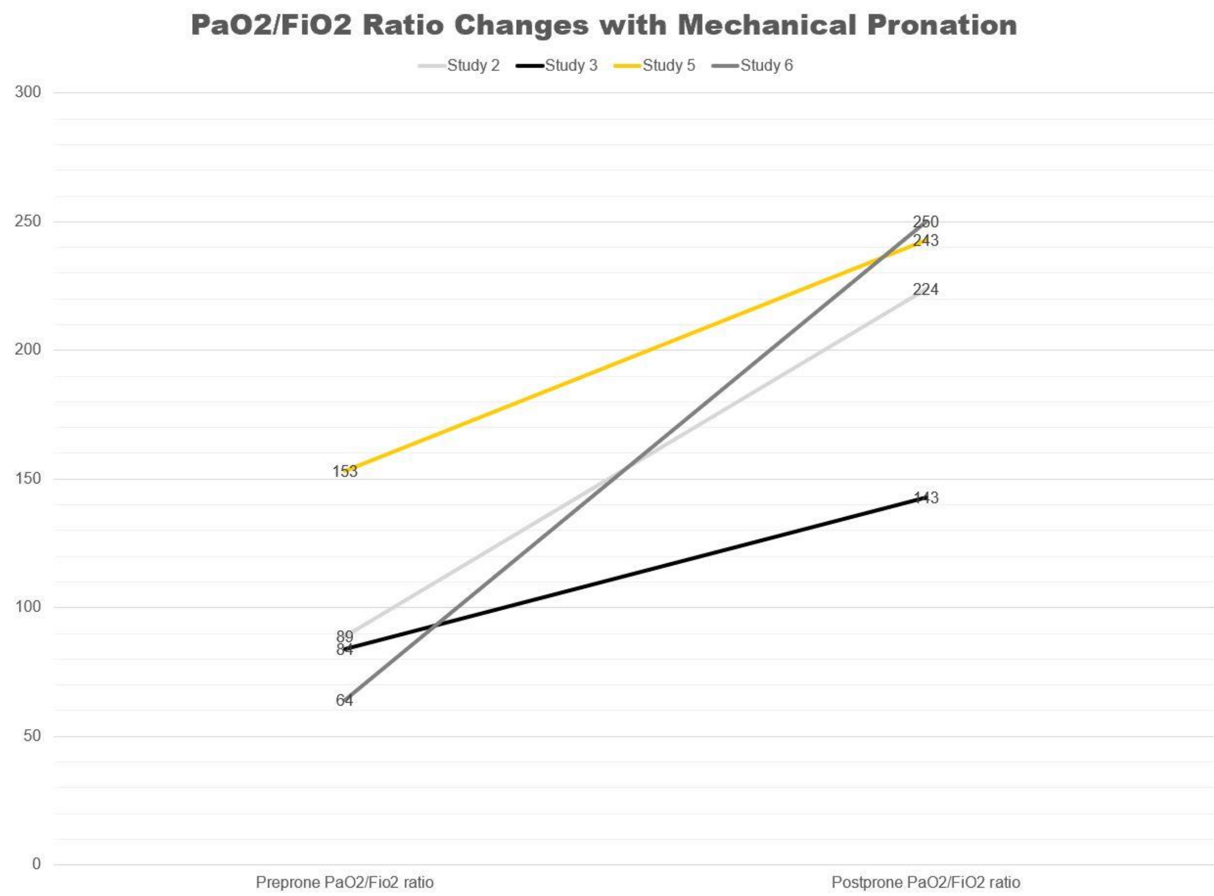
Figure 3

Mechanical pronation bed with tube management system at head of bed

Note. ARDS Foundation. (2020, November 18). A story of survival: How prone positioning saved crystal's life. ARDS Global. (https://ardsglobal.org/a-story-of-survival-how-prone-positioning-saved-crystals-life/). Copyright 2020 by ARDS Global

Figure 4

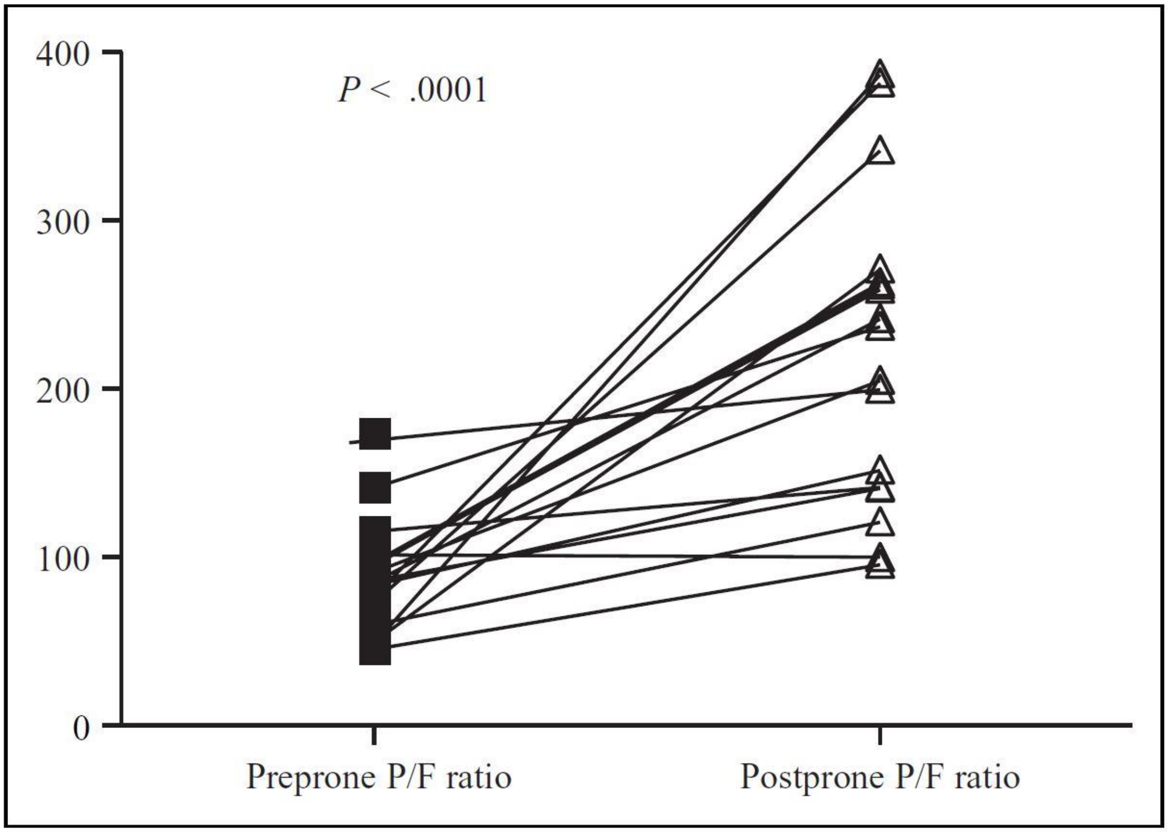
PaO2/FiO2 ratio changes with mechanical pronation



Note. Derived from:
"Automated prone positioning and axial rotation in critically ill, nontrauma patients with acute respiratory distress syndrome (ARDS)," by Bajwa, A. A., Arasi, L., Canabal, J. M., & Kramer, D. J. (2010). *Journal of Intensive Care Medicine*, *25*(2), 121–125. (https://doi.org/10.1177/0885066609356050)
"Pronation therapy case report: Nurse's perspective and lessons learned," by Berry, K., BSN, RN. (2015). *Dimensions of Critical Care Nursing*, *34*, 321-328. (https://doi.org/10.1097/DCC.0000000000000142)
"Prone ventilation in trauma or surgical patients with acute lung injury and adult respiratory distress syndrome: Is it beneficial?" by Davis, J. W., Lemaster, D.M., Moore, E. C., Eghbalieh, B., Bilello, J. F., Townsend, R. N., Parks, S. N., & Veneman, W. L. (2007). *Journal of Trauma*, *62*(5), 1201–1206. (https://doi.org/10.1097/ta.0b013e31804d490b)
"Successful use of an automated proning system to achieve prone positioning in a patient with severe ARDS requiring veno-venous ECMO," by Lehr, A. L., Smith, D. E., Toy, B., Goldenberg, R., & Brosnahan, S. B. (2020). *Respiratory Medicine Case Reports*, *31*, 101315. (https://doi.org/10.1016/j.rmcr.2020.101315)

Figure 5

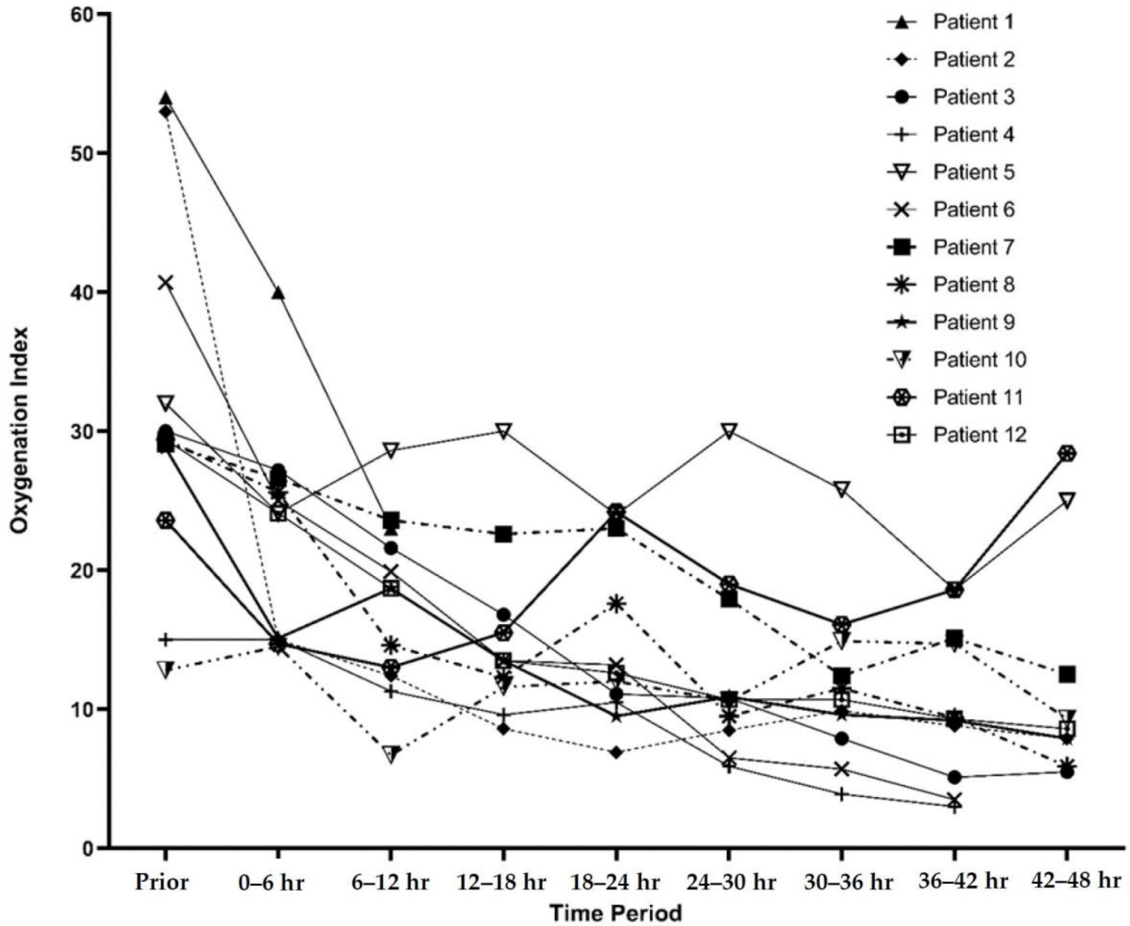
"Automated prone positioning and axial rotation in critically ill, nontrauma patients with acute respiratory distress syndrome (ARDS)" results



Note. From "Automated prone positioning and axial rotation in critically ill, nontrauma patients with acute respiratory distress syndrome (ARDS)," by Bajwa, A. A., Arasi, L., Canabal, J. M., & Kramer, D. J. (2010). *Journal of Intensive Care Medicine, 25*(2), 121–125. (https://doi.org/10.1177/0885066609356050.) Copyright 2021 by SAGE Publications

Figure 6

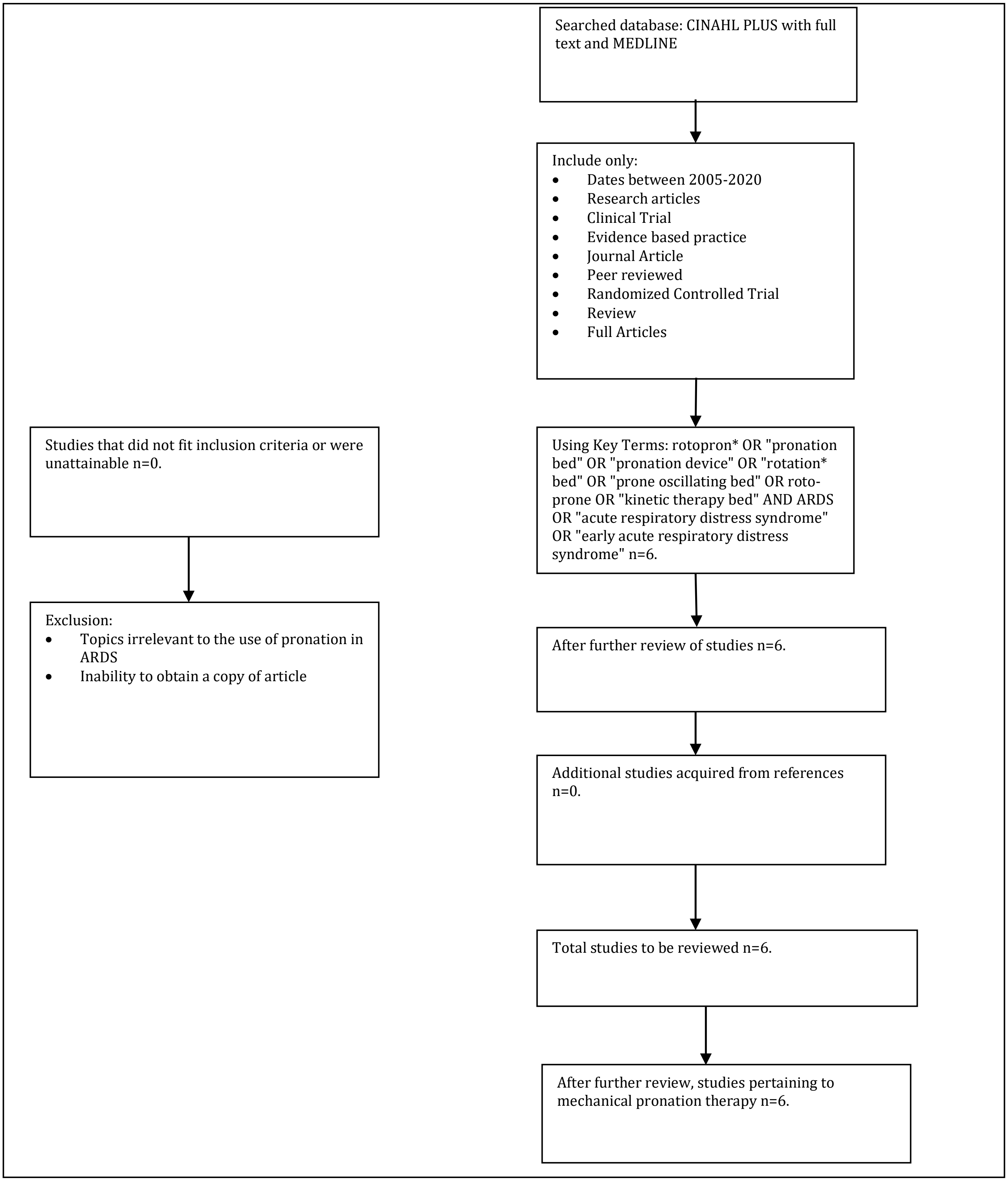
"The use of a kinetic therapy rotational bed in pediatric acute respiratory distress syndrome: A case series" results



"The use of a kinetic therapy rotational bed in pediatric acute respiratory distress syndrome: A case series," by Cater, D. T., Ealy, A. R., Kramer, E., Abu-Sultaneh, S., & Rowan, C. M. (2020). *Children*, *7*(12), 1–9. (https://doi.org/10.3390/children7120303)

Figure 7

Methodology



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