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Acute severe asthma treated by mechanical ventilation: a comparison of the changing characteristics over a 17 yr period

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Recorded cases of asthma have increased in recent years. It is unclear, however, whether this apparent increase in prevalence is accompanied by an increase in severity of the disorder. One potential measure of asthma severity is the requirement for mechanical ventilation. This paper examines those patients ventilated for severe asthma in a district general hospital over a 17 yr period. Since the methods used to assess asthma attacks and the criteria for instituting mechanical ventilation in this hospital did not alter between 1973 and 1992 (Jones criteria), it was possible to compare directly characteristics of all ventilated patients during the study period.

The comparison showed that there was a significant increase between the two study periods in the number of patients who required mechanical ventilation. Moreover, in the more recent period both the subjective speed of onset of the asthma attack and the objective time between admission and ventilation were significantly shorter. However, despite this increase in asthma severity the mortality and morbidity in the more recent study period were lower.

Overall the results of this study support the view that, in the population served by our district general hospital, asthma has increased in severity. This increased severity is indicated by an increase in the number of patients requiring mechanical ventilation and in the rapidity with which attacks evolved. However, for patients in whom ventilation was required, improved care has lowered both morbidity and mortality.

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Introduction

Whiston hospital has a long history of interest in acute asthma. In 1983, a retrospective study from this unit detailed the characteristics of those patients who had required mechanical ventilation for acute severe asthma during the preceding 10 yr (1). The criteria for mechanical ventilation employed during that period were those defined by Jones (2); those criteria are still employed at this hospital. This allows us to compare directly the characteristics of the patients from the period 1973 to 1983 with those requiring ventilation in the present study period.

The present paper concerns asthmatics admitted to Whiston Hospital for the 7 yr period between 1986 and 1992. We report the clinical features of all patients who required mechanical ventilation for severe asthma during this latest period. These features are compared with those of the patients reported in our previous study.

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The prime objective of the present study was to determine whether any changes had occurred in the prevalence or severity of asthma in our patient population. The second objective was to determine whether changes instituted in the management of ventilated patients introduced since the previous paper have been effective in reducing morbidity or mortality.

Methods

DATA COLLECTION

A database detailing the characteristics of all asthmatics ventilated at this hospital has been maintained since 1986. In our unit asthma is defined as bronchial hyperresponsiveness with a greater than 15% improvement in FEV_1 either spontaneously or after bronchodilators. Patients fulfilling the criteria for COPD, i.e. sputum production and cough for more than 3 months per year for 2 or more years, were excluded from the study.

All patients in the database are included in this paper. Certain parts of the study required additional information not collected at the time of admission; these data were

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obtained retrospectively from case notes, supported when required by direct interview. If information on a particular aspect was unavailable the patient was excluded from that part of the study; where this was the case, the number of patients considered is given in parentheses.

CRITERIA FOR VENTILATION

Assessment for admission to the intensive care unit was as previously described by Jones (2). Patients considered for mechanical ventilation were those with grade 2b asthma of longer than 8 h duration, grade 3 asthma or grade 4 asthma. Grade 2b refers to the patient who is largely confined to bed and can only get up with great difficulty. Grades 3 and 4 refer to patients who are immobilized by their disease, the distinguishing feature in the latter group being exhaustion.

The decision to ventilate a patient was either immediate or delayed. Indications for immediate positive pressure ventilation included cardiorespiratory arrest, severe exhaustion (with or without carbon dioxide retention), impaired consciousness and hypoxic confusion. Patients in whom ventilation was delayed were treated with 'stage 1' therapy. This comprised humidified oxygen, rehydration, nebulized salbutamol 5–10 mg every 2–6 h, high-dose systemic steroids and aminophylline infusion 0·6 mg kg^{-1} h^{-1}. Ventilation was then instituted if clinical parameters deteriorated, as judged by increasing heart rate, worsening peak expiratory flow (PEF), worsening gas exchange or if exhaustion developed despite these measures.

TREATMENT OF THE VENTILATED PATIENT

This aspect of care has changed significantly since 1983. Our present management is outlined below.

Initiation of Ventilation

Patients were always anaesthetized by experienced personnel. Prior to this, adequate hydration was ensured by the administration of intravenous fluid, and the stomach was emptied by insertion of a nasogastric tube. Patients were pre-oxygenated and then induced using the gas induction technique.

Ventilation

The patients were ventilated by controlled mandated ventilation (CMV) and the ventilator settings were adjusted to a respiratory rate of about 10 with a tidal volume set to maintain the peak airways pressure less than 40 cmH_2O. Compliance was ensured by infusions of propofol and a muscle relaxant. The inspiratory to expiratory ratio was usually 1:3. The percentage of oxygen administered was altered to achieve an arterial PaO_2 above 8 kPa. The aim of this regime was to minimize barotrauma by maintaining the peak airways pressure below 40 cmH_2O irrespective of the carbon dioxide level. This differs from the practice in the previous study in which CO_2 levels were actively reduced by tidal volume adjustments which frequently resulted in high airway pressures. CMV was continued until the ventilator pressures and arterial blood gases were within normal range. Weaning was achieved firstly by using synchronized intermittent mandatory ventilation followed by spontaneous breathing with the endotracheal tube in place.

Bronchial Toilet

Since the last paper bronchial lavage has been almost completely replaced by bronchoscopy without lavage. Flexible bronchoscopy was widely used to clear mucous plugs and excess secretion in patients requiring ventilation, especially if the peak airways pressure remained high. Bronchoalveolar lavage was reserved for those patients in whom the peak airways pressure remained high despite bronchoscopy. It was also used when severe air trapping developed indicating a risk of cardiac tamponade.

Medical Treatment

Conventional medical treatment for stage 1 management was continued and consisted of intravenous hydrocortisone, aminophylline and nebulized salbutamol.

Results

ADMISSION RATES AND REQUIREMENT FOR MECHANICAL VENTILATION

Whiston Hospital serves a population of approximately 340 000, a population that has remained stable from 1974 to 1992 (data provided by Public Health Department, St Helens and Knowsley Region). Between 1986 and 1992, 50 patients, from the area served by our hospital, required mechanical ventilation for the treatment of severe asthma. Of these, two patients were ventilated on more than one occasion resulting in a total of 52 episodes of ventilation during the 7 yr period. This represents just over seven episodes of ventilation each year. During our previous study, performed between 1974 and 1983, a total of 32 patients were ventilated on 34 occasions. This represents a mean annual rate of less than four patients per year. The data for the total time period are presented in Fig. 1. This reveals a significant increase in the number of patients requiring ventilation during the period 1986–1992 compared with the previous period 1974–1983 ($T = P<0·05$, Mann–Whitney test). In line with national trends (3–5) the number of admissions for the treatment of asthma also increased during this period (Fig. 2) but this increase was not statistically significant ($P<0·1$, Mann–Whitney test).

VENTILATED PATIENTS: CHARACTERISTICS AND EVOLUTION OF THE ASTHMA ATTACK

The characteristics of the patients ventilated on ITU between 1986 and 1992 were analysed. All the patients reviewed in this study fulfilled the criteria for asthma

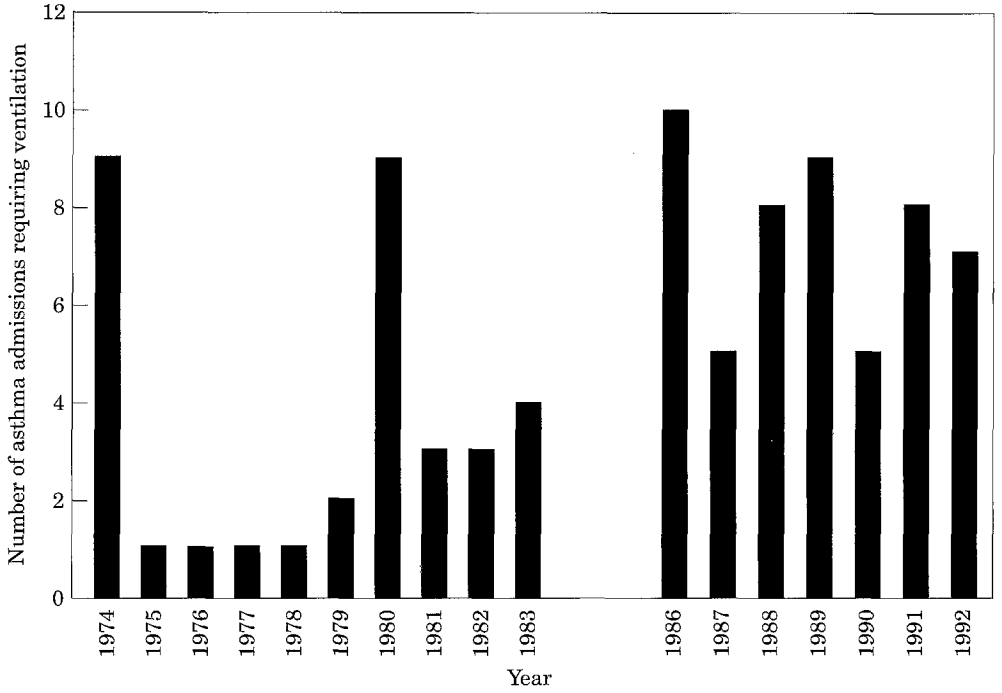

FIG. 1. Asthmatic patients admitted to intensive care for ventilation, 1974–1983 and 1986–1992. There was a significant increase in admissions between the two periods ($P<0{\cdot}05$, Mann–Whitney test).

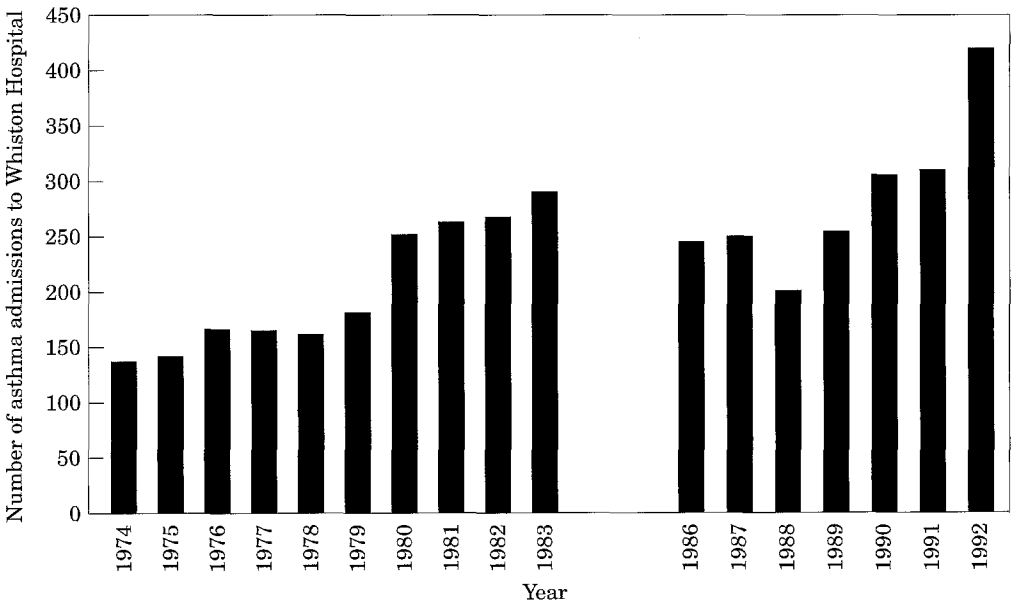

FIG. 2. Asthmatic admissions to Whiston Hospital 1974–1983 and 1986–1992. A trend for admissions to increase is apparent, but the increase between the two separate study periods was not significant ($P<0{\cdot}1$, Mann–Whitney test).

described in Methods. Spirometry data for the period preceding the ventilation episode was available in 42 patients. Thirty-one of these patients had normal spirometry between their asthma attacks, although three of the patients required regular oral steroids to maintain FEV_1. The remaining 11 patients demonstrated suboptimal FEV_1 between asthma attacks despite regular oral steroids. For the eight patients in whom spirometry was not available before the episode of ventilation, the diagnosis of asthma was confirmed subsequently. Five of the patients smoked but none of the patients considered in this study gave a history of COPD.

Where possible, we compared the present patient characteristics with equivalent data available from the previous study. We found that patient age, sex or the length of history of asthma did not differ significantly between the two periods (Table 1), supporting the view that the increase in severe asthma did not reflect any change in the

TABLE 1. A comparison of the characteristics of the patient populations admitted to ITU in the two periods of study

	1974–1983	1986–1992
Mean age (range) (years)	39·9 (16–72)	39 (15–71)
Percentage female	72%	76%
Length of history of asthma		
>5 yr	59%	74%
1–5 yr	29%	17%
<1 yr	12%	9%

TABLE 2. A comparison of the use of steroids in the two study periods

	1974–1983 (n=32)	1986–1992 (n=37)	P value
Inhaled	22%	75%	<0·01
Oral	18%	43%	<0·05

characteristics of the population served by the hospital. However, those patients admitted since 1986 were significantly more likely to have received inhaled or systemic steroids prior to admission to hospital (Table 2).

The objective indicators of severity for the asthma attack requiring mechanical ventilation were analysed (Table 3). The pulse rate and frequency of hypercapnia at the time of ventilation did not differ significantly between the two study periods; this is expected since the criteria for mechanical ventilation were not altered between 1974 and 1992. However, the interval between the subjective onset of the asthma attack and the institution of ventilatory support (mean duration of attack) differed significantly, falling from approximately 8 days in 1974–1983 to 4 days during 1986–1992 (P<0·01, unpaired t test).

Moreover, when the evolution of asthma attacks during the two study periods was examined, we found that a greater proportion of patients required ventilatory support immediately on arrival at hospital in the more recent period. These data suggest a more rapid evolution of the asthma attack, a view confirmed by the statistically significant finding that more patients required ventilation within 24 h of the subjective onset of asthmatic symptoms (Fig. 3) (P<0·05, χ^2 test).

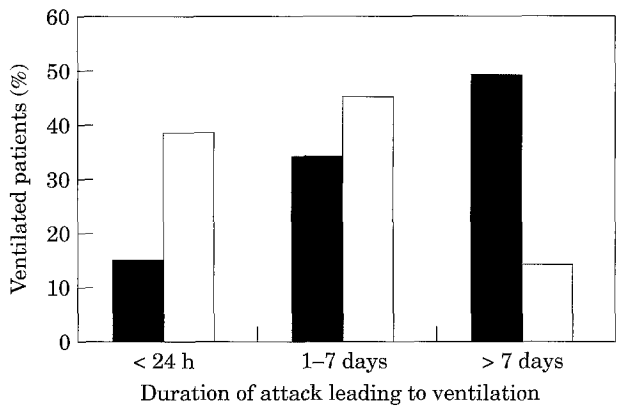

FIG. 3. Duration of the attack that resulted in ventilation for the two studies: ■, 1974–1983; □, 1986–1992.

RESOLUTION OF THE ASTHMA ATTACK AND COMPLICATIONS OF VENTILATION

A number of important changes to the management of the ventilated patient were made after 1984 (see Methods). Thus we were able to compare the duration and complications of ventilation in the two study periods. The duration of mechanical ventilation in the more recent study was less than that in the previous period but this was not significant (Table 4).

Although the incidence of complications in both studies was relatively low, our results suggest an improved outcome for ventilated asthmatics using the more recent management protocols. There was only one death during ventilation in the current study period; this compares with three deaths in the previous 10 yr period. Furthermore, the overall complication rate measured in terms of respiratory infection, pneumothorax or gastrointestinal bleeding was reduced. Three patients, including the patient who died, required prolonged mechanical ventilation for between 2 and 3 weeks; these patients had additional medical conditions complicating their asthma.

CHARACTERISTICS OF ASTHMA AFTER VENTILATION

In the 26 patients for whom data were available, we compared the peak flow and steroid dosage 6 months before and 6 months after ventilation, ensuring that the patients were subjectively stable at the time of analysis.

TABLE 3. A comparison of the characteristics of the asthma attack immediately preceding ventilation in the two study periods

	1974–1983	1986–1992
Mean duration of attack (days)	8·6 (SD 8·5)	4·25 (SD 4·89)
Immediate ventilation	35% (n=34)	50% (n=38)
Mean pulse prior to ventilation	139	134
Percentage with hypercapnia	72% (n=18)	74% (n=38)

TABLE 4. A comparison of the course and outcome of ventilatory care on the ITU between the two study periods

	1974–1983	1986–1992
Mean and range of duration of ventilation (days)	4·9 (17 h–23 days)	3·78 (12 h–25 days)
Complications		
Respiratory infection	12 (35%)	7 (14%)
Pneumothorax	6 (18%)	2 (4%)
GI bleed	3 (9%)	1 (2%)
Mortality	3	1

In terms of FEV_1 24/26 patients had a similar or improved FEV_1 6 months after the episode of ventilation. Moreover, during the present study period only two of 50 patients were ventilated on more than one occasion. In terms of steroid dosage 15/26 were receiving the same or reduced dose, while in 11/26 the dose was increased.

Discussion

Around 3 million people in the U.K. have asthma and it is generally accepted that, at least in certain geographical areas, the prevalence of asthma is increasing (6–9). Actual prevalence figures for adults are difficult to assess; however, the most recent figure from the Department of Health is quoted at about 4% (10). It is also a widely held perception that this increased prevalence is accompanied by increased severity (8,9). Since the late 1970s the death rate from asthma has increased. The rate reached its peak in the late 1980s with around 2200 patients dying from asthma. Since this time there has been a definite downward trend in the asthma deaths. The most recent figure, from 1994, is 1665 (3). However, it is unclear whether this reduction in asthma mortality reflects a reduced severity of asthma or an improvement in the overall management, in particular ventilation of severe asthmatics.

Arriving at a clear picture of asthma severity has, however, proved difficult for several reasons. First, increasing awareness of the condition in recent years has almost certainly led to an increased rate of diagnosis (6,11). Second, objective assessment of the severity of asthma within a population is difficult. However, the consistent application of the same ventilation criteria for the asthmatic over a prolonged period in this hospital has allowed us to employ the requirement for mechanical ventilation as an objective measurement of asthma severity.

The present study shows that at Whiston hospital between the periods 1974–1983 and 1986–1992 there was an increase in the annual number of patients requiring ventilation for the treatment of severe asthma. This increased requirement for mechanical ventilation parallels but exceeds an apparent increase in total hospital admissions for the treatment of asthma during the same period. Since the beginning of the study period in 1974 the total population served by Whiston Hospital has remained stable at around 340 000, and as far as can be established there has been no significant cross-boundary flow during the period (Public Health Department, St Helens and Knowsley Region, personal communication).

In older patients the differentiation of chronic asthma from COPD may be difficult, and patients with COPD may be incorrectly diagnosed as having asthma. Theoretically, the inclusion of such patients in the asthma database would have altered the composition of the two patient populations studied and consequently affected the validity of the results. However, through the application of strict diagnostic criteria in the two study periods we are confident that the two patient groups are comparable and contain only patients with asthma.

Overall therefore we feel that our findings suggest the incidence of severe asthma in our population has increased over the 17 yr study period. Total asthma admissions to the hospital between 1974 and 1992 did not show a statistically significant change, but the apparent increase trend agrees with the experience in other reported studies (5,7,8). However, in terms of the requirement for ventilation, there was a significant increase from four ventilation episodes per year in the previous study period to seven for the recent period.

In addition to the increased number of asthmatics requiring ventilation, our study also shows that the evolution of attacks of asthma was more rapid in the recent period. A higher proportion of patients required ventilation within 24 h of onset of their asthma attack, and an increased number required ventilation immediately on admission to hospital, suggesting a very rapid worsening of their condition. While we are aware that patient-reported duration of attack can be unreliable (12), such a problem would have affected both study periods and therefore is unlikely to be a major factor.

The reasons underlying this apparent increase in asthma severity cannot be determined from our data. The one significant difference that was apparent between the two patient groups related to steroid therapy. In the more recent period there was a very clear increase in the number of patients receiving both inhaled and oral steroid therapy immediately prior to their admission. The increased use of steroids in the treatment of asthma has been part of a specific policy in this hospital (1) and follows national treatment trends (13–15).

There are no data to suggest that there is any casual relationship between increased requirement for ventilation and the use of steroids; indeed, we would suggest that our increased need for ventilation is occurring despite improved treatment regimes. However, one may speculate that inhaled or oral steroids may have altered the natural history in some way. Indeed, it is possible that the increased numbers requiring ventilation or the apparent speed of onset of the severe attack may reflect an increased reliance on oral steroids by both the patient and the GP, leading to delayed hospital presentation. Two factors count against this, however. Firstly, the increasing numbers of patients being admitted to hospital, both in our study and other studies, do not support the idea that patients stay at home. Secondly, the availability of an open access asthma clinic run by experienced staff, means that our patients are well informed and are readily admitted to hospital.

An alternative reason for the increase in ventilation is that seriously ill patients who would previously have died in the community are now reaching hospital and being ventilated. However, there is no evidence of a reduction in the asthma death rate of the population served by the hospital to support such a theory (date from Office of National Statistics). We suggest therefore that the finding of an increased requirement for ventilation among our asthmatic population represents a genuine increase in severity.

An encouraging aspect of this study is that it has identified a clear improvement in the outcome of ventilation for acute severe asthma. Improved mechanical ventilation techniques and the use of prophylaxis against major complications (detailed in the Methods) have led to a reduction in both morbidity and mortality. The sole ventilatory death during the recent period occurred in a patient with coexistent medical problems. It has been stated that mechanical ventilation for the acute asthmatic can be associated with a significant mortality (16); however, this is not our experience. Our study shows that mechanical ventilation of the severe asthmatic is a safe procedure, sentiments that have been confirmed by others (17). Moreover analysis of re-admission rates and of FEV_1 after ventilation suggest that no worsening of asthma occurs after the ventilation episode, although steroid dose was increased in a proportion of patients 6 months after ventilation, perhaps reflecting caution on the part of the doctor or patient.

In conclusion, we have shown that in our patient population there appears to be an increased severity of asthma attacks, as determined by the requirement for mechanical ventilation. This increase has occurred despite more widespread use of inhaled and oral steroid therapy. We have also confirmed, however, that, when required, ventilation is an effective and safe procedure and is not associated with any deterioration in respiratory function.

References

1. Luksza AR, Smith P, Coakley J. Acute severe asthma treated by mechanical ventilation: 10 years experience from a district general hospital. *Thorax* 1986; **41:** 459–463.
2. Jones ES. The intensive therapy of asthma. *Proc R Soc Med* 1971; **64:** 1151–1152.
3. National Asthma Campaign. *National Asthma Audit 1996.*
4. Office of Health Economic. *Asthma*, Studies of Current Health Problems No. 95. London: Office of Health Economics, 1990.
5. Fleming DM, Crombie DL. Prevalence of asthma and hay fever in England and Wales. *Br Med J* 1987; **294:** 279–283.
6. Britton J. Asthma's changing prevalence. *Br Med J* 1992; **304:** 857–858.
7. Capewell S. Asthma in Scotland: epidemiology and clinical management. *Health Bull Edinburgh* 1993; **51:** 118–127.
8. Weitzman M, Gortmaker SL, Sobol AM, Perin JM. Recent trends in the prevalence and severity of childhood asthma. *J Am Med Assoc* 1992; **268:** 2673–2677.
9. Baldwin DR, Ormerod LP, MacKay AD, Stableforth DE. Changes in hospital management of acute severe asthma by the thoracic and general physicians in Birmingham and Manchester during 1978 and 1985. *Thorax* 1990; **45:** 130–134.
10. Department of Health. *Asthma – an Epidemiological Overview*. London: HMSO, 1995.
11. Peat JK, Haby M, Spijker J, Berry G, Woolcock AJ. Prevalence of asthma in adults in Busselton, Western Australia. *Br Med J* 1992; **305:** 1326–1329.
12. Bellamy D, Collins JV. 'Acute' asthma in adults. *Thorax* 1979; **34:** 36–39.
13. Sheffer AL, Taggart VS. The National Asthma Education Program. Expert panel report guidelines for the diagnosis and management of asthma. National Heart, Lung, and Blood Institute. *Med-Care* 1993; **31** (Suppl. 3): MS20–MS28.
14. British Thoracic Society, Research Unit of the Royal College of Physicians of London, Kings Fund Centre, National Asthma Campaign. Guidelines for management of asthma in adults: 1 — chronic persistent asthma. *Br Med J* 1990; **301:** 797–780.
15. Rees J, Price J. ABC of asthma. Treatment of chronic asthma. *Br Med J* 1995; **310:** 1459–1463.
16. Finfer SR, Garrard CS. Ventilatory support in asthma. *Br J Hosp Med* 1993; **49** (5): 357–360.
17. Dacht ER, Lingo S, St John RC. Clinical features, management and outcome of patients with severe asthma admitted to intensive care. *J Asthma* 1995; **32** (5): 373–377.