Accepted Manuscript

Treatment of Acute Respiratory Distress Syndrome with Prone Positioning

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PII: S0012-3692(16)52643-9
DOI: 10.1016/j.chest.2016.06.032
Reference: CHEST 545

To appear in: CHEST

Received Date: 1 March 2016
Revised Date: 11 June 2016
Accepted Date: 29 June 2016

Please cite this article as: Scholten EL, Beitler JR, Prisk GK, Malhotra A, Treatment of Acute Respiratory Distress Syndrome with Prone Positioning, CHEST (2016), doi: 10.1016/j.chest.2016.06.032.

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Title: Treatment of Acute Respiratory Distress Syndrome with Prone Positioning

Short Running Title: Prone Positioning in ARDS

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Conflicts of interest: None of the authors listed above have any relevant conflicts of interests (as defined below) to disclose.

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Funding Information: Not applicable
Notation of prior abstract publication/presentation: Not applicable
**Abbreviation list (in order of appearance):**

1. ARDS - acute respiratory distress syndrome
2. PRSOEVA trial - Proning Severe ARDS Patients trial
3. PEEP - positive end-expiratory pressure
4. PaO$_2$/FiO$_2$ - ratio of arterial oxygen tension to the fraction of inspired oxygen
5. CT – computed tomographic
6. VILI - ventilator-induced lung injury
7. $V_t$ – tidal volume
8. RR – risk ratio
9. AECC – American-European Consensus Conference (definition of ARDS)
**Abstract**

Prone positioning was first proposed in the 1970s as a method to improve gas exchange in the acute respiratory distress syndrome (ARDS). Subsequent observations of dramatic improvement in oxygenation with simple patient rotation motivated the next several decades of research. This work elucidated the physiology mechanisms underlying changes in gas exchange and respiratory mechanics with prone ventilation. However, translating physiological improvements into a clinical benefit has proven challenging; several contemporary trials showed no major clinical benefits with proning. By optimizing patient selection and treatment protocols, the most recent Proning Severe ARDS Patients (PROSEVA) trial demonstrated a significant mortality benefit with prone ventilation. This trial, and subsequent meta-analyses, support the role of prone positioning as an effective therapy to reduce mortality in severe ARDS, particularly when applied early with other lung-protective strategies. This review discusses the physiological principles, clinical evidence, and practical application of prone ventilation in ARDS.

Approximately 170,000 cases of ARDS occur annually in the United States, with mortality rates of 25-40%.¹ Treating ARDS consumes 5% of all hospital ventilator-days, which incurs great costs (an average of $115,000 per hospital stay).² ³ As early as the 1960s, when the knowledge-base for ARDS consisted of descriptive case-series, the need for effective therapies was readily apparent.⁴ Early investigators noted the reduced pulmonary compliance and increased atelectasis that characterize the disease, and suggested applying positive end-expiratory pressure (PEEP) to improve oxygenation.⁴ To reduce further atelectasis in injured lungs, Bryan proposed prone positioning, theorizing that proning would reduce pleural pressure gradients and restore aeration to dorsal lung segments.⁵ Clinical case series supported this concept, documenting significant improvement in oxygenation with proning.⁶ Subsequent studies
suggested that prone positioning improves oxygenation in most patients (70-80%) with ARDS, increasing the average ratio of arterial oxygen tension to the fraction of inspired oxygen (\(\text{PaO}_2/\text{FiO}_2\)) by +35 mmHg.\(^7\)–\(^{14}\) Proning was thus established as a rescue strategy for severe hypoxemia, and early research focused on establishing the mechanism of improved gas exchange.\(^{12,15,16}\)

**Prone Positioning and Gas Exchange**

While supine, the weight of the ventral lungs, heart, and abdominal viscera increase dorsal pleural pressure. This compression reduces transpulmonary pressure (airway opening pressure – pleural pressure) in the dorsal lung regions.\(^{17,18}\) Increased mass of the edematous ARDS lung further increases the ventral-dorsal pleural pressure gradient and reduces regional ventilation of dependent dorsal regions.\(^{19,20}\) The ventral heart is estimated to contribute an additional ~3-5 cm H\(_2\)O of pressure to the underlying lung tissue, with experimental studies showing improved ventilation of these infra-cardiac lung regions when proned.\(^{18,21}\) In addition to the weight of the heart, intra-abdominal pressure is preferentially transmitted through the (often paralyzed and relaxed) diaphragm, further compressing dorsal regions. While the above factors tend to collapse dependent dorsal regions, the gravitational gradient in vascular pressures preferentially perfuses these regions, yielding a region of low ventilation and high perfusion, manifesting clinically as hypoxemia.

Proning reduces the pleural pressure gradient from non-dependent to dependent regions in part via gravitational effects and conformational shape-matching of the lung to the chest cavity. As a result, lung aeration and strain distribution are more homogeneous.\(^{15,22–24}\) Figure 1 illustrates the gravitational and geometric factors contributing to more uniform pulmonary aeration when proned.\(^{25,26}\) When supine, both gravity and the chest wall compress the dependent lung segments, causing major inequalities in
aeration along a ventral/dorsal axis (see Fig 1. column III). In contrast, when proned, the geometry favors a more equitable aeration distribution.

Multiple physiological studies support the theory that proning promotes more homogeneous aeration of the ARDS lung. Geometric modeling of computed tomographic (CT) data demonstrated the asymmetry of lung shape leads to a greater gravitationally-induced pleural pressure gradient in the supine posture compared to prone positioning. Additional CT, nuclear, and inert-gas experiments have measured aeration and ventilation, and demonstrated improved homogeneity when proned. Finally, while the model in Figure 1 neglects abdominal factors, animal models of both volume overload and intra-abdominal hypertension have shown more evenly distributed trans-diaphragmatic forces and improved parenchymal homogeneity in the prone position.

Unlike its effects on dorsal lung aeration, proning does not have a major impact on regional distribution of pulmonary blood flow. In both the supine and prone positions, pulmonary blood flow is directed dorsally in normal and injured lungs (Figure 2). Thus, regional perfusion distribution is dictated in large part by non-gravitational factors (lung/heart geometry, airspace compression of vessels, reduction in the ventral region’s hypoxic vasoconstriction, etc.). With perfusion patterns relatively constant, and a marked improvement in ventilatory homogeneity upon proning, the shunt fraction would be expected to fall substantially upon proning. Many animal and human studies confirm this hypothesis; on average, proning injured lungs reduces the relative shunt fraction by ~30%. Thus, in most patients, decreased shunting when proned leads to clinically significant improvements in oxygenation.

**Lung Protection**
Adequate oxygenation is necessary for organ function, but many interventions in acute lung injury that raise arterial oxygen tension do not confer a survival advantage (e.g. high tidal volume ventilation, oxygen toxicity).\textsuperscript{36,37} Proning generally improves oxygenation, but its ability to attenuate mechanical lung injury may be the more important mechanism of clinical benefit. Indeed, while all major clinical trials of prone positioning in ARDS significantly improved oxygenation, the only trial to reduce mortality significantly was also the only trial to reduce ventilator-days.\textsuperscript{9} Furthermore, in this trial (PROSEVA), changes in gas-exchange did not explain the observed mortality benefit.\textsuperscript{38}

How could proning reduce VILI, ventilator-days, and death? Comparing the supine and prone aeration (gas:tissue ratio) curves in Figure 1 column III suggests a mechanism. First, note how proning improves dependent aeration, effectively recruiting parenchyma (white arrows). Second, the non-dependent lung regions show dramatic reduction in hyperinflation with proning (black arrows). The net effect is more homogenous lung aeration, which reduces regional shear strain, leading to less VILI.\textsuperscript{15,23,24}

Proning and high PEEP ventilation may have complementary benefits. In ARDS, increased PEEP is known to prevent alveolar derecruitment, but may deleteriously promote over-distension of previously well-ventilated alveoli.\textsuperscript{39,40} Proning may help mitigate these deleterious effects of PEEP.\textsuperscript{41} Adding prone positioning to high-PEEP ventilation: 1) further increases lung aeration while 2) simultaneously reducing regional hyperinflation and 3) decreasing small airway opening/closing events during the respiratory cycle.\textsuperscript{42} These observations suggest proning may decrease barotrauma and atelectrauma, and thereby protect against ventilator-induced lung injury (VILI).\textsuperscript{29} In support of this theory, rat, dog, and sheep models have shown improved histological VILI scores when comparing prone to supine ventilation.\textsuperscript{43–47} More recently, in experimental injured rodents, proning reduced expression of cellular signaling pathways known to correlate with the development of VILI, especially in ventral regions that are at risk
of hyperinflation while supine. Intriguingly, pharmacologically inhibiting these same pathways protects experimental animals from lung injury, thus identifying molecular mechanisms underlying VILI. In humans, histological data are unavailable, but both serum and bronchoalveolar lavage inflammatory markers are reduced by prone positioning, which may reflect less VILI.

Although studies of respiratory mechanics after proning have reached variable conclusions, their results suggest the importance of recruiting s lung to achieve clinical benefit. When proned, chest wall compliance typically falls initially, then increases gradually over time. Those proned patients who achieve greater drops in chest wall compliance have more pronounced improvement in oxygenation (r=0.62), potentially due to improved dorsal recruitment. Furthermore, recruitment maneuvers (sustained high pressure inflations) were found to be highly effective in improving oxygenation when applied to proned patients.

Finally, independent of mechanical effects, infectious complications may also be reduced by proning. In pigs, a tracheal position relatively anterior to the lung parenchyma markedly decreased VAP incidence. While prone, gravity can assist secretion drainage along the general dorsal-lungs to ventral-trachea drainage vector. This enhanced drainage may explain observations that proning 1) improves secretion clearance 2) causes opacities to migrate ventrally on imaging while improving overall aeration 3) may decrease rates of ventilator-associated pneumonia.

Extra-Pulmonary Organ Systems

In addition to its lung-protective effects, proning impacts cardiac and abdominal pressures. In general, total cardiac output is unchanged when proning ARDS patients. However, while prone, the right atrium moves ventrally, such that venous return now is aided by gravity. Thus, preload responsive patients may
augment their cardiac output with proning. Additionally, right ventricular afterload typically falls, likely due to relief of hypoxic pulmonary vasoconstriction. This effect may be most clinically relevant in severe ARDS populations, as proning reduces the RV dilation and septal dysfunction that accompanies this disease. To measure these hemodynamic changes accurately, pressure transducers need to be carefully re-leveled to reflect the right atrium’s more ventral position while prone.

Proning also affects the chest-abdominal interactions. Obesity worsens dependent dorsal atelectasis, and prone ventilation improves oxygenation during routine surgery in obese patient and obese animal models without lung injury. However, in obese humans with ARDS, proning may worsen intra-abdominal hypertension, and lead to subsequent renal and hepatic dysfunction. Thus, it is reasonable to monitor intra-abdominal pressure while proning, and consider using an air-mattress or a suspended abdomen if abdominal pressures become excessive. Finally, studies have reported increased vomiting and decreased tolerance of high-volume enteral feeds while prone. To facilitate gastric emptying, some centers closely monitor gastric residuals, adjust pharmacotherapy, and position the bed in reverse Trendelenburg while prone.

Clinical trials

While the physiological effects of prone positioning are well described, clinical trials have yielded mixed results regarding the clinical benefit. Table 1 reviews five major randomized trials of prone ventilation in adults. Note the significant mortality benefit of proning in the PROSEVA trial, with no mortality benefit in the previous trials. What accounts for these discrepant findings?

The 2013 PROSEVA trial design benefited from recognition of the limitations of the first studies, including: a limited sample size, significant treatment cross-over, unstandardized ventilator
management with high-tidal volumes, the inclusion of patients without or with only mild ARDS, a small “dose” of time spent proned, arbitrary criteria for cessation of proning, and enrollment of patients late in their disease course. Trial designs evolved further over time. Mancebo’s 2006 trial had potential advantages over previously published trials: patients had more severe lung injury, were enrolled early in their course, and received higher doses of proning compared to earlier trials.\textsuperscript{7} Unfortunately, slow enrollment led to early study termination with just 142 patients. The authors reported a non-significant trend towards improved survival with proning, and post-hoc analysis demonstrated considerable benefit for severely ill patients. Next, in 2009, Taccone et al. used a similar design to Mancebo, and reached enrollment goals.\textsuperscript{11} Again, no significant decrease in mortality was noted with proning, although this trial too likely was underpowered and showed a trend towards improved survival with proning.

Many possible explanations can account for the discrepant findings of Taccone and PROSEVA. As Table 1 illustrates, compared to Taccone, PROSEVA had increased power, enrolled a highly selected population of severe ARDS, had less supine/prone cross-over, more neuromuscular blockade, and, perhaps most importantly, a lower administered tidal volume ($V_t$). One recent meta-analysis divided proning trials into those with high (>8 mL/Kg) or low (<8 mL/Kg) tidal volume ventilation. Only in the low tidal volume ventilation cohort was proning shown to decrease mortality (risk ratio of death at 60-days, proning with low $V_t$, RR 0.66, 95% CI 0.50-0.86; $p = 0.002$; proning with high $V_t$, RR 1.00, 95% CI 0.88-1.13; $p = 0.949$).\textsuperscript{65} These findings suggest the benefits of proning are realized only in the background of protective low tidal volume ventilation.

Taccone did describe more frequent complications with proning compared to PROSEVA (which reported no significant increase in any complications). For Taccone, loss of vascular access, airway obstruction, extubation, and increased vasopressor requirement all occurred more frequently in the prone arm.\textsuperscript{11} All
centers in the PROSEVA trial had used prone positioning in daily practice for more than five years, minimizing risk associated with an implementation learning curve. The longer duration and more frequent proning maneuvers performed in Taccone’s trial may have increased risks. Alternatively, inter-trial adjudication of subjective events may have differed. These complications, while important to note, do not seem harmful enough to account for the magnitude of the mortality difference between these two trials.

Of note, the supine (control) group in PROSEVA may have had slightly higher acuity of illness than the prone group. Relative to the prone group, the supine group had higher mean sequential organ failure assessment (SOFA) scores and more frequent vasopressor use. However, this high-acuity supine group still had excellent clinical outcomes, and their mortality was identical to the supine group in Taccone’s “healthier” population. This finding argues against baseline differences in study arms as a mechanism to explain the different trial conclusions. The excellent control group survival in PROSEVA was likely due to strict adherence to evidence-based therapy for ARDS, namely an achieved tidal volume of 6.1 cc/kg and liberal use of neuromuscular blockers (87% of all patients).\textsuperscript{9,11}

In summary, clinical trial evidence suggests that to achieve improved survival with proning, one needs: patients with severe ARDS treated early in their course; a long duration of prone positioning (>16 hours/day); physiologically driven criteria for cessation of daily proning (e.g. minimal ventilator requirements); the concurrent use of lung-protective therapies for ARDS; and experienced staff able to minimize procedural risks. The interested readers may review other trials of prone positioning.\textsuperscript{49,50,66–71} These studies were not discussed in this review as they were smaller (5 studies had <40 patients), in unique populations (pediatrics, trauma), and had various design issues that limit their generalizability.
Practical Considerations

With this evidence base, prone positioning moves from a salvage therapy for refractory hypoxemia to an up-front lung-protective strategy intended to improve survival in severe ARDS. Indeed, proning has never been proven to afford a survival benefit when employed as a late rescue therapy for refractory hypoxemia. However, a contemporary prospective observational study (the 2016 LUNG-SAFE study) found that only 16.3% of severe ARDS patients were treated with prone ventilation. Among other factors, perceived logistical difficulties may contribute to poor implementation; interested clinicians are referred to an excellent pragmatic overview (including a pre-turn checklist) as well as an online video that models successful techniques. Generally, after prophylactic oxygenation with 100% FiO₂, proning can be safely performed with 3-4 staff members, with one member dedicated solely to the endotracheal tube (ETT) management. Immediately post-maneuver, there often is an increase in secretion mobilization that requires suctioning. Once prone, staff should especially focus on preventing pressure ulcers and managing endotracheal obstruction, for which the prone patient is at increased risk.

As far as when to revert to supine-only therapy, in PROSEVA, proning was continued for at least 16 hours/day until sustained oxygenation improvement was achieved, defined as PaO₂/FiO₂ ≥ 150 mmHg with PEEP ≤ 10 cmH₂O and FiO₂ ≤ 60% for at least 4 hours after repositioning supine. While this protocol is informative, the optimum duration of proning is unknown, and supinating prematurely might lead to derecruitment and potentially even VILI. We recommend continuing proning for at least 16 hours per day and ceasing proning when clinical variables (such as PaO₂/FiO₂, lung recruitability, ventilatory efficiency, static compliance, resolution of underlying non-pulmonary processes) show clear sustained improvement. Further research may help identify the optimal criteria to cease prone ventilation. Relatively strong contraindications to proning are: severe facial or neck trauma, pelvic/spinal instability,
elevated intra-cranial pressure (as turning the head compresses the internal jugular vein), hemoptysis, and frequent cardiac arrhythmias or high-probability of requiring CPR (Table 2). \cite{73} Experienced centers have published case reports of success proning in extreme circumstances, including third trimester pregnancy, patients on venovenous ECMO, and with invasive intracranial pressure monitoring. \cite{47,75-77}

**Next Steps**

Future studies of proning will need to emulate the extended-duration and low tidal volume approach of PROSEVA. Several clinical questions remain regarding the optimal approach to proning and concomitant lung-protective therapies. 1) What is the optimal approach to PEEP management in prone positioning, and is proning effective in patients receiving a high-PEEP strategy or might these therapies even be synergistic? 2) Does effective proning necessitate neuromuscular blockade for several days, and does this intervention contribute to critical illness neuromyopathy and associated functional impairment in survivors? 3) Is proning most effective in only a subset of patients with ARDS, and how can we further clarify the population who may have a survival (rather than just an oxygenation) benefit? 4) What is the learning curve and associated risk to patients if inexperienced centers newly adopt prone positioning?

In conclusion, proning was first recognized for its ability to improve oxygenation and historically used as salvage therapy for refractory hypoxemia. A recent multicenter trial and subsequent meta-analyses have made a compelling case that proning select patients with severe ARDS early in their course improves survival. This survival benefit is likely mediated by reduced VILI, as regional differences in lung aeration, compliance, and shear strain are minimized. In contrast to historical views, early improvement in gas exchange with proning does not reliably predict improved survival. Prone ventilation may be underutilized in clinical practice: in the LUNG-SAFE trial, only 16.4% of severe ARDS patients were
proned.\textsuperscript{72} If proning is pursued, it should be done early, with experienced staff to avoid logistical complications, and at extended durations (≥ 16 hours/day). For patients who fall outside these relatively narrow criteria, the clinician must balance the appealing physiological rationale behind proning against the equivocal evidence base for patients with less-severe lung injury, late-stage ARDS, or non-ARDS conditions.\textsuperscript{78}

**Acknowledgments**

All of the authors reviewed the literature and provided contributed important intellectual content to this review.
<table>
<thead>
<tr>
<th></th>
<th>Gattinoni</th>
<th>Guérin</th>
<th>Mancebo</th>
<th>Taccone</th>
<th>Guérin (PROSEVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prone group mortality</td>
<td>50.7% (ICU mortality)</td>
<td>32.4% (28-day)</td>
<td>43% (ICU mortality)</td>
<td>31% (28-day)</td>
<td>16% (28-day)</td>
</tr>
<tr>
<td>Control group mortality</td>
<td>48% (ICU mortality)</td>
<td>31.5 % (28-day)</td>
<td>58% (ICU mortality)</td>
<td>32.8% (28-day)</td>
<td>32.8% (28-day)</td>
</tr>
<tr>
<td>RR of mortality (prone/control)</td>
<td>1.05 ($p=0.65$)</td>
<td>1.02 ($p=0.77$)</td>
<td>0.74 ($p=0.12$)</td>
<td>0.97 ($p=0.72$)</td>
<td>0.48 ($p&lt;0.001$)</td>
</tr>
<tr>
<td>Patients (n)</td>
<td>304</td>
<td>802</td>
<td>142</td>
<td>342</td>
<td>466</td>
</tr>
<tr>
<td>Targeted disease</td>
<td>ALI* &amp; ARDS*</td>
<td>Respiratory failure with PaO$_2$/FiO$_2$&lt;300</td>
<td>ARDS*</td>
<td>ARDS*</td>
<td>ARDS* with PaO$_2$/FiO$_2$&lt;150</td>
</tr>
<tr>
<td>PaO$_2$/FiO$_2$ at enrollment</td>
<td>128</td>
<td>153</td>
<td>139</td>
<td>113</td>
<td>100</td>
</tr>
<tr>
<td>Enrollment early in disease course?</td>
<td>No</td>
<td>No</td>
<td>Yes, &lt;2 days of intubation</td>
<td>Yes, &lt;3 days</td>
<td>Yes, &lt;1.5 days</td>
</tr>
<tr>
<td>SAPS II</td>
<td>40</td>
<td>46</td>
<td>43</td>
<td>41</td>
<td>46</td>
</tr>
<tr>
<td>$V_t$ delivered</td>
<td>10.3 ml/kg</td>
<td>7.9 ml/kg</td>
<td>8.5 ml/kg</td>
<td>8 ml/kg</td>
<td>6.1 ml/kg</td>
</tr>
<tr>
<td>Patients paralyzed</td>
<td>Not reported</td>
<td>21%</td>
<td>45%</td>
<td>Not reported</td>
<td>87%</td>
</tr>
<tr>
<td>Mean increase in PaO$_2$/FiO$_2$ upon proning</td>
<td>19 mmHg</td>
<td>18 mmHg</td>
<td>32 mmHg†</td>
<td>44 mmHg</td>
<td>59 mmHg</td>
</tr>
<tr>
<td>Average time prone</td>
<td>7 hr/day</td>
<td>8 hr/day</td>
<td>17 hr/day</td>
<td>18 hr/day</td>
<td>17 hr/day</td>
</tr>
<tr>
<td>Average days prone</td>
<td>10 days</td>
<td>4 days</td>
<td>10 days</td>
<td>8.4 days</td>
<td>4 days</td>
</tr>
<tr>
<td>Significant reduction in ventilator days?*</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Difficulty enrolling?</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Cross-over (supine to prone)</td>
<td>8%</td>
<td>21%</td>
<td>8%</td>
<td>12%</td>
<td>7%</td>
</tr>
</tbody>
</table>

**Table Legend:**
- Bolded text indicates the most extreme value across all 5 trials.
- *This value was estimated based on graphical data presented in the text.
- Not all trials reported ventilator days or ICU length of stay; absence of reporting was taken to imply no significant difference.
- ALI and ARDS were defined according to the AECC definition of ARDS.
- Abbreviations: ARDS = acute respiratory distress syndrome
syndrome, RR = relative risk, ALI = acute lung injury, AEEC = American-European consensus conference, PaO₂/FiO₂ = ratio of arterial oxygen tension to the fraction of inspired oxygen, SAPS II = simplified acute physiology score II, Vt = tidal volume.
### Table 2. Summary Recommendations for Prone Ventilation

<table>
<thead>
<tr>
<th>Who to prone?</th>
<th>Who not to prone?</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Severe ARDS (PaO$_2$/FiO$_2$ &lt; 150)</td>
<td>• Facial/neck trauma or spinal instability</td>
</tr>
<tr>
<td>• Early in the course (ideally within 48 hours).</td>
<td>• Recent sternotomy or large ventral surface burn</td>
</tr>
<tr>
<td>• Best outcomes reported when proning is used in combination with BOTH low-tidal volume ventilation (6 cc/kg) and with neuromuscular blockade</td>
<td>• Elevated intracranial pressure</td>
</tr>
<tr>
<td></td>
<td>• Massive hemoptysis</td>
</tr>
<tr>
<td></td>
<td>• Patients at high risk of requiring CPR or defibrillation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>How to prone?</th>
<th>Potential complications:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Requires 3-5 people, close attention to ETT and central lines. A demonstration video and checklist are available $^9,73$</td>
<td>• Temporary increase in oral and tracheal secretions occluding airway</td>
</tr>
<tr>
<td>• Preparation: Pre-oxygenate, empty stomach, suction ETT/oral cavity, remove EKG leads and reattach to back, re-zero hemodynamic transducers</td>
<td>• ETT migration or kinking</td>
</tr>
<tr>
<td>• Support and frequently reposition pressure points: face, shoulder, anterior pelvis</td>
<td>• Vascular catheter kinking</td>
</tr>
<tr>
<td></td>
<td>• Elevated intra-abdominal pressures</td>
</tr>
<tr>
<td></td>
<td>• Increased gastric residuals</td>
</tr>
<tr>
<td></td>
<td>• Facial pressure ulcers, facial edema, lip trauma from ETT, brachial plexus injury (arm extension)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>How long to prone each day?</th>
<th>When to stop?</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Successful trials use at least 16 hours of proning per day.</td>
<td>• In PROSEVA, proning was stopped when PaO$_2$/FiO$_2$ remained &gt;150 four hours after supinating (with PEEP &lt;10 and FiO$_2$&lt;0.6).</td>
</tr>
<tr>
<td>• Long-proning sessions likely avoid derecruitment.</td>
<td>• Optimal strategy is unclear: consider continuing proning until clear improvement in gas exchange, mechanics, and overall clinical course.</td>
</tr>
</tbody>
</table>
REFERENCES


