Introduction

Perfluorocarbons are structurally similar to hydrocarbons with the hydrogen replaced by fluorine. The carbon chains vary in length and an additional moiety often is attached to the molecule which, together, give unique properties to each perfluorocarbon. In general, perfluorocarbons have excellent oxygen and carbon dioxide carrying capacity (50 mL O₂/dL and 160–210 mL CO₂/dL, respectively) [1]. They are clear, odorless, inert fluids which are immiscible in aqueous and most other solutions. They are relatively dense (1.7–1.9 g/mL), have a low surface tension (15–19 dynes/cm), and are relatively volatile with vapor pressures which range from 11 to 85 torr at 37°C. The vapor pressure of the individual perfluorocarbon governs the rapidity with which it evaporates from the lungs after intra-

Fig. 1. Representative antero-posterior radiograph of a 51 year old adult with pneumonia on extracorporeal life support (ECLS) following administration of perflubron during PLV. The lungs are well-inflated and radiopaque. (From [27] with permission)
tracheal administration. As is demonstrated in Fig. 1, perflubron (LiquiVent®, Alliance Pharmaceutical Corp., San Diego, CA), which is currently the perfluorocarbon most commonly used in clinical studies, is radiopaque, although this is not a characteristic of all of these fluids.

**Total and Partial Liquid Ventilation**

Clark and Gollan [2] first reported the ability to sustain gas exchange in the submerged, spontaneously perfluorocarbon-breathing mouse. The work of breathing, however, is markedly increased during spontaneous perfluorocarbon breathing because of the elevated resistance to flow of a fluid in the airways. For this reason, mechanical devices have been developed and tested in the laboratory to provide total liquid ventilation (TLV) in which the lungs are first filled to a volume equivalent to the functional residual capacity (FRC), approximately 30 mL/kg, and then ventilated with perfluorocarbon. Shaffer and Moskowitz [3], in 1974, documented that such a device could provide demand-regulated total liquid ventilation. In 1989, the first reports of the use of total liquid ventilation in humans were published [4, 5]. Three moribund, preterm newborns who had failed surfactant therapy were managed with TLV. Pulmonary compliance increased during the period of TLV. The gas exchange response was variable. However, this was the first demonstration of the ability to sustain gas exchange during TLV in humans. Although TLV is not being applied clinically at this time, research intending to further develop the technique of TLV is actively being performed [6].

In 1991, the first experience with partial liquid ventilation (PLV) in a normal rabbit model was reported [7]. With this technique, the lungs are filled with perfluorocarbon, in general to a volume equivalent to FRC, and then gas ventilated with a standard gas mechanical ventilator. The adequacy of perfluorocarbon dose is assessed during PLV by visually identifying a meniscus of perfluorocarbon within the endotracheal tube at end-expiration. There are many advantages to this technique over that of TLV: It does not require the use of a new device nor an understanding of the physics and physiology of fluid flows in the airways, endotracheal tube, and liquid ventilation device. Therefore, PLV can be relatively easily performed if one has an understanding of the ventilator management of critically ill patients with respiratory failure. A number of studies have demonstrated the efficacy of PLV in improving gas exchange in preterm neonatal; pediatric; and adult lung injury models which have included those induced by intravenous oleic acid administration, gastric acid aspiration, and saline lavage [8–13].

**Mechanisms of Liquid Ventilation**

The mechanisms by which gas exchange and pulmonary function are increased in the setting of liquid ventilation have been explored over the last few years. We [14] previously demonstrated the ability of total liquid, in comparison to gas ven-