Intensive Care Med (1988) 14:617–622

Intensive Care Medicine

A retrospective survey of treatment and mortality in aspiration pneumonia

K. G. Hickling[1] and R. Howard[2]

[1]Department of Intensive Care, Christchurch Hospital, Christchurch, New Zealand, and [2]Hospitals for Sick Children, Great Ormond Street, London, UK

Received: 15 December 1987; accepted: 25 April 1988

Abstract. A retrospective survey was conducted of all patients with severe aspiration pneumonitis requiring artificial ventilation in our Intensive Care Unit from 1982–1986 inclusive. Of 38 patients, 8 (21%) died. Five of these deaths were due to severe primary intracranial pathology, and occurred after complete or almost complete resolution of the pneumonitis. One death (2.5%) due to myocardial infarction was possibly related to aspiration, and 2 deaths (5%) were definitely related to aspiration. The 7.5% mortality related to aspiration is considerably lower than in previous clinical studies of severe aspiration pneumonia. There was only one death due to aspiration in patients under the age of 70. The mean arterial to alveolar oxygen tension ratio was 0.221, and the mean predicted mortality by apache II was 43%. Patients were managed with rapid intravascular volume restoration using crystalloid fluids, early ventilation, no steroids, and no immediate antibiotics. We conclude that with such management it is possible to achieve a low hospital mortality in severe aspiration pneumonia, particularly in young patients.

Key words: Aspiration pneumonia – ARDS – Treatment – Mortality – Fluid management

Most clinical studies of severe aspiration pneumonia have shown a high mortality, in the range of 30% to 82% [1–7]. Most deaths in these studies appear to be attributable to the aspiration rather than to the underlying illness. In one study [2], patients who had two or more lobes of the lung involved had a mortality of 90%. Many review articles, particularly those discussing aspiration pneumonia in association with anaesthesia, stress the importance of avoiding aspiration because of this very high mortality, and place little emphasis on treatment.

Many clinicians however, currently appear to believe that in their experience the mortality from this condition is very much lower than in these published studies. We were aware of very few patients in our Intensive Care Unit (ICU) who had died as a result of aspiration, and so undertook this retrospective study.

Patients and methods

The casenotes were scrutinised of all patients over 2 years of age who had aspiration pneumonia recorded as a diagnosis in the ICU admission/discharge book from 1982–1986 inclusive. Patients were included in the study if they fulfilled the following criteria: (1) They had a risk factor for aspiration such as impaired conscious level, bulbar function or neuromuscular function. (2) There had been a sudden (< 12 h) development of hypoxaemia, new infiltrates on chest x-ray, and either fever or leucocytosis. (3) Either the aspiration had been observed, or gastric contents had been suctioned from the endotracheal tube following intubation, or in the individual clinical setting the diagnosis of aspiration was virtually certain. (4) The patient had required artificial ventilation.

Details of the severity of the pneumonitis, treatment and hospital mortality were recorded for patients entering the study. Predicted mortality was calculated for each patient using the apache II scoring system [8].

Exclusions

Of the 57 patients who had aspiration recorded as a diagnosis during the study period, 13 were excluded either because the pneumonitis was not sufficiently severe to require ventilation, or because they did not meet all the other criteria. There were no hospital deaths in these patients.

Table 1. Data on the 38 study patients (means ± SD)

	PaO_2/FiO_2[a] (mmHg)	PaO_2/PAO_2[a] ratio	Max. temp. (°C)	Max. WBC ($\times 10^3$/cu·mm)
Before ventilation	139 ± 62	0.237 ± 0.113	38.4 ± 0.8	18.7 ± 7.1
After ventilation	136 ± 55	0.221 ± 0.096		

[a] PaO_2/FiO_2 = arterial oxygen tension to fractional inspired oxygen concentration ratio. PaO_2/PAO_2 ratio = arterial to alveolar oxygen tension ratio. "Before ventilation" values are the last values before ventilation was commenced. "After ventilation" values are the worst values within 48 h of commencement of ventilation. Maximum temperature and leucocyte count (WBC) are the highest values recorded from the time of aspiration up to 48 h following the commencement of ventilation

Table 2. Admission diagnoses in the 38 study patients

Diagnosis	Number
Head injury	5
Cerebral haemorrhage/infarct	2
Drug overdose	6
Anaesthetic related	8
Post-cardiac arrest	5
Epilepsy	2
Guillian Barré syndrome	2
Miscellaneous	8
Total	38

Table 3. Neurological deaths

1. 35 years. I.V. drug overdose-apnoea. Resuscitated. Remained vegetative, fitting. Lung function normal at 3 weeks. Died at 6 weeks
2. 68 years. Cerebellar infarction. Remained unconscious. Extubated at 6 days with near-normal lung function. Died day 15
3. 41 years. Subarachnoid haemorrhage. Rebleed on day 4 – brain death. Lung function near-normal
4. 68 years. Haematemisis. Developed dense right hemiparesis and obtundation post-op. Aspirated, ventilated. Deteriorated neurologically. Extubated on day 4 with near-normal lung function. Died day 7
5. 2 years. Meningitis – coma – aspiration. Lung function much improved by 24 h. Brain dead at 36 h

Three patients were excluded because on careful review it was felt that they had not had aspiration pneumonia, and they did not fulfill all of the criteria. There was 1 death in this group: a 72-year-old man who was admitted to hospital in a moribund condition with severe streptococcal pneumonia, septicaemia, shock and renal failure with a serum potassium of 7.8 mmol/l. He had a cardiac arrest shortly after admission to the ward, and was resuscitated, intubated, and admitted to the ICU. Because his oxygenation had deteriorated following this episode, the possibility of aspiration had been considered, but there was no evidence to support this, and his chest x-ray remained unchanged following the episode. He remained moribund and hypotensive and died shortly after admission to the ICU.

Three patients were excluded because their casenotes were lost. There was 1 death in these patients, recorded as being due to myocardial infarction. The patient had not been ventilated, so if he had aspirated it was presumably mild, and he did not meet the study entry criteria.

Results

The remaining 38 patients entered the study. Table 1 shows data on these patients relating to oxygenation, temperature and white cell count, and Table 2 shows the underlying diagnoses.

The mean predicted mortality (±SD) derived from apache II was 43% ± 24% using the patients' primary diagnosis and 42% ± 21% using aspiration as the diagnosis.

Seventeen patients had only one lobe involved radiologically, and 21 patients had involvement of 2 or more lobes.

Mortality

In total there were 8 hospital deaths (21%). This is significantly less than the 43% mortality predicted by apache II ($\chi^2 = 7.47$, $p < 0.01$). Only 3 deaths (7.5%) were considered to be related to aspiration.

Two of the 3 deaths related to aspiration were in patients with pneumonitis involving all areas of lung, and the third was in a patient with 4 lobe involvement. There were no deaths related to aspiration in patients with involvement of 3 lobes or less.

Five deaths (13%) were due to severe primary intracranial pathology, occurring after complete or almost complete resolution of the pneumonitis. We felt that these deaths were clearly unrelated to the aspiration. In no case was there a period of profound hypoxia subsequent to aspiration which we felt had contributed to the final neurologic outcome. Details of these patients are shown in Table 3.

Two deaths (5%) were due to aspiration. One was in a 33-year-old woman with Guillian Barré syndrome, who aspirated leading to severe Adult Respiratory Distress Syndrome (ARDS) ten days later. Extracorporeal CO_2 removal as described by Gattinoni [9] resulted in marked improvement in her respiratory failure but she died from a subarachnoid haemorrhage. The second was in a 78-year-old lady who died from septic shock 5 days after aspiration, having been initially treated with captopril and diuretics for 3 days for presumed heart failure before referral to the ICU.

One death may have been related to aspiration. This was in a 72-year-old man who aspirated following surgery and was ventilated. His pneumonitis had almost completely resolved by day 3, but he developed a myocardial infarction leading to a ventricular septal defect and cardiogenic shock, and died. We considered that the aspiration may have contributed to the development of his myocardial infarction.

Management

A policy of early referral had been encouraged in the hospital, and in 35 patients ventilation was commenced within 12 h of the episode of aspiration, and in 32 patients it was commenced within 6 h.

Fluid therapy consisted of rapid intravascular volume replacement with crystalloid fluids, guided by measurement of pulmonary capillary wedge pressure (PCWP) in a number of cases. In the adult patients the volume of fluid administered as normal saline or lactated Ringers solution in addition to maintenance fluids ranged from 0.75 to 7.5 l over the 24 h following admission to the ICU. Fluid was infused as required to improve blood pressure, skin perfusion and urine output, without increasing PCWP above 18 to 20 mm. Hg. After reaching a PCWP in this range, inotropic drugs were used if necessary. All PCWP measurements were made from a calibrated oscilloscope at end expiration without removing PEEP, with the transducer at mid chest position. No patients received colloid fluid. Diuretics were not used except in the one patient who developed a myocardial infarction and ventricular septal defect, and developed high wedge pressures.

No patients received steroids, and none received initial antibiotic therapy because of the aspiration, although 3 did so for other indications. 52% of patients received antibiotic therapy eventually, commencing at a mean of 4.4 days after aspiration, although this therapy was considered to be appropriate in only 36% of patients. In many patients bronchial brushings using the double sleeved protected specimen brush [10] were used to guide antimicrobial therapy.

Table 4. Mortality in aspiration pneumonia

Mendelson (1946)	0	
Awe et al. (1966)	70%	
Cameron et al. (1973)	62%	(90% if >1 lobe)
Bynum et al. (1976)	28%	(14% if $PaO_2/PAO_2 > 0.5$ 48% if $PaO_2/PAO_2 < 0.5$)
Wolfe et al. (1977)	30%	
Olsson et al. (1986)	38%	(in ventilated patients)
Baumann et al. (1986)	85%	
This study	21%	(total deaths)
	7.5%	(related to aspiration)

Discussion

Most clinical studies of aspiration pneumonia have reported a high mortality [1–7]. One of the most widely quoted studies [2] reported a mortality of 62% in 47 patients. If only 1 lobe was involved the mortality was 41%, but if 2 or more lobes were involved the mortality was 90%. Death was directly due to aspiration in 79% of the cases, related to aspiration in a further 17% and unrelated to aspiration in only 4%. Our patients had a mortality related to aspiration of 7.5% (3 of 38) overall, 14% (3 of 21) in patients with 2 or more lobe involvement, and O in those with 1 lobe involvement. Table 4 shows the reported mortality in other clinical studies. The absence of mortality in Mendelson's series in 1946 has not been explained, but there is no information on the severity of the pneumonitis or the management of these patients, and the result is difficult to interpret.

One of the difficulties in comparing mortality between published studies is that it is directly related to the severity of pneumonitis, as illustrated in the study by Cameron et al. [2] described above, and in that of Bynum et al. [3]. In the latter study the mortality was 28% overall, but in patients with an arterial to alveolar oxygen tension ratio (PaO_2/PAO_2 ratio) ≥ 0.5 the mortality was only 14%, whereas in those with a PaO_2/PAO_2 ratio < 0.5 the mortality was 48%. None of our patients had a ratio of > 0.5, and the mean of 0.237 was less than half this value.

In order to exclude patients with mild aspiration from the study we included only patients requiring artificial ventilation. Some patients who were unconscious due to intracranial pathology or drug overdose had been intubated for airway protection, and it is possible that some of these patients may not have received ventilation for their aspiration pneumonia had they not been unconscious. Six such unconscious patients had a PaO_2/PAO_2 ratio > 0.3, but none had a ratio > 0.38. Thus even these 6 patients had a severe pneumonitis and would have fallen well within the more severe group, with a mortality of 48%, in the study of Bynum et al. [3].

Unfortunately, most published studies on aspiration pneumonia have not specified the severity of the pneumonitis, but the majority have included a substantial number of patients not requiring ventilation. It does seem probable therefore, that the patients described in this study had a severity of pneumonitis at least as great as in most other published studies. The mortality of 43% predicted by the apache II scoring system is a further indication that the pneumonitis in this group of patients was severe.

There is unfortunately no specific diagnostic technique for aspiration pneumonitis, and the diagnosis is normally based on the sudden appearance of hypoxaemia, new infiltrates on chest x-ray, fever and leukocytosis following an observed episode of vomiting or regurgitation, in a patient who has a risk factor such as impaired conscious level. Aspiration of gastric contents from the trachea provides further evidence. In many patients however the episode of aspiration is not observed, but when the above clinical changes appear suddenly in a patient with previously normal lungs, in a setting such as a sedative drug overdose or general anaesthesia, it is virtually certain that the cause is aspiration.

We cannot be completely sure that in a few of our patients with head trauma, cerebral haemorrhage, or intravenous drug abuse, the lung consolidation was not due to neurogenic pulmonary oedema or ARDS from other causes, rather than aspiration. The reported mortality from these conditions is also high however, and even if such other aetiologies were present in a few patients this would not be expected to result in an artificially low mortality. There was little doubt about the diagnosis in the great majority of patients however.

Many aspects of management of this condition are controversial. There is still no universal agreement about the use of steroids, although several studies have shown a very high incidence of serious life-threatening infections in critically ill patients associated with the use of even a short course of steroids [4, 11, 12].

One of the main areas of controversy in this condition concerns fluid therapy. Some authors have argued that fluid restriction and diuretic therapy are desirable, in order to reduce blood volume and pulmonary microvascular pressure, and thus hopefully to reduce pulmonary oedema formation [13–16]. In support of this argument some studies have demonstrated a reduction in pulmonary oedema and improved gas exchange over a few hours, in various animal models of acute lung injury, following various forms of treatment achieving a reduction in lung microvascular pressure [17–19]. Other studies have failed to show any effect of such therapy on pulmonary oedema however [20–22].

It has been clearly demonstrated in a number of studies that aspiration pneumonia can result in quite profound hypovolaemia [1, 22–25] due to sequestration of fluid both in the lung and in systemic tissues [23]. Many authors and clinicians advocate fluid replacement therapy in order to restore blood volume and tissue perfusion towards normal [1, 22, 26–29].

Even if dehydration therapy does reduce pulmonary oedema and improve gas exchange in the short term, it is by no means certain that it will be beneficial in the long term. Indeed it could conceivably be detrimental and result in increased mortality. There are several reasons to consider this possibility:

1. Pulmonary oedema is only a symptom of the underlying lung injury, and it is unlikely that treating the pulmonary oedema will directly facilitate repair of the lung injury.

2. With modern supportive therapy patients with ARDS rarely die from pulmonary oedema. Deaths are usually due to sepsis or to progressive pulmonary fibrosis and pulmonary hypertension [30, 31], and following aspiration some early deaths probably occur due to profound hypotension and hypovolaemia.

3. Dehydration therapy will increase the hypovolaemia already present in many patients [1, 22–25], and thus decrease cardiac output, tissue perfusion and oxygen transport.

4. Hypovolaemic shock is clearly one of the factors which can lead to the development of ARDS. It seems quite conceivable that the addition of severe hypovolaemia to an aspiration injury may exacerbate the lung injury by further activation of mediators. It has been shown experimentally that hypoxia can act synergistically with complement activation leading to lung injury [32], and it is possible that hypovolaemia, resulting in tissue hypoxia, may act in a similar manner.

5. Recent work from several centres has demonstrated that in most patients with ARDS oxygen uptake ($\dot{V}O_2$) is dependent on oxygen delivery [33–35]. Thus a fall in cardiac output associated with dehydration therapy will likely result in a decrease in $\dot{V}O_2$, and this may result in tissue hypoxia and organ damage.

6. Popper et al. [36] demonstrated in a recent animal study that localised aspiration resulted in the presence in the lung of inflammatory mediators including activated complement components and prostaglandins, leading to generalised inflammation of all areas of the lung. This inflammation, and subsequent fibrosis, was almost completely prevented by kallikrein inhibitor given at the time of the aspiration. Thus much of the pneumonitis following aspiration appears to be a secondary effect due to the production of inflammatory mediators rather than a direct effect of the aspiration.

Manny et al. also demonstrated in a recent experimental study [23] that localised aspiration resulted in the production by the lung of thromboxane A_2, and this was present in very high concentrations in pulmonary oedema fluid. The authors felt that other inflammatory mediators were probably also produced. These substances resulted in inflammation and fluid sequestration in non-aspirated areas of lung and in systemic tissues, and at autopsy the aspirated and non-aspirated lung were indistinguishable. These mediators would presumably also be present in a high concentration in lung lymph. If dehydration therapy is successful in its goal of reducing lung microvascular pressure and fluid flux, it will reduce lung lymph flow and thus reduce the rate of lymphatic removal of inflammatory mediators from the lung interstitium. This may result in progressive lung injury in the long term even if pulmonary oedema is reduced in the short term.

It is also conceivable however, that the entry to the lung interstitium of precursors of inflammatory mediators in the pulmonary oedema fluid may accelerate the inflammatory process. If this is the case, then dehydration therapy may reduce this effect.

Thus aspiration pneumonia is a complex and incompletely understood condition, and whilst fluid therapy remains controversial it is at least possible that dehydration therapy may be detrimental to the lung in the long term. Virtually all experimental studies addressing fluid therapy in acute lung injury have been conducted for only a few hours, to assess the effect on pulmonary oedema.

Most clinical studies have not described fluid management. Long term studies are needed to assess the effect on the long term progression of the pneumonitis and on mortality. The results of this study tend to suggest that generous fluid replacement therapy is not detrimental.

The controversy concerning the use of crystalloid or colloid fluids in patients with acute lung injury is complex and will not be discussed, but many carefully conducted experimental studies using direct measurement of pulmonary extravascular water (PEVW) have shown that the choice of fluid made no difference to PEVW [22, 37–39].

Another factor which may have contributed to the low mortality in this study was the early use of ventilation, with 92% of patients having ventilation commenced within 12 h of aspiration, and 84% within 6 h. Cameron et al. have shown in an animal model [40] that the immediate use of ventilation for 6 h following aspiration reduced the mortality from 80% in the control group to 0 in the immediate ventilation group, even though most deaths in the control group occurred after several days, well after the ventilation period in the study group. Ventilation for the same duration but after a 24 h delay had no effect, the mortality remaining at 80%. The mechanism of this effect has not been explained. Henson's observation that hypoxia has a synergistic effect with complement activation in inducing lung injury [32], suggests that the early institution of ventilation may prevent hypoxia from inducing an acceleration of the inflammatory response following aspiration. Unfortunately no clinical studies have adequately addressed the question of whether this prophylactic effect of early ventilation occurs in humans following aspiration, and if so how soon ventilation must be instituted.

To our knowledge the mortality of 7.5% attributable to aspiration in this study is the lowest reported mortality in severe aspiration pneumonia requiring ventilation, and indeed it is much lower than in most reported studies including patients with less severe pneumonitis. We do not believe that these results are unique, and are aware of many other clinicians who also believe intuitively that mortality from this condition in their own Intensive Care Units is currently very low. Many recent reviews however continue to quote very high mortality figures for aspiration pneumonia, and therefore stress that prevention of aspiration is the only way to reduce mortality.

We suggest that the mortality from aspiration pneumonia can be very low, especially in young patients (only 1 patient under the age of 70 died from aspiration in this study). We also suggest that good early management including ventilation and adequate fluid replacement therapy may be important in achieving a low mortality, but more work is needed to determine the long-term consequences of different approaches to fluid and ventilatory management in this condition.

References

1. Awe WC, Flechter WS, Jacob SW (1966) The pathophysiology of aspiration pneumonitis. Surgery 60 (1):232
2. Cameron JL, Mitchell WH, Zuidema GD (1973) Aspiration pneumonia: clinical outcome following documented aspiration. Arch Surg 106:49
3. Bynum LJ, Pierce AK (1976) Pulmonary aspiration of gastric contents. Am Rev Respir Dis 114:1129
4. Wolfe JE, Bone RC, Ruth WE (1977) Effects of steroids in the treatment of patients with gastric aspiration. Am J Med 63:719
5. Justins DM (1984) A practice of anaesthesia. In: Churchill Davidson HC (ed). Lloyd-Luke, London, p 1047
6. Olsson GL, Hallen B, Hambraeus-Jonzon K (1986) Aspiration during anaesthesia: a computer-aided study of 185358 anaesthetics. Acta Anaesthesiol Scand 30:84
7. Baumann WR, Jung RC, Koss M, Boylen CT, Navarro L, Sharma OP (1986) Incidence and mortality of adult respiratory distress syndrome: a prospective analysis from a large metropolitan hospital. Crit Care Med 14:1

8. Knaus WA, Draper EA, Wagner DP, Zimmerman JE (1985) Apache II: a severity of disease classification system. Crit Care Med 13:818
9. Gattinoni L, Agostoni A, Pesenti A, Rossi GP, Vesconi S, Fox U, Kolobow T, Pelizzola A, Langer M, Uziel L, Longoni F, Damia G (1980) Treatment of acute respiratory failure with low frequency positive pressure ventilation and extracorporeal removal of CO_2. Lancet II:292
10. Wimberley N, Faling LJ, Bartlett JG (1979) A fibreoptic bronchoscopy technique to obtain uncontaminated lower airway secretions for bacterial culture. Am Rev Respir Dis 119:337
11. Demaria EJ, Reichman W, Kenney PR, Armitage JM, Gann DS (1985) Septic complications of corticosteroid administration after central nervous system trauma. Ann Surg 202:248
12. Poungvarin N, Bhoopat W, Viriyavejakul A, Rodprasert P, Buranasiri P, Sudkondhabhant S, Hensley MJ, Strom BL (1987) Effects of dexamethasone in primary supratentorial intracerebral haemorrhage. N Engl J Med 316:1129
13. Wood LDH, Prewitt RM (1981) Cardiovascular management in acute hypoxaemic respiratory failure. Am J Cardiol 47:963
14. Prewitt RM, Matthay MA, Ghignone M (1983) Haemodynamic management in the adult respiratory distress syndrome. Clin Chest Med 4:251
15. Simmons RS, Berdine GG, Seidenfeld JJ, Prihoda J, Harris GD, Smith JD, Gilbert TJ, Mota E, Johansen WG (1987) Fluid balance and the adult respiratory distress syndrome. Am Rev Respir Dis 135:924
16. Crandall ED, Staub NC, Goldberg HS, Effros RM (1983) Recent developments in pulmonary oedema. Ann Int Med 99:808
17. Prewitt RM, McCarthy J, Wood LDH (1981) Treatment of low pressure pulmonary oedema in dogs. Relative effects of hydrostatic and oncotic pressure, nitroprusside, and positive end-expiratory pressure. J Clin Invest 67:409
18. Broe PJ, Toung JK, Permutt S, Cameron JL (1983) Aspiration pneumonia: treatment with pulmonary vasodilators. Surgery 94:95
19. Gottlieb SS, Hansen DH, Wood LDH, Long GR (1986) The effect of nitroprusside on oedema and oxygen delivery in canine hydrochloric acid aspiration. Am Rev Respir Dis 134:A94
20. Yanos J, Curet-Scott M, Crawford G, Meller J, Wood LDH, Sznajder JI (1987) Reduced pulmonary vascular pressure and flow does not increase clearance of pulmonary oedema. Am Rev Respir Dis 135(4):A8
21. Sznajder JI, Zucker AR, Wood LDH, Long GR (1986) The effects of plasmapheresis and haemofiltration on canine acid aspiration pulmonary oedema. Am Rev Respir Dis 134:222
22. Peitzman AB, Shires GT, Illner H, Shires TG (1982) Pulmonary acid injury. Effects of positive end-expiratory pressure and crystalloid vs colloid fluid resuscitation. Arch Surg 117:662
23. Manny J, Manny N, Lelcuk S, Alexander F, Feingold H, Kobzik L, Valeri CR, Shepro D, Hechtman HB (1986) Pulmonary and systemic consequences of localised acid aspiration. Surg Gynaecol Obstet 162:259
24. Toussaint GPM, Chiu C, Hampson LG (1974) Experimental aspiration pneumonia: haemodynamics, ventilator and membrane oxygenator support. J Surg Res 16:324
25. Cameron JL, Caldini P, Toung JK, Zuidema GD (1972) Aspiration pneumonia: physiologic data following experimental aspiration. Surgery 72:238
26. Broe PJ, Toung TJK, Cameron JL (1980) Aspiration pneumonia. Surg Clin N Am 60:1551
27. Zorab JSM (1984) Pulmonary aspiration. Br Med J 288:1631
28. Chapman RL (1977) Treatment of aspiration pneumonitis. Int Anaesthesiol Clin 15:85
29. Cunningham AJ, Slazenger M (1984) Aspiration pneumonia – Mendelson syndrome; a review. Ir Med J 77:252
30. Pratt PC, Vollmer RT, Shelburne JD (1979) Pulmonary morphology in a multihospital collaborative extracorporeal membrane oxygenation project. I. light microscopy. Am J Pathol 95:191
31. Rinaldo JE, Rogers RM (1982) Adult respiratory distress syndrome. Changing concepts of lung injury and repair. N Engl J Med 306:900
32. Larsen GL, Webster RO, Worthen GS, Gumbay RS, Henson PM (1985) Additive effect of intravascular complement activation and brief episodes of hypoxia in producing increased permeability in the rabbit lung. J Clin Invest 75:902
33. Kariman K, Burns SR (1985) Regulation of tissue oxygen extraction is disturbed in adult respiratory distress syndrome. Am Rev Respir Dis 132:109
34. Danek SJ, Lynch JP, Weg JG, Dantzker DR (1980) The dependence of oxygen uptake on oxygen delivery in the adult respiratory distress syndrome. Am Rev Respir Dis 122:387
35. Mohsenifar Z, Goldbach P, Tashkin DP, Campisi DJ (1983) Relationship between oxygen delivery and oxygen consumption in the adult respiratory distress syndrome. Chest 84:267
36. Popper H, Juettner F, Pinter J (1986) The gastric juice aspiration syndrome (Mendelson syndrome). Aspects of pathogenesis and treatment in the pig. Virchows Arch 409:105
37. Baudendistel L, Dahms TE, Kaminski DL (1982) The effect of albumin on extravascular lung water in animals and patients with low-pressure pulmonary oedema. J Surg Res 33:285
38. Sturm JA, Carpenter MA, Lewis FR, Graziano C, Trunkey DD (1979) Water and protein movement in the sheep lung after septic shock: effect of colloid versus crystalloid resuscitation. J Surg Res 26:233
39. Sturm JA, Wisner DH (1985) Fluid resuscitation and hypovolaemia. Intensive Care Med 11:227
40. Cameron JL, Sebor J, Anderson RP, Zuidema GD (1968) Aspiration pneumonia. Results of treatment by positive pressure ventilation in dogs. J Surg Res 8:447

Dr. K. G. Hickling
Department of Intensive Care
Christchurch Hospital
Christchurch
New Zealand