Risk factors and costs associated with an asthma attack

G Hoskins, C McCowan, R G Neville, G E Thomas, B Smith, S Silverman

Abstract

***Background*—A study was undertaken to identify asthma patients at risk of an attack and to assess the economic impact of treatment strategies.**

***Methods*—A retrospective cohort analysis of a representative data set of 12 203 patients with asthma in the UK over a one year period was performed. Logistic multiple regression was used to model the probability of an attack occurring using a set of categorised predictor factors. Health service costs were calculated by applying published average unit costs to the patient resource data. The main outcome measures were attack incidence, health service resource use, drug treatment, and cost estimates for most aspects of asthma related health care.**

***Results*—Children under five years of age accounted for 597 patients (5%), 3362 (28%) were aged 5–15 years, 4315 (35%) 16–44, 3446 (28%) 45–74, and 483 (4%) were aged over 74 years. A total of 9016 patients (74%) were on some form of prophylactic asthma medication; 2653 (22%) experienced an attack in the year data collection occurred. Overall health care expenditure was estimated at £2.04 million. The average cost per patient who had an attack was £381 compared with £108 for those who did not, an increase of more than 3.5 times. In those aged under five and those over 75 years of age there were no significant markers to identify risk, but both groups were small in size. The level of treatment step in the British Thoracic Society (BTS) asthma guidelines was a statistically significant factor for all other age groups. Night time symptoms were significant in the 5–15, 16–44 and 45–74 age groups, exercise induced symptoms were only significant for the 5–15 age group, and poor inhaler technique in the 16–44 age group.**

***Conclusions*—Patients at any treatment step of the BTS asthma guidelines are at risk of an asthma attack, the risk increasing as the treatment step increases. Poorly controlled asthma may have a considerable impact on health care costs. Appropriate targeting of preventive measures could therefore reduce overall health care costs and the growing pressures on hospital services associated with asthma management.**

(*Thorax* 2000;**55**:19–24)

Keywords: asthma; BTS guidelines; treatment; cost

Tayside Centre for General Practice, University of Dundee, Kirsty Semple Way, Dundee DD2 4AD, UK
G Hoskins
C McCowan
R G Neville
B Smith

Department of Mathematics, University of Dundee, Dundee DD1 4HN, UK
G E Thomas

Astra Zeneca plc, Alderley House, Alderley Park, Macclesfield, Cheshire SK10 4TF, UK
S Silverman

Correspondence to:
Mrs G Hoskins, Tayside Centre for General Practice, University of Dundee, Dundee DD2 4AD, UK

Received 11 March 1999
Returned to authors 28 May 1999
Revised manuscript received 13 September 1999
Accepted for publication 27 September 1999

Asthma is a major health care problem. Increasingly common, with high morbidity, it can be fatal.[1–4] It is the commonest cause of acute medical admission in childhood and has a major impact on acute hospital services for adults.[5 6] Anti-asthma medications constitute a major proportion of all drugs prescribed in general practice,[7] and the cost to the UK health service is estimated to be in excess of £500 million a year.[8]

Those who experience an acute attack or persisting asthma symptoms can lose time from work or school and experience impaired quality of life.[9] In the UK over 17 million working days are lost every year due to asthma, with the total annual cost to the UK economy estimated at over £1 billion.[8]

Effective treatments for the management of asthma are available and the outcome of an attack can be influenced by medical intervention.[10] Guidelines for the management of asthma have been recommended to assist health professionals to provide the best possible care and reduce morbidity.[11] The British Thoracic Society (BTS) asthma guidelines and Global Initiative in Asthma (GINA) guidelines have placed treatment in a stepwise form for easier use. A rapid response to deteriorating symptoms by increasing prophylaxis is not only beneficial for the individual patient but also has potential consequences for health service resources.[10]

The availability of a large, UK wide, data set on the management of asthmatic patients in general practice[12 13] provided the opportunity to highlight identifiable factors common to those patients most at risk of an asthma attack. Knowledge of the shared characteristics of patients who have experienced an attack may allow targeting of, and management changes in, patients with similar features at an earlier stage, thus reducing the chances of an attack. This may not only improve the quality of treatment provided to asthma patients, but also increase their faith in health care and allow for a more judicial use of resources.

The purpose of this study was therefore to identify the health service utilisation patterns of a representative sample of UK asthmatic patients observed over a 12 month period. By matching patient resource use patterns with published unit cost data, cost estimates for different aspects of asthma health care could be constructed and a theoretical projection of the economic impact of managing "at risk" patients devised.

Methods

The UK wide National Asthma Management Study,[12] contributing 11 249 (92%) patients,

and the Tayside Asthma Management Initiative,[13] contributing 954 (8%) patients, involved an audit of general practice asthma management. Participating practices, a representative UK sample, recorded information relating to 30 patients randomly selected from their asthma register (a list of randomised numbers and a protocol on their use was provided by the research unit), and all 30 patients were invited to undergo a clinical assessment of their asthma status. The databases from both studies were combined to establish a database of 12 203 patients with asthma in which retrospective information on resource use within a 12 month period was recorded. This included the number of patient initiated general practice consultations and the number of asthma review consultations by the general practitioner (GP) or practice nurse, admission to hospital and length of stay, attendance at Accident & Emergency (A&E) and outpatient departments, number of asthma attacks, emergency nebulisations, and short courses of systemic steroids. In addition, all prescribed asthma medication was recorded and subsequently a treatment step from the BTS asthma guidelines was assigned to each patient. Information from the study on clinical assessment, carried out with the aid of the Tayside Asthma Assessment stamp,[12 13] was also recorded. Using a score from 0 to 3 (3 being most severe), this gives details of the presence of night time, early morning, or exercise induced symptoms in the month before assessment; the number of days off due to asthma in the same period; a subjective assessment of medication compliance as satisfactory or unsatisfactory, based on questioning of the patient during review and knowledge of prescribed medication over the previous 12 month period; peak expiratory flow (PEF) at the time of the review; inhaler technique assessed by the health professional during the review and categorised as satisfactory or unsatisfactory; and arrangements for follow up review.

The database was used to identify and evaluate the risk factors which were associated with an asthma attack. The General Practitioners in Asthma Group (GPIAG) definition of an attack was used: "an episode of respiratory symptoms which prompts an urgent consultation with a doctor, is of sufficient severity to prevent the patient working/attending school/performing domestic duties/playing and results in increased use of anti-asthma medication".[12 14 15]

For this analysis patients were grouped by age: under 5 years, 5–15, 16–44, 45–74, 75 years or more. Logistic multiple regression was used to model the probability of occurrence of an asthma attack using a set of categorised predictor factors which included treatment step in the BTS guidelines, night time symptoms, early morning symptoms, exercise induced symptoms, sex, possession of a self-management plan, ownership of a peak flow meter, poor treatment compliance, and poor inhaler technique.

Effects for dichotomous predictor factors are presented by means of the ratio of the attack odds for the presence level to the absence or reference level of the factor. For the BTS treatment step, step 0 was taken as the reference level and odds ratios were obtained for steps 1 to 5. Step 0 was selected as it was the most appropriate approximation to absence of attacks. Approximate 99% confidence intervals for the odds ratio are also given. A confidence interval not including 1 provides evidence of some effect on attack occurrence when that level of the risk factor is compared with the reference level.

In addition, the data on resource use, together with data on published unit costs,[16–19] were used to cost the pattern of health care for each patient. Patient costs were calculated by pricing each individual item of resource use—namely, every consultation, each specific drug, all hospital contacts and, where applicable, length of hospital admission. Where source data values were incomplete, a mean cost per patient for that value was determined from all patient records in the database. This was necessary for only one value—length of hospital stay.

A comparison of health care costs between patients who had an asthma attack and those who did not was made using the difference and ratio of mean costs, along with appropriate confidence intervals for these quantities. To allow for the highly skewed cost distributions, the bootstrap method with 2000 resamples was used to obtain these confidence intervals.[20] Where both sample sizes were very large, normal based large sample results could be used for the difference in means.

Results

Three hundred and sixty one practices from throughout the UK participated in the National Asthma Management Study and provided details on 11 249 patients. A further 954 patients were recruited from the 32 practices who participated in the Tayside Asthma Management Initiative, giving a representative cohort of 12 203 patients. The 393 practices that participated in the two studies represented a total population base of 2 568 783. The 8% of patients from the Tayside study had comparable results to the larger national study.[13]

PATIENTS

The demographic details of the patients and the results of treatment are summarised in tables 1–6. Half of the cohort were male; 74% were on step 2 or above of the BTS asthma guidelines and 2653 (22%) had experienced at least one asthma attack during the year of data collection. Patients in the under five age group had the highest incidence of attacks (37%) and used other health care services most often. A total of 9625 patients (79%) attended for the clinical assessment connected to the audit. Secondary care use was similar for those who attended the study clinical review and those who did not. The average length of inpatient stay was 4.04 days. Poor compliance with medication was recorded for 16% of the patient sample and 9% had poor inhaler technique.

Table 1 Age breakdown of study variables

	Age groups (years)					
	<5	*5–15*	*16–44*	*45–74*	*75+*	*Total*
No. of patients	597 (5%)	3362 (28%)	4315 (35%)	3446 (28%)	483 (4%)	12 203
No. who had an attack	221 (37%)	697 (21%)	809 (19%)	794 (23%)	132 (27%)	2653(22%)
No. who did not have an attack	376 (63%)	2665 (79%)	3506 (81%)	2652 (77%)	351 (73%)	9550(78%)
Hospital contacts within previous 12 months						
Admitted	80 (13%)	78 (2%)	91 (2%)	109 (3%)	24 (5%)	382(3%)
A&E attendance	63 (11%)	94 (3%)	125 (3%)	75 (2%)	9 (2%)	366(3%)
Outpatient attendance	93 (16%)	180 (5%)	139 (3%)	294 (9%)	35 (7%)	741(6%)
Attended for study review	469 (79%)	2742 (82%)	3052 (71%)	2950 (86%)	412 (85%)	9625(79%)
Practice consultations						
No.	1671	5060	4863	5663	858	18 115
% patients	81	63	52	59	60	59
Practice reviews						
No.	1292	6098	5596	6835	956	20 777
% patients	75	72	59	70	67	67

RISK FACTORS

The associations between risk factors and the incidence of asthma attacks are shown in tables 3, 4 and 6. Across all age groups it was not uncommon for patients to experience one or more of night time symptoms, early morning symptoms, or exercise induced symptoms. Attack rates generally increase with BTS treatment step. For treatment steps 0–4 attack rates in those aged under five were consistently higher than in the other age groups. There were few patients at treatment step 5.

The numbers of patients aged under five or 75 or over were small and, for these two age groups, none of the factors was strongly associated with an increased chance of an attack. For each of the other age groups there was a strong positive association between attack incidence and each of BTS treatment step and night time symptoms. In addition, there was evidence that exercise induced symptoms were a significant risk factor in the 5–15 age group, and poor inhaler technique in the 16–44 age group. Neither early morning symptoms nor poor compliance were positively associated risk factors in any age group.

RESOURCE COSTS

Tables 7 and 8 show a breakdown of average costs of medication and resource use per patient, comparing those who suffered one or more attacks with those who had none. The 22% of patients in the attack group accounted for about 50% of total resource use costs. Average total costs per patient were estimated to be £273 more (95% CI £241 to £338) or 3.53 times higher (95% CI 3.20 to 3.87) in the attack group than in the non-attack group. Even after subtracting the costs of hospital stays, which represent about 44% of the total expenditure of the attack group, the estimated average cost per patient in the attack group was still £111 (95% CI £103 to £120) more or 2.10 times (95% CI 2.01 to 2.20) that in the non-attack group. Similarly, for both primary care consultation and prescription medication average costs were higher in the attack group by factors of 2.36 (95% CI 2.27 to 2.45) and 1.71 (95% CI 1.62 to 1.80), respectively.

An analysis by BTS treatment step shows that, although the comparison of total costs changes with disease severity, costs for attack patients were double or more those for non-attack patients.

Table 2 Distribution of patients by treatment step in the BTS asthma guidelines and age group (% of column total in parentheses)

BTS treatment step	*Age group (years)*					
	<5	*5–15*	*16–44*	*45–74*	*75+*	*Total*
0	35 (6%)	271 (8%)	440 (10%)	186 (5%)	21 (4%)	953 (8%)
1	177 (30%)	612 (18%)	938 (22%)	444 (13%)	63 (13%)	2234 (18%)
2	164 (27%)	1134 (34%)	1874 (43%)	1274 (37%)	173 (36%)	4619 (38%)
3	164 (27%)	884 (26%)	732 (17%)	828 (24%)	101 (21%)	2709 (22%)
4	55 (9%)	436 (13%)	278 (6%)	549 (16%)	76 (16%)	1394 (11%)
5	2 (0%)	25 (1%)	53 (1%)	165 (5%)	49 (10%)	294 (2%)
Total	597	3362	4315	3446	483	12 203

Table 3 Attack percentage by BTS treatment step and age group (in brackets when subgroup size less than 100)

BTS treatment step	*Age group (years)*					
	<5	*5–15*	*16–44*	*45–74*	*75+*	*Overall*
0	(9)	4	4	10	(14)	6
1	30	13	9	12	(16)	13
2	34	22	18	18	18	20
3	48	21	28	22	25	25
4	(55)	35	42	41	(41)	40
5	(50)	(60)	(68)	50	(63)	56
Overall	37	21	19	23	27	22

Discussion

Given the major cost burden of asthma on health service resources and the detrimental effect of an attack on a patient's lifestyle, early identification of factors associated with risk of an attack could contribute to better patient management and also have an impact on use of health service resources.

The database used for this study was large and provided the opportunity to investigate a variety of potential risk factors. The study has highlighted a number of factors which indicate risk of an asthma attack; the factors differ between age groups. Level of treatment step in the BTS asthma guidelines was a statistically significant factor in the 5–15, 16–44, and 45–74 age groups. Night time symptoms were an important marker for an attack across the same range of age groups and, although only having a modest effect on the odds of an attack, appeared to be the best symptom marker for the likelihood of an attack. Other factors identified as potential markers in particular age groups were exercise induced symptoms and poor inhaler technique. Poor compliance with medication, however, did not feature as an important risk factor for any age group.

Table 4 Estimated attack odds ratios for BTS treatment steps 1–5 relative to treatment step 0 by age group with 99% confidence intervals

BTS treatment step		Age group (years)				
		<5	5–15	16–44	45–74	75+
1	Odds ratio	3	4.03*	1.09	0.85	0.61
	99% CI	0.4 to 24	1.03 to 15.7	0.47 to 2.55	0.37 to 1.95	0.1 to 5.6
2	Odds ratio	2.3	6.55*	2.11	1.1	0.75
	99% CI	0.3 to 18	1.72 to 24.9	0.96 to 4.62	0.53 to 2.30	0.1 to 5.2
3	Odds ratio	4.1	5.8*	3.49*	1.23	0.94
	99% CI	0.5 to 32	1.52 to 22.1	1.56 to 7.81	0.58 to 2.60	0.13 to 6.75
4	Odds ratio	5.7	11.2*	5.66*	3.07*	2.16
	99% CI	0.6 to 50	2.9 to 43	2.42 to 13.2	1.45 to 6.50	0.3 to 15.7
5	Odds ratio	3.3	16.2*	14.7*	3.96*	4.9
	99% CI	0 to 221	2.3 to 116	4.5 to 47.8	1.70 to 9.22	0.6 to 39

*There is strong evidence that the corresponding odds ratio is different from 1 as the confidence interval does not include 1.

Table 5 Percentage of patients showing recent symptoms, poor compliance, and poor inhaler technique by age group

	Age group (years)					
	<5	5–15	16–44	45–74	75+	Total
Recent symptoms						
Early morning	36	29	44	52	60	43
Night	45	27	36	38	40	35
Exercise	41	50	55	67	83	58
Poor compliance	15	16	19	13	12	16
Poor inhaler technique	14	7	8	10	15	9

In clinical practice detailed knowledge of the factors associated with risk of an attack within the different age categories could help in prioritising management of poorly controlled patients. Used in conjunction with appropriate drugs this could aid development of management strategies to reduce the chance of an attack. Identification of risk factors highlights the fact that management plans have to be individualised as risk factors differ depending on age. The absence of non-compliance with medication as a significant risk factor for an attack is interesting. The evaluation of compliance was determined by specific questioning of the patient at the time of assessment as well as knowledge of medication prescribed in the previous 12 month period. The partially subjective nature of this evaluation is open to inaccuracy but it may also indicate that "poor compliance" is less influential in leading to uncontrolled asthma than previously thought. It is perhaps more likely to be a combination of both.

The cost of managing patients who experience an acute asthma attack impinges heavily on health care budgets. The difference in cost of treating a patient who has an attack compared with one who does not has major implications. Identification of patients in danger of an attack and an improvement in the quality of their treatment may reduce the number of patients experiencing an attack or the number of attacks experienced by any individual patient. This would not only improve a patient's quality of life, but may also enable financial resources to be used in a more beneficial way for the patients.

The patients in this study were a randomly selected sample from general practice asthma registers. They represented patients of all ages and both sexes from the mild end of the disease spectrum to the most severe. The practices which participated in the studies from which the database was formed were a representative sample of practices from all regions of the UK, of varying sizes and levels of practice resource.[12 13]

Caution must be practised when interpreting data from national correspondence surveys. The GPs who contributed data voluntarily enrolled into the project, which may be construed as introducing a recruitment bias in favour of GPs interested in asthma. The definition of an attack given for the purpose of the studies has been in use for a number of years and was a pragmatic attempt at a working definition for professionals in general practice. As long as the debate on what should be categorised as a severe attack, a mild attack, or merely an exacerbation of symptoms continues, it is difficult to give GPs a more precise classification.

The method of data collection relied on accurate recording of information in patients' notes; the recording booklet used a tick box

Table 6 Raw attack percentages for presence and absence of each of recent symptoms, poor compliance and poor inhaler technique by age group, plus estimated adjusted odds ratio with 99% confidence intervals

		Age group (years)				
		<5	5–15	16–44	45–74	75+
Recent symptoms						
Early morning	Absent	35	19	17	18	23
	Present	48	27	28	29	33
	Odds ratio	1.28	1.1	1.06	1.19	1.24
	99% CI	0.65 to 2.50	0.81 to 1.51	0.79 to 1.42	0.90 to 1.59	0.57 to 2.69
Night	Absent	36	19	15	19	23
	Present	44	30	33	33	39
	Odds ratio	0.94	1.53*	2.16*	1.69*	1.86
	99% CI	0.49 to 1.82	1.13 to 2.08	1.63 to 2.87	1.29 to 2.22	0.92 to 3.78
Exercise	Absent	34	18	16	17	21
	Present	47	26	26	27	31
	Odds ratio	1.52	1.33*	1.19	1.18	0.88
	99% CI	0.82 to 2.84	1.01 to 1.76	0.90 to 1.57	0.88 to 1.58	0.34 to 2.32
Poor compliance	Absent	42	22	21	24	29
	Present	37	21	28	27	30
	Odds ratio	0.82	0.82	1.18	1.32	1.35
	99% CI	0.35 to 1.90	0.56 to 1.18	0.86 to 1.61	0.92 to 1.89	0.50 to 3.67
Poor inhaler technique	Absent	43	22	21	25	31
	Present	35	24	31	21	21
	Odds ratio	0.8	1.17	1.63*	0.75	0.68
	99% CI	0.32 to 2.00	0.70 to 1.95	1.06 to 2.52	0.48 to 1.17	0.24 to 1.94

*There is strong evidence that the corresponding odds ratio is different from 1 as the confidence interval does not include 1.

Table 7 Estimated average cost of treatment (£) per patient by cost category and estimated ratio of costs with 95% confidence interval for main categories

	Attack (n=2653)	*No attack (n=9550)*	*Ratio of costs*	*95% CI*
Patient initiated GP consultation	24.07	8.23		
Practice initiated GP consultation	15.42	5.60		
Patient initiated nurse consultation	1.85	0.92		
Nurse review	8.63	6.42		
Primary care (total)	49.97	21.17	2.36	2.27 to 2.45
Drugs	127.38	74.63		
Emergency	1.14	0.09		
Medication (total)	128.53	74.72	1.72	1.63 to 1.82
Hospital stay	169.18	7.04		
Outpatients	23.69	4.68		
A & E	9.73	0.28		
Secondary care (total)	202.60	12.00	16.9	12.6 to 22.8
Overall total	381.09	107.89	3.53	3.20 to 3.87

Table 8 Average total cost (£) of treatment by BTS treatment step and occurrence of attack with sample size, and estimated ratio of costs with 95% confidence interval

BTS treatment step	*Attack*		*No attack*		*Ratio of costs*	*95% CI*
	Cost	*n*	*Cost*	*n*		
0	139	53	11	900	12.6	5.9 to 24.3
1	191	283	37	1951	5.2	3.6 to 6.9
2	209	911	93	3708	2.25	1.98 to 2.57
3	319	684	152	2025	2.1	1.83 to 2.38
4	634	556	305	838	2.08	1.73 to 2.49
5	1133	166	310	128	3.65	2.65 to 4.95
Overall	381	2653	108	9550	3.53	3.20 to 3.87

format. Based on experience in previous studies, this was considered the easiest and most efficient way to record the information. For each patient, responders were asked to record the type of drug agent used and the number of prescriptions over the year of data collection. Product names were not recorded. Difficulties were reported by some practices in accurately recording this information, which may potentially have led to under-reporting of medication use. The use of retrospective data allied with clinical assessment of present symptoms mirrors the process of history, diagnosis and prognosis with treatment that all clinicians practise when dealing with patients. The use of large databases using recognised outcome measures is a logical way forward to predict morbidity.[21]

The cost of prescription medication is based on an arithmetical average cost, taking account of prescription levels and recommended daily dosage of a particular, routinely used product at the adult dose, and may therefore be an underestimate. Varying the drug and device used within the groups of drugs may increase costs. There are gaps in knowledge for unit costs, but the values used represent the most up to date information from the PSSRU, University of Kent.[16] There will, however, be regional variations on costs.

The cost of emergency drugs used to treat acute asthma attacks was 0.2% of total expenditure, representing a minor cost when compared with the cost of hospital stay. Treating more of the hospitalised patients within general practice may lead to substantially lower costs. Ignoring hospital admission, the cost of treating patients in the attack group over the course of a year was more than double that of treating those who had no attack. The average cost estimate of £381 per annum for managing a patient who has suffered an attack, compared with £108 for a patient who has not experienced an attack, highlights the potential for health care finances.

We conclude that knowledge of risk factors used in conjunction with appropriate treatment could aid the development of management strategies to reduce the chance of an asthma attack occurring. This could also have major implications for resource usage. The high "cost" of treating patients who have had an attack highlights the importance of prevention. To reduce the number of attacks, good compliance with preventive treatment must be optimum. Medications used in the maintenance of asthma control and prevention of attacks are costly, but attacks are more costly both for the patient and the health service. Increased expenditure in, and correct use of, preventive treatment may help to reduce asthma attack rates with a subsequent improvement in patient lifestyle and a potential financial benefit to the health service. Analysis of data from retrospective observational studies cannot show causation; it can only find associations. It is difficult from this study to assess when the attack preceded a risk factor or vice versa and caution must therefore be exercised when interpreting the results. This study represents a logical step in predicting risk factors, but accurate assessment of the value of modifying risk factors in terms of a reduction in asthmatic attacks requires confirmatory evidence from a prospective study. Further work linking treatment strategies to patient outcome data could be of value in further understanding how positioning of treatment steps in the BTS asthma guidelines relates to asthma control. An understanding of this could help in targeting those patients who are poorly controlled.

Funding: Educational grant from Astra Zeneca plc.

Conflict of interest: Sue Silverman is an employee of Astra Zeneca plc.

1 Anderson HR, Butland BK, Strachan DP. Trends in the prevalence and severity of childhood asthma. *BMJ* 1994;**308**:1600–4.
2 Burr ML, Butland BK, King S, *et al*. Changes in asthma prevalence: two surveys 15 years apart. *Arch Dis Child* 1989;**64**:1452–6.
3 Campbell MJ, Cogman GR, Holgate ST, *et al*. Age specific trends in asthma mortality in England and Wales 1983–95: results of an observational study. *BMJ* 1997;**314**:1439–41.
4 Godley CC, Bucknall CE, Slack R, *et al*. Scottish confidential inquiry into asthma deaths 1994–6. *Asthma Gen Pract* 1998;**6**(Suppl 1):S3.
5 Action Asthma. *The occurrence and cost of asthma 1990*. Worthiness: Cambridge Medical Publications, 1990.
6 Pearson MG, Ryland I, Harrison BD, on behalf of the British Thoracic Society's Standards of Care Committee. National audit of acute severe asthma in adults admitted to hospital. *QHC* 1995;**4**:24–30.
7 Pearson MG, Neville RG, Richardson N, *et al*. Actual cost of asthma prescribing in general practice at each step of the guidelines. *Thorax* 1995;**50**(Suppl 2):S65.
8 National Asthma Campaign. National Asthma Audit 1999/2000. Direct Publishing Solutions Ltd, 1999.
9 Juniper EF, Guyatt GH, Epstein RS, *et al*. Evaluation of impairment of health related quality of life in asthma: development of a questionnaire for use in clinical trials. *Thorax* 1992;**47**:76–83.
10 McCarthy TP, Taylor MD, Richardson PD. The management of asthma using clinical protocols: is it cost effective, and does it improve patients' lifestyles? *Br J Med Econ* 1992;**2**:13–24.
11 British Thoracic Society, *et al*. Guidelines for the management of asthma: a summary. *BMJ* 1993;**306**:776–82.
12 Neville RG, Hoskins G, Smith B, *et al*. Observations on the structure, process and clinical outcomes of asthma care in general practice. *Br J Gen Pract* 1996;**46**:583–7.
13 Hoskins G, Neville RG, Smith B, *et al*. Tayside Asthma Management Initiative. *Health Bull* 1998;**56**:586–91.

14 Neville RG, Clark RA, Hoskins G, *et al*, for General Practitioners in Asthma Group. National Asthma Attack Audit 1991–1992. *BMJ* 1992;**306**:559–62.
15 Neville RG, Hoskins G, Smith B, *et al*, for General Practitioners in Asthma Group. How general practitioners manage acute asthma attacks. *Thorax* 1997;**52**:153–6.
16 Netten A, Dennett J. *Unit costs of health and social care*. PSSRU, University of Kent: 1997.
17 Duncan E, ed. *MIMS*. London: Haymarket Medical Ltd, November 1997.
18 *British National Formulary*. London: British Medical Association and Royal Pharmaceutical Society of Great Britain, March 1997.
19 Office of Health Economics. *Compendium of health statistics*. 9th ed. London: OHE, 1995.
20 Davison AC, Hinkley DV. *Bootstrap methods and their application*. Cambridge: Cambridge University Press, 1997.
21 Neville RG, Bryce FP, Clark RA, *et al*. The use of children's medical records to predict the risk of asthma attack. *Scot Med J* 1995;**40**:138–40.