ELSEVIER

Original Contributions

Pressure on the Face While in the Prone Position: ProneView™ *versus* Prone Positioner™

Benjamin I. Atwater, MD,* Eric Wahrenbrock, MD,† Jonathan L. Benumof, MD,‡ William J. Mazzei, MD§

Department of Anesthesiology, University of California at San Diego School of Medicine, San Diego, CA

Study Objective: *To measure the surface pressure on the face of a patient placed in the prone position with the most commonly used prone positioning devices, a non-face-contoured positioner (PP) and a new face-contoured device (PV).*

Design: *Prospective, randomized comparison.*

Setting: *Operating room in an American academic medical center.*

Subjects: *35 randomly recruited adult volunteers.*

Interventions: *Surface pressure on the face was measured in awake subjects placed in the prone position, with the head and neck in the position of most comfort, using both the PP and PV devices.*

Measurements: *Surface pressure was obtained using an array of small transducers imbedded in a thin cushion that was interfaced between the face and positioning device. The amount of extension or flexion of the head on the neck was estimated using an angular measurement of eye-ear line and horizontal line.*

Main Results: *The average surface pressure on the face was less with the PV than with the PP (21 ± 3 mmHg vs. 27 ± 5 mmHg; $p < 0.0001$). The number of areas where pressure exceeded 30 mmHg and 50 mmHg was lower for the PV than the PP (15 ± 7.5 areas vs. 19 ± 7.2 areas > 30 mmHg; $p < 0.05$; 5.2 ± 3.3 areas vs. 9.0 ± 5.0 areas > 50 mmHg; $p < 0.0001$). Pressure on the chin increased with extension of the head or neck ($p < 0.05$) with both devices.*

Conclusions: *Surface pressure on the face in the prone position is 29% higher with the non-face-contoured PP than with the face-contoured PV. The number of areas on the face where the surface pressure is greater than 50 mmHg is 80% higher with the PP than the PV. Small degrees of head extension increases pressure on the chin. Both devices produce areas of pressure, typically over the chin, which may be associated with local skin damage. Keeping the head and neck in a non-flexed, non-extended position may minimize pressures.*

Keywords: Patient positioning; prone positioning devices; surface pressure, facial.

*Resident in Anesthesiology

†Associate Professor of Anesthesiology

‡Professor of Anesthesiology

§Clinical Professor of Anesthesiology

Address correspondence to Dr. Mazzei at the Department of Anesthesiology, UCSD Medical Center, 8770, 200 West Arbor Drive, San Diego, CA 92103-8770, USA. E-mail: wmazzei@ucsd.edu

Supported in part by Dupaco, Inc., Oceanside, CA, which provided the pressure sensing pad used in this study. Dr. Mazzei is a paid consultant for Dupaco, Inc.

Received for publication December 3, 2002; revised manuscript accepted for publication June 16, 2003.

Journal of Clinical Anesthesia 16:111–116, 2004

360 Park Avenue, South, New York, NY 10010

0952-8180/04/$–see front matter
doi:10.1016/j.jclinanc.2003.06.001

Figure 1. ProneView™ Protective Helmet System (PV; Dupaco, Inc., Oceanside, CA). A face-contoured foam insert rests inside a rigid plastic helmet that is mounted above a mirror. The patient's eyes can be observed directly through the mirror.

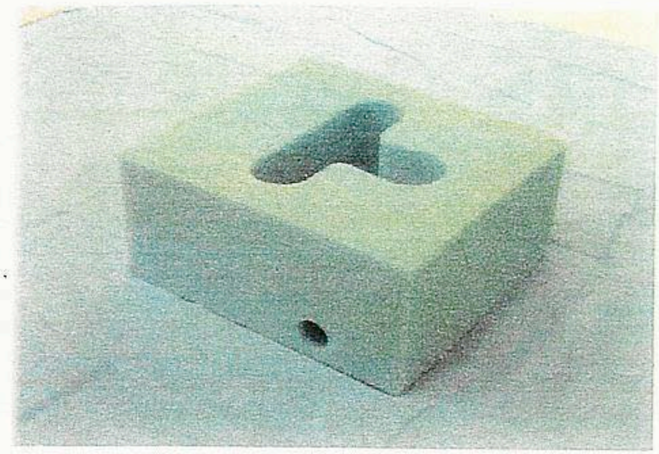

Figure 2. Prone Positioner (PP). A non-face-contoured foam support with a T-shaped hole for the eyes and nose.

Introduction

In performing surgery on a patient who is placed in the prone position, the patient's face is supported by padded devices that attempt to safely secure the head while minimizing pressure about the face. All padded devices contain spaces or holes where the eyes rest so as to prevent any pressure on or around the globes. Skin damage on the face, most commonly over the chin, occurs with all prone positioning devices (personal communication). It is presumed that this skin damage is caused by excessive pressure on the face. Further, blindness is a rare but catastrophic complication for patients undergoing surgery in the prone position. Although several mechanisms for blindness have been postulated, increased intraocular pressure is felt to be a contributing factor in certain cases.[1] Although anesthesiologists try intermittently to determine whether any part of the padded support device is pressing on the eye during surgery, these checks are difficult to perform with previously available prone positioning devices. Surprisingly, to date, no study has ever measured facial and periorbital pressures with any padded support device.

The ProneView™ Protective Helmet System (PV; Dupaco Inc., Oceanside, CA) recently has been introduced to improve protection of the face and eyes during surgery in the prone position. The PV has a face-contoured, foam-face interface, an expansive opening for the eyes, and an attached mirror that permits easy, continuous observation of the eyes during surgery (*Figure 1*). We hypothesized that the large, face-contoured foam contact area of the PV would reduce the surface pressure on the face when compared with the surface pressure produced by the non-face-contoured Prone Positioner™ (PP; Voss Medical Products, San Antonio, TX; *Figure 2*). In this study, the surface pressure on the face was measured and compared for the PV and the PP.

Materials and Methods

After obtaining UCSD School of Medicine institutional review board approval, 35 healthy adult volunteers were randomly recruited from personnel working in the operating rooms at UCSD Medical Center. After giving informed consent, each subject was placed in the prone position on an operating room table equipped with chest rolls 15.4 cm (6") in diameter and 62 cm (24") in length, which were placed longitudinally on both sides of the table. After randomization of subjects to receive the PP or PV, each subject's face was placed on the selected positioning device, onto which a three-part thin, flexible pressure-sensing pad (Xsensor™ Technology Corp., Calgary, Alberta, Canada) had been applied (*Figure 3*). These pads contain 60 pressure sensors per 10 cm^2, each of which sample at 5 Hz to record pressure between 0 and 220 mmHg (the sensor pad is calibrated at the factory and at yearly intervals thereafter). When connected via a 32-bit

Figure 3. The pressure sensing pad draped over the ProneView.

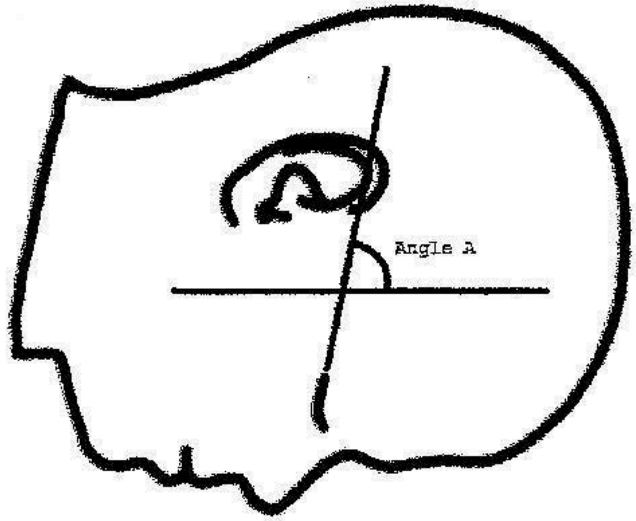

Figure 4. Extension of the head and neck was estimated by measuring Angle A, the angle formed by the intersection of a horizontal line with the line connecting the lateral corner of one eye and the superior aspect of the ear's insertion to the scalp. Increases in Angle A correspond to head and neck extension.

interface to a Compaq personal computer, each sensor provides a pressure measurement for a portion of the pad 1.61 cm^2 in area above the sensor.[2] The subject was asked to adjust his or her head and neck so as to obtain the most comfortable position that did not allow any portion of the eyes to contact the pressure-sensing pad. The subject was then asked to place his arms at his side in the internally rotated position (i.e., palms up relative to the operating room table) and then to relax as much as possible. One hundred twenty pressure measurements from each cell in the sensor pad were then recorded (every 0.5 sec for 1 min). In addition, the angle formed by the intersection of a horizontal line with the line connecting the lateral corner of one eye and the superior aspect of the ear's insertion to the scalp was measured (Angle A; *Figure 4*). After obtaining measurements with either the PP or PV, the protocol was repeated with the other device, and an additional 120 pressure measurements were recorded.

Statistical Analysis

The mean of the 120 pressure measurements for each sensor was calculated. For anatomic comparison, the sensors were divided into three zones (*Figure 5*); the Chin Zone consisted of all sensors lying below the superior border of the lower lip, the Maxillary Zone represented all sensors located between the inferior border of the upper lip and the superior orbital ridge, and the Forehead Zone consisted of all sensors located above the superior orbital ridge. The average pressure on the face in each zone was then obtained by finding the mean of the pressures for all sensors in a given zone. Similarly, the overall average pressure on the face was obtained by finding the mean of the pressures for all sensors for a given subject.

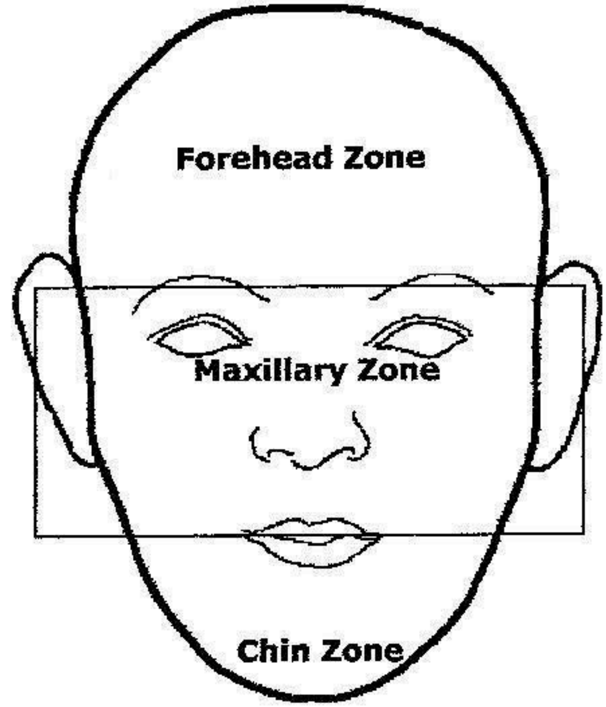

Figure 5. Facial zones used for pressure comparisons. The Chin Zone consisted of all cells lying below the superior border of the lower lip, the Maxillary Zone represented all cells located between the inferior border of the upper lip and the superior orbital ridge, and the Forehead Zone consisted of all cells located above the superior orbital ridge.

The number of sensors that had mean pressures greater than 30 mmHg and greater than 50 mmHg were counted for both positioning devices for each subject. The average pressure for each zone, the overall average pressure, the average number of sensors having a pressure greater than 30 and 50 mmHg in each Zone, and the total average number of sensors having a pressure greater than 30 and 50 mmHg were compared between devices using a Chi-square test. A p-value ≤ 0.05 was considered significant.

The weight supported by each zone, as well as the total supported weight of the head, was calculated by obtaining the product of the average pressure for a zone times the surface area of all the areas in that zone that registered a pressure. The fraction of weight on the chin and forehead *versus* Angle A was analyzed by linear regression.

Results

Subjects varied in size from 40 to 100 kg (74 ± 14 kg); 16 were men and 19 were women. The angular measure of head extension/flexion from the horizontal varied from 75 to 110 degrees (91 ± 11 degrees).

A typical three-dimensional plot of pressures for the PP and PV is shown in *Figure 6*. The pattern of pressures varied greatly among the subjects. Although the data

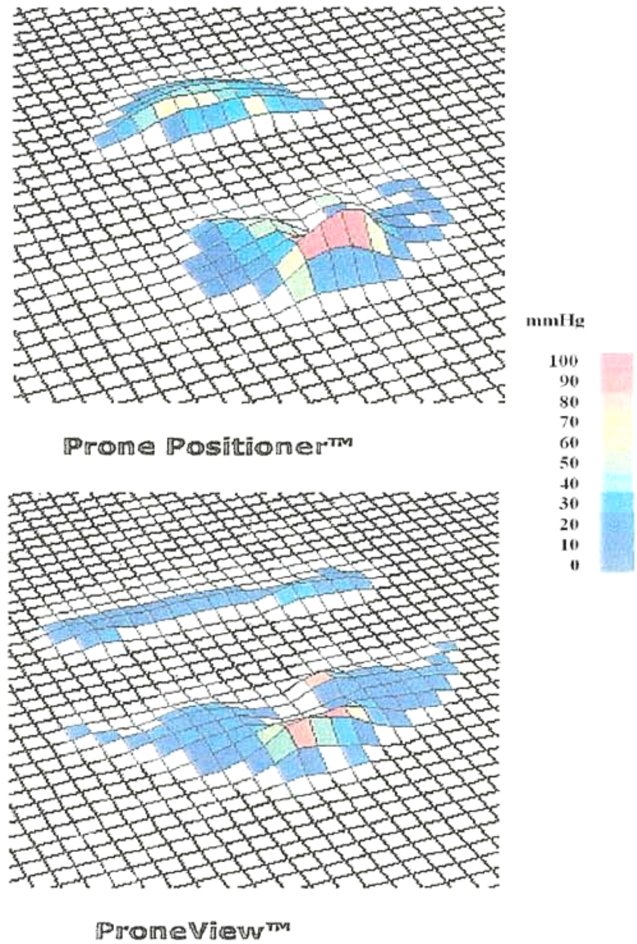

Figure 6. Three-dimensional plot of pressures for a single patient lying on the Prone Positioner (PP) and the ProneView Protective Helmet System (PV). Pressure is indicated in two ways: first, *via* color coding, as shown in the scale to the right of the image; second, topographically, with height proportional to the magnitude of pressure.

exhibited a great deal of variability, a positive trend was found between the proportion of total weight supported by the chin zone and Angle A for both devices (*Figure 7*), and a negative trend was found between the proportion of total weight supported by the forehead zone and Angle A for both devices (*Figure 8*). Neither of these correlations achieved statistical significance, however.

For all three zones, the average surface pressure over a given zone using the PV was less than the average surface pressure using the PP (*Table 1*). Similarly, the overall average pressure for the entire face was less with the PV than with the PP. The number of sensors with pressure greater than 30 mmHg was less with the PV than with the PP in the maxillary zone. In the chin zone, the number of cells with pressure greater than 50 mmHg was less with the PV than with the PP in the chin zone (*Table 2*).

Discussion

The safe level of surface pressure on the face is unknown. Prior surface pressure measurements have been obtained almost exclusively to study the physiology of decubitus ulcers.[3] In general, mattress manufacturers assert that maintaining surface pressures below 32 mmHg prevents the creation of decubitus ulcers.[1] However, such recommendations are based on studies in which a relatively large

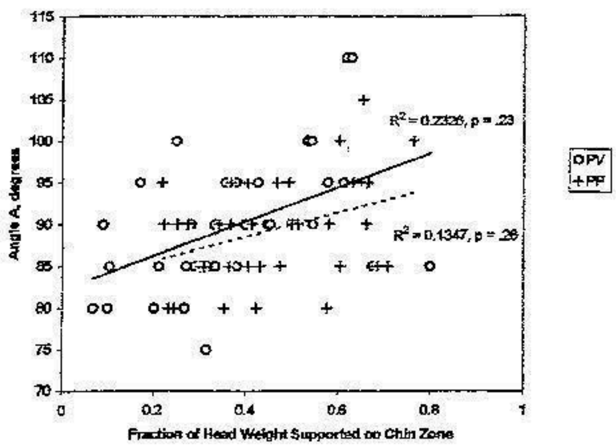

Figure 7. Proportion of total weight of head supported by chin zone vs extension of neck (Angle A) for both the Prone Positioner (PP) and the ProneView Protective Helmet System (PV).

area of skin (10 cm^2) overlying a bony prominence (such as the ischial tuberosity) is exposed to continuous pressure for 12 to 72 hours, and thus are not necessarily valid guidelines for patients undergoing surgery.[5] Herrman *et al.*[5] showed that skin perfusion in rats is acutely reduced to zero when surface pressure equals 58.2 ± 3.6 mmHg. In addition to facial surface pressure, there are other important determinants of face and eye damage that are not understood. The duration of complete skin ischemia that produces irreversible damage is unknown. Sloughing of skin over the chin has occurred when using the Voss Prone Positioner™ at our medical center for surgery that has lasted between 6 and 7 hours. Finally, the degree of facial small vessel disease (e.g., atherosclerosis) and the level of facial small vessel blood pressure (arterial, capillary, and venous) are largely unknown. Consequently, our endpoints of 30 mmHg and 50 mmHg for data analysis were

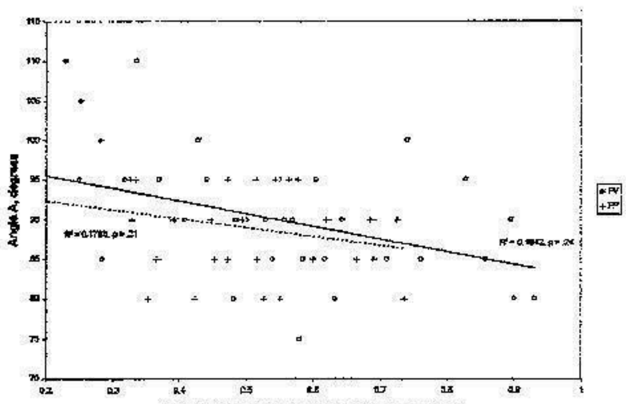

Figure 8. Proportion of total weight of head supported by forehead zone *versus* extension of neck (Angle A) for both the Prone Positioner (PP) and the ProneView Protective Helmet System (PV).

Table 1. Average Surface Pressure on the Face for Each Zone and for Entire Face with Both the Voss Prone Positioner™ and the Dupaco ProneView™ Devices

	PP (mmHg)	PV (mmHg)	*p*-value
Forehead zone	26 ± 7	22 ± 4	<0.05*
Maxillary zone	23 ± 5	18 ± 3	<0.05*
Chin zone	30 ± 15	21 ± 12	<0.05*
Entire face	27 ± 5	21 ± 3	<0.05*

Note: Data are means ± SD.

* = statistically significant

Voss Prone Positioner™, Voss Medical Products, San Antonio, TX. ProneView™ Protective Helmet System, Dupaco, Inc., Oceanside, CA.

chosen to allow comparison to mattress and surface perfusion studies.[1-4]

Minimizing the surface pressure over the bony prominences of the face is likely to reduce the incidence of skin damage when a patient must undergo surgery in the prone position. Minimizing the surface pressure can be accomplished by maximizing the contact surface area with a supporting pad. The amount of contact surface area can be assessed by measuring the average surface pressure applied against a support pad. Because the average surface pressure is equal to the weight of the head divided by the contact surface area, and because the weight of the head is constant for a given patient, the larger the contact surface area, the lower the average surface pressure. Compared with devices used before the introduction of the PP, such as the horseshoe support or "catcher's mask," the PP provides a greater area of contact against the patient's face, thereby distributing the pressure over a larger area and reducing the pressure over the bony prominences. Unfortunately, the T-shaped hole used in the PP is not contoured to facial geography and does not insure that the patient's eyes do not contact the foam during surgery. The PV device is contoured to the patient's face and has a large opening for the eyes. The face-contoured foam used in the PV allows a greater area of contact with the face than the PP, which resulted in the lower surface pressures that were found in this study.

With both devices, and regardless of body weight, we found areas where the surface pressure exceeded the value where skin perfusion may go to zero. These areas were primarily over the chin, although they occasionally occurred on the forehead immediately superior to the supraorbital ridge. Pressures greater than 50 mmHg were not found over the zygomas. This finding may explain why skin breakdown has not been reported in that area of the face.

In this study, we measured the position of the head to see how much head flexion or extension affected pressure on the face. Even though the range of our angular measurements was small, we found that extending the head tends to increase pressure over the chin, and conversely, flexing the head tends to increase pressure over the forehead. It may be that maintaining the head and

Table 2. Average Number of Cells with Pressure Greater than 30 mmHg or 50 mmHg for Each Zone and for the Entire Face Using the PP or PV device

	Number of Cells Having Pressure > 30 mmHg			Number of Cells Having Pressure > 50 mmHg		
	PP	PV	*p*-value	PP	PV	*p*-value
Forehead zone	11.0 ± 4.9	11.0 ± 8.0	0.91	3.6 ± 4.0	2.5 ± 2.6	0.18
Maxillary zone	2.7 ± 2.6	0.5 ± 1.1	<0.05*	0.83 ± 1.2	0.63 ± 0.5	0.38
Chin zone	5.5 ± 3.5	3.9 ± 3.8	0.10	4.5 ± 3.6	2.1 ± 2.4	<0.05*
Entire face	19.0 ± 7.2	15.0 ± 7.5	<0.05*	9.0 ± 5.0	5.2 ± 3.3	<0.05*

*Indicates statistical significance.

neck in a non-flexed, non-extended position minimizes the areas of high surface pressure.

Because surface pressure measurements currently are not obtained on patients placed in the prone position, it is not possible for the anesthesiologist to optimize the position of the head with either the PP or PV. Nevertheless, based on this study, we believe that use of the PV device will likely produce lower surface pressures compared with the PP device. Development of simple surface pressure measurement devices may enable practitioners to minimize pressures in the future.

This study prompts the need for two further investigations. First, the degree of head flexion/extension may be very important with respect to the distribution of pressures. Measurements of surface pressures during large changes in head position are needed to confirm this theory. Second, surface pressures on the face may differ in anesthetized patients from awake subjects due to the loss of voluntary control of muscles and elimination of active effort to decrease surface pressure on the face. Surface pressures should be obtained in patients undergoing surgery in the prone position.

In summary, we found that surface pressures on the face in a patient placed in the prone position average below 30 mmHg, but small areas of high pressure exist in all patients, primarily over the chin. A head support device that contours to the face reduces skin surface pressure on the face compared with flat supports, which may reduce the incidence of skin damage during surgery in the prone position. Further, maintaining the head and neck in a non-flexed, non-extended position may reduce the number of high pressure areas and thereby decrease the risk of skin damage.

References

1. Roth S, Nunez R, Schreider BD: Unexplained visual loss after lumbar spine fusion. *J Neurosurg Anesthesiol* 1997;9:346–8.
2. Babbs CF, Bourland JD, Graber GP, Jones JT, Schoenlein WE: A pressure-sensitive mat for measuring contact pressure distributions of patients lying on hospital beds. *Biomed Instrum Technol* 1990;24:363–70.
3. Whittemore R: Pressure-reduction support surfaces: a review of the literature. *J Wound Ostomy Continence Nurs* 1998;25:6–25.
4. Krouskop TA, Garber SL: Interface pressure measurements [Letter]. *J Enterostomal Ther* 1990;17:182.
5. Pressure ulcers prevalence, cost and risk assessment: consensus development conference statement–The National Pressure Ulcer Advisory Panel. *Decubitus* 1989;2:24–8.
6. Herrman EC, Knapp CF, Donofrio JC, Salcido R: Skin perfusion responses to surface pressure-induced ischemia: implication for the developing pressure ulcer. *J Rehabil Res Dev* 1999;36:109–20.