Childhood asthma: can computers aid detection in general practice?

Sheree Kable, Richard Henry, Rob Sanson-Fisher, Malcolm Ireland, Ross Corkrey, and Jill Cockburn

SUMMARY

Background: *Childhood asthma remains underdiagnosed in general practice. Computers with a patient interface have the potential to screen children for asthma in a time-efficient manner.*

Aim: *To develop a concise, validated self-report measure that calculates an 'asthma score' that predicts likelihood of asthma and its severity in childhood.*

Design of study: *Computerised questionnaire survey in general practitioners'(GPs') waiting rooms, followed by a written questionnaire and either bronchial challenge or skin allergy testing at the regional teaching hospital.*

Setting: *Children between 18 months and 18 years old accompanied by a parent or guardian in five group practices in Newcastle in New South Wales, Australia.*

Method: *The responses from both the computerised questionnaire and the written questionnaire were compared with physician assessment of asthma, based on an existing validated questionnaire and clinical tests.*

Results: *Six items were identified to be independently and significantly associated (at* P*<0.05) with the presence of asthma and its severity: parent or self-reported asthma, previous diagnosis, wheeze in the past year, physical activity affected by symptoms, night cough in the past year, and visits to a GP in the past year. From the regression model a linear score was derived that indicates whether a child is likely to have asthma and its likely severity.*

Conclusions: *The asthma score is a valid indicator of asthma and its severity in children in general practice.*

Keywords: *asthma; children; computers; screening.*

S Kable, B Med, PhD, fellow; R Corkrey, BSc, senior statistician; and J Cockburn, BSc, MSc, PhD, professor of behavioural science, Discipline of Behavioural Science in Medicine; and R Sanson-Fisher, B Psych, Clin M Psych, PhD, dean of faculty, Faculty of Medicine and Health Sciences, University of Newcastle, New South Wales, Australia. R Henry, MD, FRACP, professor of paediatrics, School of Paediatrics, University of New South Wales, Sydney Children's Hospital, Australia. M Ireland, B App Sci, FRACGP, information technology program director, Hunter Urban Division of General Practice, Newcastle, New South Wales, Australia.

Address for correspondence

Dr Sheree Kable, Discipline of Behavioural Science in Medicine, University of Newcastle, Locked Bag No 10, Wallsend NSW 2287 Australia. E-mail: sheree.kable@newcastle.edu.au

Submitted: 11 October 1999; Editor's response: 9 March 2000; final acceptance: 29 October 2000.

Introduction

Childhood asthma is a significant health problem in many countries with an estimated prevalence of asthma symptoms of over 30% in some regions.[1-3] However, it remains underdiagnosed in general practice.[4-7] Many children do not have their symptoms reported to a doctor[8] and others have significant delays in diagnosis.[9,10] A more active approach to the detection and assessment of asthma is called for that is able to mesh easily into busy general practices.[8,11]

A computerised asthma questionnaire has been developed for completion by children and their parents in general practitioners' waiting rooms that is aimed at assessing asthma status and management. We conducted this study to determine if the computer questionnaire could be used to accurately detect asthma and assess its severity in children.

The aims of the project were:

- to determine which items in the computer questionnaire were predictive of asthma and its severity in children; and
- to develop a scale that computes an asthma score to predict the likelihood of the presence of asthma and its severity in children.

Method

Setting and participants

The study was conducted in Newcastle in New South Wales, Australia in 1997. Five group general practices consented for a computer with the questionnaire to be installed in the waiting room of each surgery and for a research assistant to attend to recruit parents and children. To be eligible a child had to be between 18 months and 18 years old and be accompanied by a parent or guardian. Children from the same family were eligible to participate.

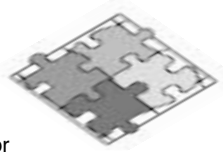
Design

Parents and children first completed the computerised questionnaire in the general practitioners' waiting rooms. Later they attended an appointment at the regional teaching hospital to complete a written questionnaire and undergo bronchial challenge or skin allergy testing. A consultant paediatric respiratory physician reviewed the written questionnaires and tests and rated each child as either no asthma or as one of three asthma severity categories.

The computer questionnaire

The computer questionnaire is a touch-screen program installed on IBM-compatible PCs (486 CPU) fitted with touch-screen monitors. Questions were based on items from the International Union against Tuberculosis and Lung Disease (IUATLD) Bronchial Symptoms Questionnaire and the International Study of Asthma and Allergies in Childhood

HOW THIS FITS IN



What do we know?
Asthma is still underdiagnosed in general practice. Many children do not have their symptoms reported to a doctor and others have significant delays in diagnosis.

What does this paper add?
A computerised asthma score has been developed which quantifies the likelihood of asthma in children and indicates its severity, and can be used for screening in general practice.

(ISAAC) questionnaire.[12,13] It comprised a total of 31 questions plus medication lists, seven of which related exclusively to management (included for later studies). The other 24 questions concerned the parent and/or child's perception of whether they had asthma (parent/child report), the occurrence and frequency of wheezing, coughing or shortness of breath, triggers for these symptoms, interference with sleep or physical activity, impact on school attendance, medical care sought, previous bronchiolitis, and a previous diagnosis of asthma. Five variables were created from a question that asked about asthma medications taken in the last 12 months: use of relievers, non-steroid preventers, inhaled steroids, oral steroids, and all preventers together. This brought the number of variables to be analysed to 29.

Selection of measures

There is no gold standard of asthma diagnosis. However, the combination of symptom questionnaires and bronchial provocation tests to establish the presence of asthma has been widely used in epidemiological studies[14,15] and were chosen as outcome measures. The questionnaire used was a detailed pen and paper questionnaire derived from questions in the IUALTD and ISAAC questionnaires[12,13] adapted for use in general practice. Bronchial provocation testing was carried out with 4.5% saline according to a widely established protocol, saline being chosen as it has the best specificity of bronchial provocation tests.[16,17] Children under six years old are generally unable to perform spirometry adequately to give meaningful provocation tests, therefore allergen skin tests were used in this age group as they are the least invasive test able to be used in this age group that correlates well with asthma.[18,19]

Outcome factor

The written questionnaires and tests were reviewed by a respiratory paediatric physician (RH) who was blind to computer questionnaire results. The diagnosis of asthma was made on the basis of a clinical history of recurrent symptoms in the previous year, the doctor's diagnosis, and response to therapy. Atopy, airways obstruction on lung function testing, and airway hyper-responsiveness were regarded as supportive. Frequency of exacerbation in the past 12 months was used to categorise severity. Each participant was rated into one of four categories: no asthma, infrequent episodic asthma (up to six attacks per year), frequent episodic, and persistent asthma (symptoms most days).

Analysis

Statistical analysis was undertaken using the software JMP IN 3.2 (SAS Institute). Univariate analysis was conducted to determine which items in the computer questionnaire had significant associations at $P<0.05$ with physician-assessed asthma category, using chi-squared and Fisher's exact test. These variables were entered into ordinal logistic regression using the forward stepwise technique to determine the best predictive model of asthma category from the computer questionnaire.[20] Hypothesis testing employed the Kruskal–Wallis test (rank sums) for non-parametrically distributed data.

Results

The computer questionnaire was completed for 326 children with an average time taken of 11.0 minutes. One hundred and sixty-nine (51.8%) children attended the clinic appointment. The clinic attenders did not differ significantly from non-attenders on any questionnaire item except that a higher proportion reported symptoms on exertion compared with non-attenders (39.6% and 24.8% respectively, $P<0.004$).

Participants

The mean age of participants was 6.1 years (standard deviation = 3.3). From the computer questionnaire, 60 (35.5%) children were reported to have asthma and 116 (68.6%) were reported to have at least one asthma-like symptom in the past year. Eighty-four children underwent saline bronchial challenge (30 positive and three not completed because of discomfort). Eighty-five children underwent skin allergy testing (14 children being positive for one or more allergens).

Of the 169 children in the analysis, 84 (49.7%) were considered to have current asthma based on physician assessment with 52 of these categorised as 'infrequent episodic', 26 as 'frequent episodic', and six as 'persistent'.

Items associated with physician assessment of asthma

Of the 29 variables from the computer questionnaire, all were associated with physician assessment in univariate analysis ($P<0.05$) except for age, two triggers of asthma (drugs or food, and emotion), and admission to an intensive care unit.

A best-fitting ordinal logistic regression model was computed. The six variables found to be independently associated with the four-category physician assessment of asthma are reported in Table 1.

When considering a 'yes' response to the question, 'Do you (or does your child) have asthma?' (i.e. a positive parent/child report), the specificity was very high at 99% although the sensitivity was only 70%. Overall, 15% of the sample (n = 25) answered 'no' or 'don't know' to the parent/child report question but were classified as having asthma by the physician.

The next most predictive item was a previous diagnosis of asthma. Although sensitivity and specificity of this item were high (0.88 and 0.86) for nearly one-third of the children with a reported previous diagnosis (26 out of 86) the child or parent did not state that the child had asthma (answered 'no' or

Table 1. Variables from asthma computer questionnaire independently associated with asthma as assessed by physician.

Variable	No asthma	Asthma	Total	*P*-value	OR
Parent/self-reported asthma					
Yes	1	59	60		15.3
Don't know	16	18	34	<0.0001	1.6
No	68	7	75		
Previous diagnosis					
Yes	12	74	86	0.005	2.4
No	73	10	83		
Wheeze in last 12 months					
Yes	8	58	66	0.003	2.1
No	77	26	103		
Visited GP more than three times in past 12 months					
Yes	1	23	24	0.02	2.0
No	84	61	145		
Night cough: more than three episodes in past 12 months					
Yes	5	32	37	0.04	1.7
No	80	52	132		
Has symptoms with physical activity					
Yes	3	33	36	0.04	1.6
No	82	51	133		
Total	85	84	169		

Table 2. Sensitivity and specificity of asthma score in children without a positive parent/child report: whole group, less than five years old, and five years old and over.

Age (years)	Asthma score	Assessed diagnosis		Total	Sensitivity (%)	Specificity (%)
		Asthma	No asthma			
Whole group: 18 months to 17 years old	≥ 1.9	21	17	38	84	80
	< 1.9	4	67	71		
	Total	25	84	109		
18 months to four years old	≥ 1.9	10	6	16	100	83
	< 1.9	0	29	29		
	Total	10	35	45		
Five to 17 years old	≥ 1.9	11	11	22	73	78
	< 1.9	4	38	42		
	Total	15	49	64		

'don't know'). Physician assessment of asthma was positive for 15 of these 26.

Overall, the six individual items had high specificity, ranging between 0.84 and 0.99 but sensitivity varied from 0.27 to 0.88.

Development of the asthma score

From the regression model a linear score was obtained, corresponding to the logit of the probability of events. The scores were transformed into a scale ranging between 1 and 10 using a linear combination. These scores were compared with physician assessment to determine the accuracy of the scale for detecting asthma and predicting its severity.

As nearly all children with a definite parent/child report of asthma were assessed as asthmatic (59 of 60) those who had a negative or indeterminate report were analysed separately for detection (n = 109).

Detecting the presence of asthma

Choosing a cut-point of greater than 1.9 as positive for asthma to maximise sensitivity and specificity, the asthma score has a sensitivity of 84% and a specificity of 80% in children who did not have asthma recognised by the child or parent. In children aged five to 17 years the sensitivity was 73% and specificity 78%. In the pre-school age group, in whom asthma is generally difficult to diagnose, the specificity was 100% and sensitivity was 83%.

Severity

Figure 1 shows the medians and interquartile intervals of the asthma scores for each physician-assessed category (including 'no asthma'). The Kruskal–Wallis test showed a significant difference between the four categories (P<0.0001). Using the Kruskal–Wallis test with the Bonferroni correction for simultaneous tests each category is shown to be significantly different to every other category (P<0.0001 for each comparison) except between 'frequent episodic' and 'persistent' asthma.

The cumulative probability of a child being in each of the four categories for each possible score is plotted in Figure 2. This shows that as the asthma score increases so does the likelihood that asthma is present, with increasing scores also corresponding to increasing severity. From this graph we can calculate the probabilities of a child with any given asthma score being in any particular category. For example, a child with an asthma score of 4.0 would have approximately a 30% probability of having no asthma, 66% probability of

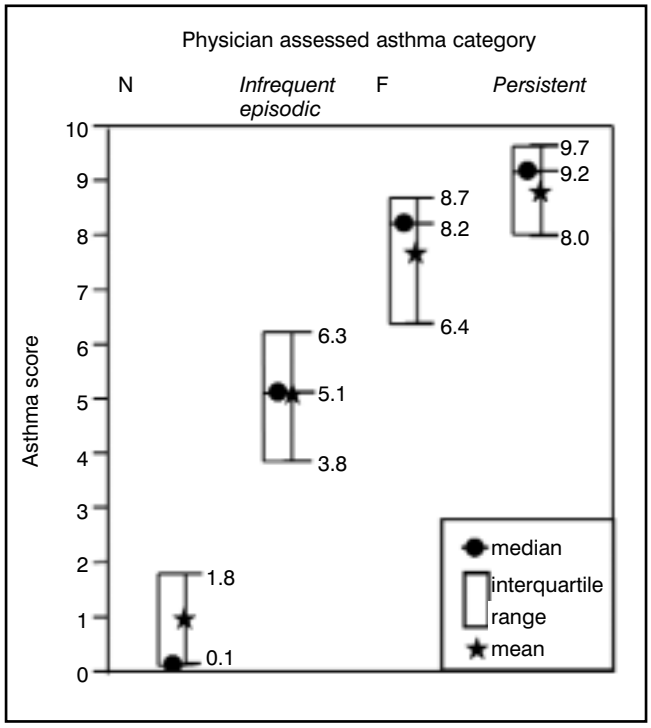


Figure 1. Medians, interquartile ranges, and means of asthma scores by category of assessed diagnosis.

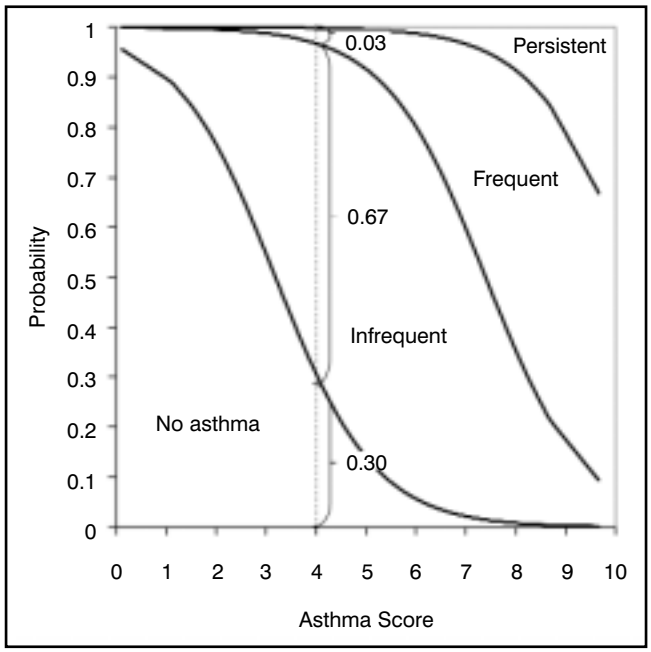


Figure 2. Cumulative probabilities of asthma categories: asthma scores plotted against the likelihood of a child with that score falling into each of the asthma categories.

having infrequent episodic asthma, 3% probability of having frequent episodic asthma, and less than 0.2% probability of having severe asthma.

Discussion

We determined that six items in the computer questionnaire were independently associated with physician-assessed asthma and developed an asthma score that quantifies the likelihood of asthma and indicates severity.

The sample

The main limitations of this study are concerned with the sample. There is a high proportion of reported asthma (35.5%) as well as a high proportion of children who had at least one asthma-like symptom in the past year (68.6%). This may be owing to the study population being drawn from a general practice setting where children with illness attend, rather than a population sample. As the scale was developed for use in general practice this high proportion is not unreasonable.

However, the sample may not be representative of all children who attend general practice and of concern is the fact that only half of those who completed the computer questionnaire attended the clinic appointment. Parents whose children display asthma-like symptoms may have been more likely to be motivated to take part. However, the only identified difference was that attenders reported a higher prevalence of symptoms on exercise compared with non-attenders. While any difference between attenders and non-attenders would not affect the internal validity of the study, it could affect the ability to generalise the results as the sensitivity of the asthma score could be lower for all children attending general practice.

Items

Each of the six variables with an independent association with physician-assessed asthma have face validity and have been reported to have associations with asthma and its severity in a variety of settings.[21-26]

The sensitivity of a positive parent/child report is 70% which is similar to the mean sensitivity of self-reported asthma found by Toren *et al* in their literature review of adults assessed by questionnaire.[27] The specificity was also similar to the mean specificity found in that review at almost 98%.

Most screening questionnaires of asthma have only 'yes' and 'no' options for reported asthma. In this study, 'don't know' was an option, and over half of the children with this answer were assessed as having asthma compared with 98% of those who said 'yes' and 9% of those who said 'no'. This implies that children whose parents (and/or the children themselves) who are unsure about whether or not they have asthma are the group most likely to benefit from efforts at increased detection. Also, the children who said 'no' and were later assessed as asthmatic by the physician were all categorised as infrequent episodic; however, four out of 18 assessed as asthmatic in the 'don't know' group had more severe frequent episodic. This stresses the importance of diagnostic energy being directed towards the indeterminate group.

It is nevertheless interesting that of those with a previous diagnosis of asthma and sufficient symptoms to support a current diagnosis by physician assessment, 15 children had a parent/child report of asthma that was negative or indeterminate. It is unlikely that these children will be receiving appropriate treatment as recognising asthma is the first step to proper management.[6,28]

Asthma score

The asthma score is able to detect asthma with good sensitivity and specificity in children who do not have a definite parent/child report that compares well with other screening questionnaires.[23-26,29] Importantly, it proved to have particularly high sensitivity in pre-school children who are generally more difficult to diagnose, which heightens its potential usefulness. Also, unlike many questionnaires and checklists used for asthma detection, this score quantifies the likelihood of asthma and is also able to discriminate between infrequent asthma and those with a more severe and frequent condition.

We believe that the approach of using a scaled asthma score to indicate the likelihood and severity of asthma more closely models the nature of the disease than the traditional 'asthma versus no asthma' approach.[30] Historically, asthma has been approached with a dichotomous mindset when in fact there is no magic point in the spectrum of symptomatology that represents a cut-off into asthma/not asthma, and any attempts to do so are artificial. Asthma is a spectrum of pathophysiology from a slight wheeze or cough to life-threatening airways obstruction. The development of the asthma score has been an attempt to transform a categorical rating into an indication of 'asthma-ness' incorporating both detection of asthma and its severity, much as one might (to use a laboratory example) check for the presence and severity of anaemia by a haemoglobin level.

We believe that this approach to asthma could be adopted more widely both for clinical use and epidemiological studies. In the past, such an approach may have been logistically impractical with its need for the rapid integration of large amounts of information; however, with the advent of widespread computer technology this approach has become easily applicable.

Demands on the time and energy of GPs, as well as expectations upon them, continue to increase. As the use of information technology in medicine advances there is likely to be a heightened demand for direct patient/computer interfaces to ease the burden of information gathering and assist the GP in identifying otherwise undetected health problems. The computerised questionnaire for childhood asthma and the consequent asthma score represents another step in the development of practical, clinical applications of information technology to general practice.

References

1. The International Study of Asthma and Allergies in Childhood (ISAAC) Steering Committee. Worldwide variation in prevalence of symptoms of asthma, allergic rhinoconjunctivitis, and atopic eczema: ISAAC. *Lancet* 1998; **351:** 1225-1232.
2. Pearce N, Weiland S, Keil U, *et al*. Self-reported prevalence of asthma symptoms in children in Australia, England, Germany and New Zealand: an international comparison using the ISAAC protocol. *Eur Respir J* 1993; **6:** 1455-1461.
3. Robertson, CF, Dalton MF, Peat JK, *et al*. Asthma and other atopic diseases in Australian children. Australian arm of the International Study of Asthma and Allergies in Childhood. *Med J Aust* 1998; **168:** 434-438
4. Siersted HC. Boldsen J, Hansen HS, *et al*. Population based study of risk factors for underdiagnosis of asthma in adolescence: Odense schoolchild study. *BMJ* 1998; **316(7132):** 651-655.
5. Crain, EF, Weiss, KB, Bijur, PE, *et al*. An estimate of the prevalence of asthma and wheezing among inner-city children. *Pediatrics* 1994; **94(3):** 356-362.
6. Joseph CL, Foxman B, Leickly FE, *et al*. Prevalence of possible undiagnosed asthma and associated morbidity among urban schoolchildren. *J Pediatrics* 1996; **129(5):** 735-742.
7. Tse M, Cooper C, Bridges-Webb C, Bauman A. Asthma in general practice. Opportunities for recognition and management. *Aust Fam Phys* 1993; **22(5):** 736-741.
8. Siersted HC. Commentary: Improving the diagnostic rate in asthma: a community issue. *BMJ* 1998; **316(7132):** 657.
9. Charlton I, Jones K, Bain J. Delay in diagnosis of childhood asthma and its influence on respiratory consultation rates. *Arch Dis Child* 1991; **66(5):** 633-635.
10. Jones A, Sykes A. The effect of symptom presentation on delay in asthma diagnosis in children in a general practice. *Respir Med* 1990; **84(2):** 139-142.
11. Toop LJ. Active approach to recognising asthma in general practice. *BMJ* [Clinical Research Edition] 1985; **290:** 1629-1631.
12. Burney PGJ, Laitinen LA, Perdrizet S, *et al*. Validity and repeatability of the IUALTD (1984) Bronchial Symptoms Questionnaire: an international comparison. *Eur Respir J* 1989; **2:** 940-945.
13. Burney PGJ, Chinn S. Developing a new questionnaire for measuring the prevalence and distribution of asthma. *Chest* 1987; **91(suppl):** 79S-83S.
14. Asher MI, Pattemore PK, Harrison AC, *et al*. International comparison of the prevalence of asthma symptoms and bronchial hyper-responsiveness. *Am Rev Respir Dis* 1988; **138:** 524-529.
15. Pattemore PK, Asher M, Harrison AC, *et al*. The inter-relationship among bronchial hyper-responsiveness, the diagnosis of asthma, and asthma symptoms. *Am Rev Respir Dis* 1990; **142:** 549-554.
16. Araki H, Sly P. Inhalation of hypertonic saline as a bronchial challenge in children with mild asthma and normal children. *J Allergy Clin Immunol* 1989; **84:** 99-107.
17. Riedler J, Reade T, Dalton M, *et al*. Hypertonic saline challenge in an epidemiologic survey of asthma in children. *Am J Respir Crit Care Med* 1994; **150:** 1632-1639.
18. Martinez FD, Wright AL, Taussig LM, *et al*. Asthma and wheezing in the first six years of life. *N Engl J Med* 1995**; 332(3):** 133-138.
19. Song CH. Skin sensitization in asthmatic children less than 36 months of age. *Ann Allergy Asthma Immunol* 1997; **79(3):** 273-276.
20. Agresti, A. *Analysis of ordinal categorical data*. New York: Wiley, 1984.
21. Burr ML. Diagnosing asthma by questionnaire in epidemiological surveys. *Clin Exp Allergy* 1992; **22:** 509-510.
22. Kaur B, Anderson HR, Austin J, *et al*. Prevalence of asthma symptoms, diagnosis, and treatment in 12-14 year old children across Great Britain (international study of asthma and allergies in childhood, ISAAC UK). *BMJ* 1998; **316:** 118-124.
23. Jenkins MA, Clarke JR, Carlin JB, *et al*. Validation of questionnaire and bronchial hyper-responsiveness against respiratory physician assessment in the diagnosis of asthma. *Int J Epidemiol* 1996; **25:** 609-616.
24. Steen N, Hutchinson, A, McColl E, *et al*. Development of a symptom based outcome measure for asthma. *BMJ* 1994; **309(6961):** 1065-1068.
25. Frank TL, Frank PI, McNamee R, *et al*. Assessment of a simple scoring system applied to a screening questionnaire for asthma in children aged 5-15 years. *Eur Resp J* 1999; **14:** 1190-1197.
26. Woolf RL, Berry CA, O'Connor T, Coover L. Validation of the brief paediatric asthma screen. *Chest* 1999; **116(4, supp 1):** 224S-228S.
27. Toren K, Brisman J, Jarvholm B. Asthma and asthma-like symptoms in adults assessed by questionnaires. A literature review. *Chest* 1993; **104(2):** 600-608.
28. Cuijpers C E, Wesseling GJ, Swaen GM, *et al*. Asthma-related symptoms and lung function in primary school children. *J Asthma* 1994; **31(4):** 301-312.
29. Linna O. Spirometry, bronchodilator test or symptom scoring for the assessment of childhood asthma. *Acta Paediatr* 1996; **85(5):** 564-569.
30. Carleton RA. Lingua Medica: dichotomous disservice? *Ann Int Med* 1997; **126:** 589-591.

Acknowledgments

We would like to thank Dr Peter Gibson and Sister Robyn Hankin for their input to this project.