

*In Reply:*

Although it is possible to produce or induce differential inspiratory and expiratory obstruction at the level of the soft palate, this was not relevant to the circumstances of our study. Our purpose was to define evolution of vulnerability to upper airway collapse along the pathway from wakefulness through conscious sedation and unconscious sedation to anesthesia. Our methods are standard tools for determining upper airway collapsibility. The pharyngeal critical pressure, which is associated with occlusion (inspiratory and expiratory—assessed over a sequence of five consecutive inspiratory efforts), quantifies this.<sup>1</sup> The intramuscular genioglossus electromyogram not only provides direct information regarding activation of the major upper airway dilator muscle but also reflects activation of the other upper airway muscles.<sup>2</sup> It is evident from our findings that this evolution is an alinear process with a disproportionate increase in collapsibility occurring proximate to loss of consciousness and coincident with a precipitate decrease in the upper airway muscle activation in response to application of negative pressure to the upper airway.<sup>3</sup> These findings hold independent of the precise site of upper airway obstruction, presence of a catheter in the upper airway, or whether or not the mouth is taped.

Nevertheless, the velopharynx is the most common primary site of upper airway obstruction during both anesthesia<sup>4,5</sup> and sleep;<sup>6,7</sup> hence, Dr. Kempen is on firm ground with his suggestion that the soft palate might be important! Indeed, as has been our previous experience in anesthetized subjects with and without sleep apnea,<sup>5,8–10</sup> the primary site of collapse was velopharyngeal in a substantial majority of subjects during our recent study. Seven of our subjects collapsed at this site. Retrolingual collapse was observed in two (subjects 2 and 5). As Dr. Kempen surmises, the site of collapse was determined manometrically according to methods previously described.<sup>5</sup>

Commonly, it is velopharyngeal obstruction that causes hypopneas and accompanying arousals during sleep. Similarly, velopharyngeal collapse is a common site of obstruction during anesthesia and postanesthetic recovery, accounting for the usefulness of the nasopharyngeal airway in these situations. Unlike infants or other mammals, adults are not obligate nasal breathers, so that oral breathing represents an alternative route when the velopharynx is occluded. However, as Dr. Kempen points out in citing Drummond,<sup>11</sup> recourse to oral breathing during anesthesia may well indicate impending airway difficulty, regardless of phase of respiration.

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## Venous Air Embolism during Total Laparoscopic Hysterectomy

*To the Editor:*

We read with great interest the article by Kim *et al.*<sup>1</sup> in the July 2009 issue of *ANESTHESIOLOGY*. In this study, the authors warn us of the high frequency of venous gas embolism that can occur during laparoscopic hysterectomy as opposed to total abdominal hysterectomy. Their study calls for several comments.

The authors found approximately 25% of patent foramen ovale (PFO) among their patients, which is consistent with what we know from autopsic series.<sup>2</sup> However, the detection of a PFO could have been enhanced by an end-inspiratory occlusion maneuver or by the application of positive end-expiratory pressure during transesophageal echocardiography.<sup>3–5</sup>

No indication on the filling of the left heart by bubbles, especially for patients presenting with a PFO, was reported. This would have informed us of the risk of systemic air embolism, which is ultimately the most daunting complication.

Only major neurologic complications that are rare in clinical practice were evaluated. It would have been interesting to assess the risk of minor neurologic complications that are often underdiagnosed, especially in elderly patients.

When venous air embolism occurs, the authors suggest placing the patient in a left lateral recumbent position. Animal studies have found no benefit from the left lateral position in improving hemodynamic performance,<sup>6,7</sup> and human data are lacking. Conversely, in the case of a major event, such as cerebral gas embolism, the authors did not mention hyperbaric oxygen therapy. This therapy has potential benefits in the case of arterial gas embolism<sup>8,9</sup> and has to be mentioned in the therapeutic arsenal.

Finally, we are clearly faced with a paradox. Venous air embolism is frequently found during laparoscopic procedures,<sup>1,10</sup> PFO exists in 25 to 30% of patients, and mechanical ventilation increases right atrial pressure favoring right-to-left flow through a foramen ovale, especially if there is positive end-expiratory pressure.<sup>11</sup> However, systemic complications as a result of paradoxical embolism, especially cerebral complications, are rare. An explanation often evoked is the high solubility of carbon dioxide in blood. However, a gas embolism is rapidly transformed into a nongas embolism because of the adhesion of platelets to the bubble.<sup>12</sup> Moreover, if bubbles are detected in the heart, they can be in the brain, only a few seconds later through a PFO.

To conclude, it is perhaps time to call for a large study allowing the evaluation of the frequency of cerebral complications of gas embolism during laparoscopic surgery, especially minor ones, and to open a database of major complications, which are possibly underestimated today and most of them not being published. After all, we want to ask a question: should we contraindicate laparoscopic surgery in patients with a known PFO and prefer total abdominal surgery?

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## In Reply:

We appreciate the comments and questions from Drs. Dubar and Fischler regarding our article.<sup>1</sup>

We agree that the detection of a patent foramen ovale (PFO) would have been enhanced if we had used the methods that they had recommended. Because the incidence of PFO in Koreans has been well known,<sup>2,3</sup> our focus was not the incidence of PFO in this study.

We also tried to find bubbles in the left heart, especially PFO cases and any neurologic complications after surgery, but we did not find any. However, if we had conducted postoperative cognitive function test, such as the Mini Mental State Examination,<sup>4</sup> minor neurologic complications might have been found.

Although animal studies found no benefit from the left-lateral decubitus (Durant's) position in improving hemodynamic performance, it can allow gas bubbles to rise into the apex of the right atrium. So, it may be helpful for trapping and aspirating bubbles entrained in the right atrium.

As one of the specialists in diving medicine, the corresponding author (K.J.K.) totally agrees with them that hyperbaric oxygen therapy has potential benefits for arterial air embolism and cerebral air embolism.

The major reason why systemic complications resulting from paradoxical embolism with carbon dioxide are rare may be because of the high solubility of carbon dioxide in blood (0.60 ml CO<sub>2</sub>/ml blood).<sup>5</sup> Air embolism can be rapidly transformed into a nonair embolism because of the adhesion of platelets to the bubble, as they had pointed out. However, endothelial cells are important because they can be damaged by bubbles that are small enough to pass through the blood circulation without obstructing the blood flow.

In contrast to laparotomy, laparoscopic surgery has several benefits such as improved and more rapid recovery, re-