Clinical Commentary

The Pragmatics of Prone Positioning

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Patients with acute respiratory distress syndrome (ARDS) or acute lung injury (ALI) are frequently kept in the supine position for days to weeks, with the only variation being periodic 15–45° turns to both lateral decubitus positions. A number of observations suggest, however, that the primary horizontal posture should be prone rather than the supine. When patients are prone:

1. Functional residual capacity may be higher, thereby reducing end-expiratory airspace closure (1, 2). This benefit is important relative to gas exchange as it will particularly affect the dorsal lung, and this region receives the greatest proportion of perfusion in all postures (3, 4).
2. The generally dorsal-to-ventral orientation of the major airways may allow more efficient drainage of secretions (5).
3. Regional ventilation and regional ventilation-to-perfusion relationships are more uniform (6–9) and gas exchange is improved (10–12) as a result of the anatomy of the diaphragm (13), postural differences in chest wall mechanics (14), and/or because the lungs fit into the thorax with less distortion from the heart, mediastinum, and diaphragm (15–18).
4. The effect of recruiting maneuvers on oxygenation is both increased and prolonged (19).
5. Ventilator-induced lung injury may be reduced (20, 21).

Prone ventilation has not been associated with a high incidence of serious complications or problems (11, 12), but many clinicians and nurses are reluctant to employ the intervention because it represents a departure from routine intensive care unit practice. Our extensive experience with prone ventilation has led us to recognize that numerous issues should be considered before, during, and after the turning process and that critical aspects can be easily overlooked. Accordingly, we suggest that a specific algorithm should be used, regardless of whether the team is experienced with prone positioning or is trying it for the first time. The purpose of this communication is to provide such an algorithm and discuss its components (Table 1).

Indications

The beneficial effects of prone ventilation on oxygenation have been observed in patients with ARDS and ALI resulting from numerous conditions (e.g., aspiration, pneumonia, sepsis, trauma, cardiac surgery). There are theoretical reasons to suggest that the improvement in patients with a pulmonary cause for ARDS/ALI might be less than in those with an extrapulmonary cause (22). Yet, Lim and colleagues (23) found impressive responses in both ARDS subtypes, with only minor differences in the timing of the response. Oxygenation also improves when patients with congestive heart failure are turned prone (24).

Contraindications

Although no studies have objectively identified any absolute contraindications to prone positioning, we suggest that serious burns or open wounds on the face or ventral body surface, spinal instability (as might be seen in patients with rheumatoid arthritis or trauma), pelvic fractures, or life-threatening cardiac arrhythmias or hypotension should preclude prone positioning. Some methods of prone positioning require the head to be turned sharply to one side or the other. Such torsion may compress the jugular veins and, as such, should be avoided in patients with increased intracranial pressure. This problem can be avoided by using specially designed beds that allow patients to be turned while the position of the head and neck remains fixed.

Tracheotomy tubes present a logistic difficulty when considering prone positioning, but there are several ways by which patients can be supported such that these tubes will have no direct contact with the bed or the supporting padding and would not be subjected to undue torsion.

Chest tubes inserted in the dorsal or ventral pleural space to drain fluid or gas, respectively, will be less well positioned for these purposes when patients are turned prone. Although we know of no documented instance where this has adversely affected gas exchange, this problem should be anticipated before the turn if patients have ongoing drainage of large volumes of pleural fluid or large air leaks so that additional chest tubes can be inserted without delay. In our experience, patients with large bronchopleural fistulas seldom benefit from prone positioning.

Patients with obesity, ascites, or other problems resulting in increased intra-abdominal pressure may increase abdominal pressure further when turned prone, but this effect is neither intrinsically hazardous nor predictably detrimental to gas exchange. In fact, there are both theoretical arguments and some clinical data (11) suggesting that obese patients may actually have a greater improvement in gas exchange when turned prone, perhaps because the effects of the supine posture may be worse in obese patients. The compression of the inferior vena cava that occurs in supine women during late-stage pregnancy is improved by left lateral decubitus positioning. The effect of the prone position has not been assessed in this setting.

Dialysis and other central catheters may need to be carefully secured and should receive increased attention during the turning process, but the presence of these catheters should not be considered a contraindication to prone positioning.

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TABLE 1. ALGORITHM FOR PRONE POSITIONING

Preparation

1. Check for contraindications.
   a. Facial or pelvic fractures
   b. Burns or open wounds on the ventral body surface
   c. Conditions associated with spinal instability (e.g., rheumatoid arthritis, trauma)
   d. Conditions associated with increased intracranial pressure
   e. Life-threatening arrhythmias
2. Consider possible adverse effects of prone positioning on chest tube drainage.
3. Whenever possible, explain the maneuver to the patient and/or their family.
4. Confirm from a recent chest roentgenogram that the tip of the endotracheal tube is located 2–4 cm above the main carina.
5. Inspect and confirm that the endotracheal tube and all central and large bore peripheral catheters are firmly secured.
6. Consider exactly how the patient's head, neck, and shoulder girdle will be supported after they are turned prone. Assemble all needed pillows, foam pads, or other types of supports that might be needed.
7. Stop tube feeding, check for residual, fully evacuate the stomach, and cap or clamp the feeding and gastric tubes.
8. Prepare endotracheal suctioning equipment, and review what the process will be if copious airway secretions abruptly interfere with ventilation.
9. Decide whether the turn will be rightward or leftward.
10. Prepare all intravenous tubing and other catheters and tubing for connection when the patient is prone.
    a. Assure sufficient tubing length
    b. Relocate all drainage bags on the opposite side of the bed
    c. Move chest tube drains between the legs
    d. Reposition intravenous tubing toward the patient's head, on the opposite side of the bed

The Turning Procedure

1. Place one (or more) people on both sides of the bed (to be responsible for the turning processes) and another at the head of the bed (to assure the central lines and the endotracheal tube do not become dislodged or kinked).
2. Increase the $F_{I_{O_2}}$ to 1.0 and note the mode of ventilation, the tidal volume, the minute ventilation, and the peak and plateau airway pressures.
3. Pull the patient to the edge of the bed furthest from whichever lateral decubitus position will be used while turning.
4. Place a new draw sheet on the side of the bed that the patient will face when in this lateral decubitus position. Leave most of the sheet hanging.
5. Turn the patient to the lateral decubitus position with the dependent arm tucked slightly under the thorax. As the turning progresses the nondependent arm can be raised in a cocked position over the patient's head. Alternatively, the turn can progress using a log-rolling procedure.
6. Remove ECG leads and patches. Suction the airway, mouth, and nasal passages if necessary.
7. Continue turning to the prone position.
8. Reposition in the center of the bed using the new draw sheet.
9. If the patient is on a standard hospital bed, turn his/her face toward the ventilator. Assure that the airway is not kinked and has not migrated during the turning process. Suction the airway if necessary.
10. Support the face and shoulders appropriately avoiding any contact of the supporting padding with the orbits or the eyes.
11. Position the arms for patient comfort. If the patient cannot communicate avoid any type of arm extension that might result in a brachial plexus injury.
12. Auscultate the chest to check for right mainstem intubation. Reassess the tidal volume and minute ventilation.
13. Adjust all tubing and reassess connections and functions.
14. Reattach ECG patches and leads to the back.
15. Tilt the patient into reverse Trendelenberg. Slight, intermittent lateral repositioning (20–30°) should also be used, changing sides at least every 2 hours.
16. Document a thorough skin assessment every shift, specifically inspecting weight bearing, ventral surfaces.

Practical Problems to Consider Before Turning

Without appropriate preparation and direct visual monitoring, the process of turning may, in theory, cause catheter extraction or endotracheal extubation. In practice, however, these problems do not occur more commonly than in patients who are not turned (11, 12). Personnel involved in the turning process have many things to do in rapid succession such that their attention can be distracted away from the catheters and the endotracheal tube. Accordingly, we recommend having one person assigned to do nothing more than monitor the central lines and the endotracheal tube during the turning process. This person should be aware of the possibility that the endotracheal tube may kink during or after repositioning (11), with the potential to produce life-threatening hypotension, hypoventilation, pneumothorax, and even cardiac or respiratory arrest.

Endotracheal tubes may move during the turning process as well as with repositioning the head and neck after turning. Correctly positioning the endotracheal tube relative to the carina before the turn (i.e., the distal end of the tube located 2–4 cm above the main carina) will allow the greatest excursion of tip position without extubation or mainstem bronchus intubation. Although oral fixators may help limit tube movement, they may also increase the risk of the tube kinking after turning.

Because central venous catheters can also kink, their patencies should be checked shortly after turning. The patency of all catheters through which vasopressor agents are being administered should be monitored throughout the turning process.

On occasion, prone positioning can result in such copious drainage of airway secretions that ventilation becomes impaired. Large volumes of nasal and oral secretions can also appear. Suctioning equipment should be prepared *before* turning, and personnel should be ready to aggressively suction the airway as soon as the prone position is achieved.

Oxygenation commonly falls transiently during the turning process. An abrupt reduction in pulse oximetry should not be interpreted as a failure of prone positioning. Although only 50–75% of patients will have an improvement in their oxygenation on turning prone, occasional patients will experience desaturation (11). In our experience, if oxygenation falls during the turning process, it returns at least to the degree seen when the patient was supine within a minute or two of turning.

Chest wall compliance may decrease on turning prone (14). If this occurs and pressure-control ventilation is being used, tidal volume will fall and Pa_{CO_2} will rise unless the respiratory rate is adjusted.

Voltages and vectors measured on the electrocardiogram may change somewhat between positions as the heart shifts in the thorax and the electrodes are moved from the chest to the back.

The head is usually turned to the left or right when patients are turned prone to minimize any orbital or facial pressure and to avoid lip or nasal trauma caused by the endotracheal tube. This lateral rotation may be difficult to accomplish in elderly patients who have stiff cervical spines or in those with cervical disk disease. In such circumstances we consider using foam donuts that suspend the head off of the bed without any lateral rotation. These donuts may, however, result in greater facial trauma as the weight of the head is supported by a much smaller surface area. Any pillows, pads, and other devices that might be needed to support the head or other body parts after the turn should be available *before* beginning the process.

The number of people it takes to safely turn a patient depends, in part, on the size of the patient and the patient's ability to assist with the turn. In general, we recommend that two or three people physically reposition the patient while an additional person monitors the endotracheal tube and the central catheters. The last person should also be prepared to immediately suction the airway or adjust the ventilator as required. Four or more people may be needed to turn larger patients.

Ventilated patients frequently receive benzodiazepines and/or other agents for sedation, but this practice can prolong ventilation (25) and, accordingly, should not be routine. Although Gattinoni and colleagues (12) found increased use of sedation or muscle relaxants in 55 and 28% of turning maneuvers, respectively, the administration of these agents was not apparently governed by a protocol. It should not be assumed that a prone patient will require additional sedation. Some patients indicate they are *more* comfortable when they are prone. Under ideal circumstances, caregivers should be able to talk with patients to facilitate comfortable positioning of their heads, necks, and limbs and to determine when subsequent position adjustments might be needed. Being able to verbally interact with patients may also lead to less skin breakdown on ventral body surfaces. On occasion, however, agitation may be more than desirable and sedating doses of medications may be needed, *but this need not be the rule*. Paralytics have deleterious effects on the diaphragm (26) and, as such, should be used very sparingly in *all* patients with respiratory failure, regardless of position.

Practical Problems to Consider After Turning

Facial edema is common in prone patients, as the loose connective tissue of the face moves to a relatively dependent position. Periorbital swelling can be so substantial that it interferes with vision. A partially filled (600 ml) intravenous bag wrapped with a thin towel may be useful in padding and supporting the orbital areas. In our experience, facial edema can be minimized if the patients are also placed in the reverse Trendelenberg position (assuming this does not result in or accentuate hypotension). The patient's friends and families should be warned about the appearance of a patient with gross facial edema and informed that the swelling will rapidly resolve when the patient is repositioned supine, leaving no permanent change.

Pressure between the firm bed surface and the eyes, cheeks, breasts, anterior iliac spines, knees, and abdomen puts patients at risk of orbital ischemia, facial and other dermatologic trauma, and esophageal reflux unless proper precautions are taken. Attention should be paid to padding areas that are in contact with the bed. Although no studies address this issue, we suggest that feeding tubes should be inserted beyond the duodenum and that the stomach should be frequently decompressed as gastric pressures will increase in the prone position. Gastric residuals are not affected by the prone position, however (27). Adding reverse Trendelenberg positioning may also reduce the risk of esophageal reflux and/or aspiration (akin to reducing the risk of aspiration by raising the head of supine patients).

The transducer to which a pulmonary artery catheter is connected should be re-zeroed to the midaxillary line, just as would be done if the patient were supine. Although there is a considerable shift of the heart in a ventral direction on turning patients prone, the level of the left atrium relative to the new zero reference is sufficiently fixed, so that the pulmonary arterial occlusion pressure will accurately reflect the left ventricular filling pressure (20).

UNRESOLVED QUESTIONS

Does Prone Positioning Reduce the Morbidity or Mortality of Patients with ARDS? Gattinoni and colleagues (12) recently published the first study designed to assess the effect of prone positioning on survival in patients with ALI/ARDS. Although oxygenation was markedly improved in the patients ventilated prone, no change in overall mortality was observed by intention-to-treat analysis. An accompanying editorial by Slutsky (28) points out a number of weaknesses in Gattinoni's study design that limit the applicability of the results. First, patients randomized to prone ventilation only received it an average of 7 hours/day. Animal studies indicate that ventilator-induced lung injury can develop within hours, or even minutes, after instituting an injurious ventilatory strategy (21, 29, 30). Accordingly, any potentially beneficial effect of prone ventilation could have been diluted by the limited period of time the intervention was applied. Second, the study was considerably underpowered to use mortality as an end-point. Interestingly, as described in the article, enrollment was stopped early because caregivers were unwilling to forgo use of prone positioning in the control group. Third, there was no attempt to institute prone ventilation early in the course of ALI/ARDS (e.g., over 20% of the patients were treated long enough before randomization to suffer skin breakdown). Accordingly, ventilator-induced lung injury could have already developed by the time the patients were enrolled. Fourth, 8% of the patients randomized to receive supine ventilation were turned prone on 43 occasions because of severe hypoxemia, and 27% of the patients randomized to prone ventilation missed a total of 91 periods of pronation largely because of "staffing limitations." Finally, the intervention was only applied for 10 days. *Post hoc* analysis indicated that mortality was strikingly reduced (47 versus 23%) in the subset of patients with the worst gas exchange ($Pa_{O_2}/FI_{O_2} < 88$) and in those with Simplified Acute Physiology II scores higher than 49 (19 versus 49%). Moreover, those patients who received the highest tidal volumes appeared to benefit most from prone positioning. Accordingly, despite the lack of overall effect reported, Slutsky (28) concluded that it was reasonable to use prone ventilation for severely ill patients with ALI/

ARDS. The question of whether prone ventilation reduces the mortality of these patients is an open one.

When in the Course of ARDS Should the Prone Position be Used? How Long Should it be Employed During Each 24-Hour Period? When Should it be Discontinued? Should it be Used in Patients Who do not Improve Their Oxygenation? If prone ventilation has no effect on morbidity or mortality, it follows that its use should be restricted to those few patients who have life-threatening hypoxemia when they are supine. Unfortunately, reliable indicators predicting who will or will not respond have not yet been identified. If, on the other hand, prone ventilation is ultimately found to improve outcomes, the answers to the aforementioned questions will depend on whether the beneficial effect is the result of improving oxygenation or of reducing ventilator-induced lung injury and whether the two mechanisms are linked. If outcome is improved by improving oxygenation (thereby being able to reduce the $F_{I_{O_2}}$ and the level of positive end-expiratory pressure), then prone ventilation would only be of use when oxygenation is severely impaired, should only be used in patients demonstrating an improvement, and should be discontinued when oxygenation improves to the point that the patient can be supported with low levels of $F_{I_{O_2}}$ and positive end-expiratory pressure. If, however, prone ventilation reduces mortality by reducing ventilator-induced lung injury, it would follow that patients should be turned prone as soon as a diagnosis of ARDS is established (or potentially, even when they are identified as being at risk); it should be employed as much of the day as possible, regardless of its effect on oxygenation, and it should be continued well into the recovery phase.

What is the Role of Periodic Partial Repositioning (i.e., 15–60°) to the Left and Right Lateral Decubitus Positions When Patients are Primarily Prone Rather than Supine? Studies by Munro (31) in the 1940s established a 2-hour turning interval as the standard of practice to limit skin breakdown in supine patients. Although the effect of various frequencies and degrees of periodic partial repositioning from the prone posture has never been studied, we can think of no reason why it should be *less* than the every-2-hour standard. Some ventral body surfaces have less subcutaneous supporting tissue than the corresponding dorsal surfaces that support the weight of the patient. Accordingly, intermittent partial repositioning might have to be *more* frequent in prone patients to limit skin breakdown. Among the factors thought to contribute to the development of atelectasis are impaired clearance of secretions from dependent airways and failure to sufficiently expand ventilating regions. Because the forces contributing to atelectasis are attenuated, and secretion clearance is enhanced, when patients are prone, the extent to which periodic partial turning is needed to prevent atelectasis might also be reduced when prone.

Does the Prone Position have a Role in Treating Patients with Conditions Other than ARDS? The effects of prone ventilation have not been systematically studied in patients with airflow limitation. Conceivably, prone positioning could improve gas exchange by reopening dependent airspaces or redistributing ventilation (particularly in patients with enlarged hearts and more rotund abdomens). Similarly, patients with the obesity hypoventilation syndrome should improve their hypoxemia on turning prone. Oxygenation and secretion clearance might also improve in patients who have pneumonia in dorsal lung segments (i.e., the right and left superior or posterior basal segments). Patients with respiratory failure from interstitial lung disease do not appear to improve their oxygenation with prone ventilation (24).

Should the Abdomen be Suspended? Functional residual capacity is increased on going from the supine position to the prone one and increased further by suspending the abdomen in the prone position (2). Most reports showing improved oxygenation by prone ventilation have not employed abdominal suspension. Whether further increases can be obtained by doing so has not been investigated.

Are Air-Cushioned Beds Useful? Although the pressure of the bed surface against weight-bearing ventral prominences can result in skin breakdown, heightened vigilance is generally sufficient to prevent serious ulceration. Air-cushioned beds might reduce skin complications by spreading forces over a greater area, but in some instances, they may also hinder the ability to use pillows and foam supports to assist in weight bearing. In addition, one of the proposed mechanisms explaining why the prone position improves dorsal lung ventilation is that it decreases ventral chest wall compliance (14). This effect may, in theory, be diminished by air-cushioned beds.

In conclusion, despite its demonstrated potential to improve oxygenation and secretion drainage, many physicians, nurses, and respiratory therapists have little experience with the proning process, or with caring for or monitoring patients when they are prone. We have routinely employed prone ventilation for many years, and the algorithm presented summarizes our combined experience. Although numerous questions remain regarding patient selection, timing, duration, body angulation, and body supports, careful attention to the details described, both before and after turning, should minimize complications and facilitate the turning process. Whether prone ventilation reduces the morbidity or mortality of ARDS/ALI remains to be determined.

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