In Reply—In reply to Drs. Blomberg and Huson, I must admit that certain restrictions on soft tissue resolution are imposed by the use of wide window CT imaging (2000–4000 H.U.) as required in CT-peridurography. The dorsi-median dural fold and its ligamentous attachments become indistinguishable in these wide grey scale images. Likewise, the dorsolateral connective tissue planes and their fibroadipose contents are of one density outlined only by the concentrated radiographic contrast material in the adjacent epidural compartments. Consequently, the juncture of the "dorsomedian ligamentous band" and the "dorsomedian dural fold" is not clearly seen.

We have noted the absence of the dorsomedian dural fold in the physiological state in magnetic resonance imaging (MRI) of the lumbar spine. The dorsomedian ligamentous band and dorsolateral connective tissue planes also are not seen, but are apparently obscured by the high radio signal of fat in the epidural space.

The division of the dorsolateral epidural space into separate anterior and posterior compartments was seen in all 40 of our CT-peridurograms; however, the triangular configuration of the connective tissue junctions was seen in only 31 of the examinations. The CT scans would consist of 30 or more consecutive axial sections at 5 mm intervals, extending from L3 through S1 vertebral levels.

At fluoroscopy, unilateral filling of the posterior epidural space might progress over two or three vertebral levels before filling of the contralateral space would occur. For this reason, we used a curved catheter to distribute the contrast material equally between the right and left posterior spaces in our diagnostic studies. Similarly, as seen on CT, the anterior or posterior compartment of one side might fill preferentially over one to two vertebral levels before filling of the adjacent compartment would occur. Consequently, while the compartments freely communicate, the tendency of this degree of preferential filling would indicate more than connective tissue planes composed of fibrous strands alone.

At dissection, however, only the dorsomedian connective tissue band would resist tearing produced by traction on the dura. The delicate nature of the lateral membranous connective tissue planes may explain the lack of their demonstration on epiduroscopy and in epidural casts in cadavers.

EDWARD R. SAVOLAJNE, M.D.
Associate Professor
Departments of Radiology and Neurosurgery
Medical College of Ohio
3000 Arlington Avenue
Toledo, Ohio 43699

(Accepted for publication June 13, 1988.)

The Use of PEEP in Patients in the Sitting Position

To the Editor.—The contribution of Dr. Zaslow et al.1 to the discussion and understanding of the phenomenon of paradoxical venous air embolism (PVAE) was most welcome. However, while I doubt that it was their intention, I am concerned that the report may be misunderstood by some as advocacy of the use of PEEP during procedures performed upon patients in the sitting position. It should not be viewed as such. The limitations of the study, some of which are acknowledged by the authors, and other considerations relevant to the use of PEEP should be fully appraised.

Zaslow et al. measured right atrial pressure (RAP) and pulmonary capillary wedge pressure (the latter as an index of left atrial pressure [LAP]) during the application of PEEP in patients undergoing surgical procedures in the sitting position. A positive RAP-LAP gradient (i.e., RAP > LAP) occurred infrequently during the application of 10 cm H2O of PEEP. This was in contrast to the incidence reported by other investigators.2,3,4 In support of their observations, Zaslow et al. introduce a discussion of the manner in which PEEP might be anticipated to influence the RAP-LAP pressure gradient.

Previous observations made during deliberate attempts to provoke right atrial to left atrial shunting (for the purpose of identifying patients at risk for PVAE) may be relevant to this discussion. In both unanesthetized3 and anesthetized4 patients, maneuvers which generated positive airway pressures were observed to provoke right-to-left shunting, apparently principally during the phase immediately following the release of airway pressure. The investigation by Cucchiara et al.5 of anesthetized subjects also sought evidence of right-to-left shunting at the time of end expiration (no PEEP). Right-to-left shunting at end expiration was not observed in any patient, including those in whom it had been seen in the release phase following positive airway pressure.

These observations raise two questions with respect to the report of Zaslow et al. The first relates to the timing of the RAP and LAP measurements. These measurements were performed by Zaslow et al. at end expiration. The reports mentioned above suggest that a positive RAP-LAP gradient is more likely to occur early in the expiratory phase. Accordingly, the data of Zaslow et al. as well as that of others2,3,4 may underestimate the actual incidence of positive RAP-LAP gradients. The second question is whether the peak pressure achieved during a positive airway pressure maneuver is an important variable in determining the frequency or volume of shunting. Neither study mentioned above attempted to examine this relationship, and the answer is accordingly a matter of speculation. However, it is reasonable to be concerned that PEEP, which inevitably increases the peak airway pressure achieved with each inspiratory phase, might increase the likelihood of a positive RAP-LAP gradient during the subsequent expiratory phase. Because of these questions, I doubt that investigations of the influence of PEEP on the potential for the occurrence of PVAE should be viewed as complete, or that PEEP should be viewed as a risk factor for PVAE without an evaluation of the RAP-LAP gradient during the entire respiratory cycle.

An additional minor point arises from the same discussion of the manner in which PEEP might be expected to alter the right atrial to left atrial gradient. Zaslow et al. argue that the intrathoracic air pressures generated as a result of the application of PEEP should be transmitted equally to both atria. This is almost certainly the case. However, the effects on the vascular resistances confronting the two ventricles may differ substantially. The data of Zaslow et al. indicate that the application of 10 cm of PEEP resulted in a 50% increase in pulmonary vascular resistance, but were simultaneously accompanied by a very
small decrease in systemic vascular resistance. In selected patients with myocardial dysfunction, this might well be expected to result in greater increases in right atrial than left atrial mean pressure.

Much of the interest in the use of PEEP during procedures performed on patients in the sitting position is derived from the initial hope that the incidence of air entrapment would be reduced. There have been no investigations of PEEP that have used the incidence of confirmed VAE as an endpoint. However, there is substantial evidence, some of which is cited by Zaslows and colleagues, that hemodynamically acceptable levels of PEEP will not produce positive venous pressure at a cranial operative site. Accordingly, the prevention of venous air entrapment in patients in the sitting position is not a rationale for the use of PEEP, which should be viewed as firmly established.

The hemodynamic effects of PEEP, when applied in patients in the sitting position, may also be a matter of clinical significance. The effects of 10 cm of PEEP on mean arterial pressure (MAP) and cardiac output (CO) were negligible in the population studied by Zaslows and colleagues. However, others have reported substantially greater alterations. For example, Perkins and colleagues observed reductions in MAP and CO of 14 and 15% respectively. The differences may be related to the age of the patient population (not specified in either report) or to anesthetic technique. It follows that in some patients, hemodynamic changes may be a significant limitation to the use of PEEP.

My review of the available literature leads me to doubt that PEEP should be employed routinely during procedures performed in patients in the sitting position. It should probably be withheld for situations where there are specific pulmonary indications for its use. However, when the preoperative evaluation suggests the probable need for intraoperative PEEP, anesthesiologists at our institution are likely to approach their surgical colleagues about the feasibility of alternatives to the sitting position.

JOHN G. DRUMMOND, M.D.
Associate Professor of Clinical Anesthesiology
Neuroanesthesia Research, M-029
La Jolla, California 92039

Anesthesiology
69:799–800, 1988

In Reply—We appreciate Dr. Drummond's thoughtful comments concerning the safety and efficacy of PEEP during surgery in patients in the sitting position. We believe our article adequately addressed the issue of safety. In our study, 10 cm H2O of PEEP increased both right atrial pressure (RAP) and left atrial pressure (LAP), but did not result in a positive RAP-LAP gradient in any of the 20 patients. Similarly, 10 cm H2O of PEEP did not significantly affect the magnitude by which LAP exceeded RAP. These results are consistent with our prior study in dogs, which demonstrated no effect of PEEP on the LAP-RAP gradient either before or during venous air embolism. Our results differ from those of Perkins and colleagues, and we considered possible reasons for this discrepancy. The Perkins-PEARSON et al. study referred to by Dr. Drummond did not investigate the effects of PEEP.

We agree that maneuvers that dynamically alter airway pressure can reverse the normally positive LAP-RAP gradient. This does not imply that 10 cm H2O of PEEP will have a similar effect. Multiple studies have used contrast echocardiography to demonstrate paradoxical movement of microbubbles during or following the release of the strain phase of a Valsalva maneuver. The magnitude and timing of the airway pressure changes that occur are dramatically different from the changes that occur with 10 cm H2O of PEEP. The study by Dr. Cucchiara and colleagues demonstrated paradoxical movement of microbubbles when 20 cm H2O positive airway pressure was held for 5 s and released. As we discussed in our article, 20 cm H2O of PEEP may be sufficient to reverse the direction of the LAP-RAP gradient in some patients.

We examined the effects of ventilation on RAP, LAP, and the LAP-RAP gradient during 0 and 10 cm H2O PEEP in the 20 patients in our study. Phasic positive pressure ventilation increased LAP at least as much as RAP, and the effect on the instantaneous LAP-RAP gradient did not change with the application of PEEP. We did not examine the transient effects of removal of PEEP on the LAP-RAP gradient in our clinical study. However, in our dog study, we continuously monitored LAP and RAP and observed no transient changes in the LAP-RAP gradient with either the application or removal of PEEP. We therefore believe that 10 cm H2O of PEEP will not predispose to paradoxical air embolism during venous air embolism.

Dr. Drummond questions the effects of PEEP on systemic hemodynamics and systemic and pulmonary vascular resistances. The small effects of low levels of PEEP on systemic hemodynamics are primarily due to decreased venous return and can be reversed if necessary by fluid administration. High levels of PEEP can increase pulmonary vascular resistance, but this is a relatively minor phenomenon at low levels of PEEP. In our study, PEEP increased FVR an average of only 58 dynes sec cm−2 (0.72 mmHg·1·min−1), a value unlikely to pro-