MEDICAL PRACTICE

*Computers in Medicine***Allergy screening using a microcomputer**

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Abstract

Data are presented to show that a microcomputer can be programmed to: (1) analyse a standard allergy questionnaire, (2) reliably predict the ranked order probabilities with which IgE antibody tests will produce positive results, (3) store the IgE test results, and (4) print a comprehensive report that summarises and integrates the clinical and laboratory data. Consequently, the practitioner who refers a blood sample and a questionnaire completed by the patient to a centre where both can be analysed will obtain enough practical information to decide whether to treat or refer that patient to a specialist. The microcomputer is therefore potentially of great value in any preliminary allergy investigation.

Introduction

The discovery of immunoglobulin E (IgE) and its identification as reagenic antibody^{1 2} has resulted in a much better understanding of allergic disease. The clinical history provides a base for any allergy investigation; on it rests (a) the choice of confirmatory tests for allergens, (b) the interpretation of those tests, and (c) the patient's treatment. Taking a detailed history is time consuming, and difficult cases are liable to different interpretations even by experts.³ In the United Kingdom most patients consult general practitioners, who rarely have the time to take a detailed history and often lack the knowledge to select specific allergy tests. It has been our objective to show that programs written for a microcomputer can be used to overcome these problems.

In theory it should be possible to predict the IgE-mediated allergies of patients who answer a standard allergy questionnaire by referring their answers to a data base compiled from (1) previous patients' answers given to the same questionnaire and (2) their IgE antibody profiles. Such an approach is feasible, and because 95% of atopic people in the United Kingdom have IgE antibodies to one or more of three common inhalant allergens (grass pollen, house dust mite, and cat epithelium) the production of a data base does not require a main frame computer.⁴

It is the advent of cheap microcomputers that makes a data-based allergy investigation a practical proposition, and a screening system for IgE-mediated allergy using a Tandy TRS-80 microcomputer is demonstrated. We show that it is capable of (a) predicting allergies and (b) integrating the clinical history with laboratory results. As a result the general practitioner is presented with a report containing sufficient information for him to decide if referral to an allergy specialist is desirable.

Patients and methods

Patients had been referred to the Radio-Allergosorbent Test Allergy Unit by medical consultants and general practitioners with symptoms possibly related to IgE-mediated allergy. All had completed an allergy questionnaire and had sent a blood specimen for total and specific IgE estimations. Fifteen hundred patients (group 1) were used to construct the data base and a further 554 patients (group 2) to test the data base; no infants were included in checking total IgE concentrations. Total serum IgE concentrations were determined by conventional radio-immunoassay using a fast second antibody separation technique,⁵ and IgE antibodies specific for common inhalant allergens were estimated by Phadebas RAST (Pharmacia Diagnostics).

DATA BASE: GROUP 1 PATIENTS

These 1500 patients were used to develop the allergy screening procedure. They were classified into four groups according to their specific grass/mite/cat IgE results: (1) no specific IgE, (2) specific

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IgE to *Dermatophagoides pteronyssinus* or cat, or both, (3) specific IgE only to grass pollen, and (4) specific IgE to grass and one, or both, of the perennial allergens. Each questionnaire was analysed to compare how often the various answers occurred in each of the four groups: two algorithms were then constructed, one for the seasonal allergen and the other for the perennial allergens, using Bayes's theorem and approximately independent clusters.⁶ Each algorithm assigned a questionnaire into one of five groups according to the increasing likelihood of finding an allergen in that patient's serum. Rules for suggesting individual allergens were based on knowledge of time and place of their occurrence.

TESTING THE DATA BASE: GROUP 2 PATIENTS

All 554 patients in this group were referred during a 12-month period (to allow for seasonal variations in the type of patient) and were investigated by the allergy screening procedure. Data-base predictions for a reduced number of patients were compared with results of testing their sera with the panel of 13 allergens in the table. The panel analysis was reduced so as to exclude half of those who were very unlikely to have any positive radio-allergosorbent test results. Thus of the 216 patients with a total IgE under 40 kU/l, negative grass/mite/cat radio-allergosorbent test results, and whose history scores were "0," only 108 were tested with the panel allergens.

Common British allergens tested in radio-allergosorbent test

Perennial	Seasonal
House dust mite	Grass (meadow fescue)
Cat	Mugwort
Dog	Plantain
<i>Penicillium notatum</i>	<i>Alternaria tenuis</i>
<i>Aspergillus fumigatus</i>	<i>Cladosporium herbarum</i>
Horse	Silver birch
	London plane tree

Allergy screening procedure

The allergy screening procedure (summarised in fig 1) consisted of sending the allergy questionnaire, designed for patient compliance and easy transfer of answers to the computer, and a blood specimen for total and specific IgE measurements to the laboratory. The question-

FIG 1—Flowchart for analysis of questionnaire and blood samples.

naire answers were stored on 5¼-inch floppy discs in a Tandy TRS 80 Model 111 microcomputer equipped with 48k RAM and twin double-density 80 track drives. All questionnaires were analysed by a computer program that (a) summarised the history, (b) highlighted the main clinical features, (c) scored the seasonal and perennial histories as 0, 1, 2, 3, or 4 (0 refers to a less than 1 in 8 probability of any positive IgE-radio-allergosorbent test result, 4 to a probability that is equal to or greater than 3 in 4, and the other scores to intermediate probabilities), and (d) predicted the allergens likely to be contributing to the symptoms described—the seasonal and perennial allergen lists extended to include "less-likely" allergens if the total serum IgE concentration is over 200 kU/l.

After consideration of the results for total serum IgE, grass/mite/cat radio-allergosorbent test and perennial/seasonal algorithms, decisions were made as to which, if any, of the allergens in the table should be tested. Decisions were based on the four criteria listed below, where perennial and seasonal allergens referred to those selected after study of the patient's completed questionnaire.

(1) More perennial allergens if specific IgE to *D. pteronyssinus* or cat, or both, were found or total IgE was over 80 kU/l and the perennial history algorithm did not place the questionnaire in the lowest grade.

(2) More seasonal allergens if specific IgE to meadow fescue pollen was found or total IgE was over 80 kU/l and the seasonal history algorithm did not place the questionnaire in the lowest grade.

(3) If the total IgE was over 200 kU/l, even if the probability of any positive radio-allergosorbent test result was low, then the following moulds were to be tested: *Alternaria tenuis*, *Aspergillus fumigatus*, *Cladosporium herbarum*, and *Penicillium notatum*.

(4) Similarly, irrespective of the history analysis, if the total IgE was over 2000 kU/l then all the remaining allergens in the table were to be tested.

Total and specific IgE results to the predicted allergens were entered into the computer, and the final report was printed with a summary of the history, the total and specific IgE results, and comments which integrated the results with the history.

Results

Group 2 patients were analysed in detail. Of the 554 sera tested, 298 (54%) had at least one positive radio-allergosorbent test result, and these were distributed: seasonal allergens (83 cases); perennial allergens (93); and seasonal and perennial allergens (122).

ALLERGY SCREENING PROCEDURE COMPARED WITH RADIO-ALLERGO-SORBENT TEST PANEL RESULTS

Data-base predictions, interpreted in conjunction with total IgE results, selected only 3861 allergen tests compared with the 7202 performed with the panel of 13 allergens. Of the predicted tests, 842 (22%) were positive and 945 (24%) were borderline—that is, Phadebas radio-allergosorbent test grade "1." Altogether 3341 tests were predicted as unnecessary, and of these, 34 (1%) were positive and 19 (0.6%) borderline results. The seasonal and perennial correlations were divided as follows:

Seasonal—The computer predictions program assigned 298 patients as probably negative and 256 as probably positive. When compared with results of the allergen panel, positive seasonal radio-allergosorbent test results were found in only four patients with negative predictions (1.3%) but in 201 patients with positive predictions (79%).

Perennial—Two hundred and fifty-six patients were predicted as probably negative and 298 as probably positive. The predictions were mainly confirmed by the allergen panel results: positive perennial radio-allergosorbent test results were found in only two patients with negative predictions (0.8%) but in 213 with positive predictions (71%).

RELATION OF HISTORY SYMPTOM GRADES WITH POSITIVE IGE-RADIO-ALLERGO-SORBENT TEST RESULTS

Seasonal and perennial algorithms placed the 554 questionnaires among the history grades as shown in fig 2. The distribution showed that seasonal histories were usually either positive or negative but that perennial histories were more evenly distributed in each grade. The probabilities of positive seasonal radio-allergosorbent test results increased as the seasonal history grade increased—likewise positive perennial radio-allergosorbent test results and perennial history grades (fig 3).

RELATIONSHIP OF TOTAL IgE AND POSITIVE IgE-RADIO-ALLERGO-SORBENT TEST RESULTS

The 418 patients aged over 2 years who had the full panel of allergens tested were analysed. The probabilities of finding any positive radio-allergosorbent test results were calculated for total IgE concentrations above and below 80 kU/l, and again above and below 200 kU/l, using the fact that 54% of patients had at least one positive result. Knowledge of both total IgE and grass/mite/cat specific IgE

FIG 2—Distribution of seasonal and perennial history scores ranked in order of probabilities of predicting any positive radio-allergosorbent test result.

FIG 3—Correlating seasonal and perennial history scores and the percentage of positive radio-allergosorbent test results in each ranked order probability group.

antibody concentrations allowed better prediction of a positive radio-allergosorbent test result than did total IgE alone (fig 4). Furthermore, negative grass/mite/cat radio-allergosorbent test results and total IgE less than 80 kU/l made any other positive radio-allergosorbent test result to inhalant allergens most improbable (fig 4c).

Grass/mite/cat radio-allergosorbent test results were more discriminating than total IgE in identifying the atopic person. Of the 298 patients with any positive radio-allergosorbent result, 283 were positive to grass/mite/cat radio-allergosorbent tests. Consequently, the probability of a positive radio-allergosorbent test result in a patient who was grass/mite/cat negative was 0.05.

PATIENT REPORT FORMS

Report A was returned to a doctor whose patient had perennial chest and gut symptoms but a non-atopic history. The grass pollen specific IgE measured by the radio-allergosorbent test was probably of limited diagnostic value.

Report B showed that the history, which was strongly suggestive of symptoms related to both seasonal and perennial allergens, was supported by the IgE investigations.

FIG 4—Bar charts representing probability of any positive radio-allergosorbent test results according to whether serum total IgE concentration is (a) above or below 80 IU/ml and (b) above or below 200 kU/l under three different conditions.

Discussion

About 15% of the population of the United Kingdom is atopic,⁷ therefore natural exposure to common environmental allergens sensitises about eight million of our citizens. As only a small proportion of these can be referred to allergy clinics an efficient method is required to identify those patients in most need of specialist attention.

The general practitioner can obtain much useful information about the probability that atopic allergy is contributing to his patient's symptoms; he has only to refer a blood sample and questionnaire completed by the patient to a centre where both can be processed in the sequence summarised in fig 1. The questionnaire is entered into the computer and analysed. Then the baseline tests—total IgE and grass/mite/cat radio-allergosorbent test—plus the radio-allergosorbent test results for those allergens suggested by the questionnaire analysis are measured. The results are entered into the computer, which checks if the four criteria detailed in the section on the allergy screening procedure are satisfied. If not it suggests further allergens. Finally, reports of the forms A and B are printed and sent to the doctor. The comment section of these reports show the necessary integration between total IgE, grass/mite/cat radio-allergosorbent test result, and clinical history.

TOTAL AND GRASS/MITE/CAT IGE TESTS

A total IgE estimation determines how diligently the search for allergies should be conducted. For example, fig 4 shows that

specific IgE antibodies are more likely to be discovered when total IgE concentrations are above rather than below 80 kU/l. Also the higher that the patient's IgE concentration is the greater is the likelihood of identifying multiple atopies.

A knowledge of specific IgE concentrations to the most common allergens is even more discriminating than a total IgE estimation. In this study 95% of those patients with any positive radio-allergosorbent test result had raised concentrations of IgE specific to at least one of three common allergens—grass pollen, *D pteronyssinus*, and cat epithelium. When grass/mite/cat radio-allergosorbent test results were considered together with a total IgE concentration, however, extra IgE tests were warranted only if the radio-allergosorbent test results were positive and total IgE was over 80 kU/l (fig. 4b). If the grass/mite/cat radio-allergosorbent test was negative then extra tests were unlikely to be positive no matter what the total IgE concentration was (fig 4c).

INTEGRATION OF HISTORY AND IGE RESULTS

The history symptom scores were a necessary control on the validity of IgE results. Allergens to which specific IgE antibodies are discovered may be irrelevant to the presenting complaint. In report A the discovery of a positive grass radio-allergosorbent test result is of limited diagnostic help in a case of perennial asthma, unless it is an indication of wheat flour allergy.

REPORT FOR REFERRING DOCTOR
=====

ALLERGY INVESTIGATION PATIENT NO: 6059 Micky Mouse
=====

DATE OF BIRTH: 10/12/18
DATE OF QUESTIONNAIRE: 12/03/82
TODAYS DATE: 18/05/82

TO:
DR E SMITH
XXXXXXXXXX
XXXXXXXXXX
XXXXXXXXXX
XXXXXXXXXX

CLINICAL HISTORY ASSESSED BY QUESTIONNAIRE Fold

SYMPTOMS : INVOLVE-CHEST-GUT
No family history of atopy
AGE OF ONSET WAS 45
SYMPTOMS ARE PERENNIAL
REGULARLY IN CONTACT WITH :-BIRDS.
OCCUR BOTH INDOORS & OUTDOORS
OCCUR BOTH NIGHT & DAY
IMPROVE ON FROSTY OR SNOWY WINTER DAYS
SMOKING :-Started at age 15
Smoked 20 cigarettes a day
Inhaled moderately
Stopped smoking at age 57
NO SKIN TESTS PERFORMED
FOOD :
Patient is uncertain if food affects his/her symptoms.
Food screen :
gut symptoms.

BLOOD TEST RESULTS
TOTAL SERUM IGE = 56 UNITS/ML
PHADEBAS IGE-RAST RESULTS FOR SPECIFIC ALLERGENS
(RAST results are graded :0, 1, 2, 3, 4, where 0 is negative and 4 is strongly positive, 1 is borderline except for moulds when it is regarded as probably clinically significant.)
TIMOTHY GRASS(2)
NEGATIVE RESULTS :
HOUSE DUST MITE PTERONYSSINUS CAT EPITHELIUM
COMMENTS
The total IgE of 56 units/ml is in normal range - atopy possible.
The patient has positive specific IgE antibodies to at least one common U.K. allergen and is therefore atopic.
The questionnaire was analyzed to see if specific IgE tests confirmed the allergens suggested by history.
The history does not suggest that the patient's symptoms may be related to seasonal allergens.
END OF REPORT FROM:
RAST ALLERGY UNIT, BENENDEN CHEST HOSPITAL, CRANBROOK, KENT TN17 4AX.

Report A.

REPORT FOR REFERRING DOCTOR
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ALLERGY INVESTIGATION PATIENT NO: 6060 Snow White
=====

DATE OF BIRTH: 15/08/49
DATE OF QUESTIONNAIRE: 02/03/82
TODAYS DATE: 18/05/82

CLINICAL HISTORY ASSESSED BY QUESTIONNAIRE Fold

SYMPTOMS : INVOLVE-EYES-NOSE-CHEST
3 relation(s) have a possible ATOPIC history
AGE OF ONSET WAS 12
SYMPTOMS ARE SEASONAL AND SYMPTOMS ARE PERENNIAL
Months occur 5 6 7 8 9
Months worst 6 7 8
OCCUR IN :
4 FROM 5 MONTHS of the GRASS season
3 FROM 4 MONTHS of the WEED season
4 FROM 5 MONTHS of the CLADOSPORIUM HERBARUM season
4 FROM 5 MONTHS of the ALTERNARIA TENUIS season
2 FROM 4 MONTHS of the TREE season
WORST IN :
3 FROM 3 MONTHS at height of the GRASS season
1 FROM 2 MONTHS at height of the WEED season
2 FROM 3 MONTHS at height of the CLADOSPORIUM HERBARUM season
1 FROM 3 MONTHS at height of the ALTERNARIA TENUIS season
WORST NEAR GRASS, TREES
Aggravated by dusting &/or making beds
CAUSED BY CATS
REGULARLY IN CONTACT WITH :-DOGS.
REGULARLY IN CONTACT WITH :-HORSE.
REGULARLY IN CONTACT WITH :-GUINEA PIGS.
REGULARLY IN CONTACT WITH :-GOAT
OCCUR IN 2 SETS, ONE INDOORS, ONE OUTDOORS
OCCUR MAINLY IN THE DAY
IMPROVE ON WET SUMMER DAYS (suggests weeds more than outdoor moulds)
IMPROVE ON FROSTY OR SNOWY WINTER DAYS
SMOKING :- NEVER (Less than 400 cigarettes in patients lifetime.)
NO SKIN TESTS PERFORMED
FOOD :
Patient believes not affected by food.
Food screen :
age of onset <30.

BLOOD TEST RESULTS
TOTAL SERUM IGE = 875 UNITS/ML
PHADEBAS IGE-RAST RESULTS FOR SPECIFIC ALLERGENS
(RAST results are graded :0, 1, 2, 3, 4, where 0 is negative and 4 is strongly positive, 1 is borderline except for moulds when it is regarded as probably clinically significant.)
TIMOTHY GRASS(4) SILVER BIRCH(3)
CLADOSPORIUM HERBARUM(1) CAT EPITHELIUM(2)
HORSE DANDER(2) PLANTAIN(1)
MAPLE LEAF (LONDON PLANE)(2) HOUSE DUST MITE
DOG DANDER(4) PTERONYSSINUS(3)
NEGATIVE RESULTS :
MUGWORT GUINEA PIG EPITHELIUM
ASPERGILLUS FUMIGATUS ALTERNARIA TENUIS
PENICILLIUM NOTATUM
COMMENTS
The total IgE of 875 units/ml is above most common adult non-allergic levels - atopy likely.
The patient has multiple positive specific IgE antibodies to common U.K. allergens (both seasonal and perennial) and therefore is atopic. This is possibly the cause of the high total IgE.
The questionnaire was analyzed to see if specific IgE tests confirmed the allergens suggested by history.
The history strongly suggests that the patient's symptoms may be related to seasonal allergens.
... especially, GRASSES, TREES, CLADOSPORIUM
The history strongly suggests that the patient's symptoms may be related to perennial allergens.
... especially, DUST & HOUSE DUST MITE, CATS.
... possibly, DOGS, HORSES.
END OF REPORT FROM:
RAST ALLERGY UNIT, BENENDEN CHEST HOSPITAL, CRANBROOK, KENT TN17 4AX.

Report B.

In report B raised specific IgE concentrations are discovered as a result of history predictions. This would very likely constitute a reason for treatment. The referring doctor may consider that the patient's symptoms are completely explained by the findings in the report, as in form B. When positive results are encountered that appear unrelated to the history, however, as in form A, further questioning of the patient may elicit present or past seasonal symptoms.

A few patients had class "4" history grades but no positive radio-allergosorbent test results. This may indicate an allergen yet to be discovered—possibly an occupational one—a non-IgE-mediated mechanism or perhaps an exceptional interference in the radio-allergosorbent test by antibodies of another class. Whatever the reason, in such cases referral to an allergy specialist would be recommended. Indeed, referral should be considered when either the patient's symptoms are not fully explained by the report or advice on management is required.

We conclude that microcomputers are now powerful enough to operate a complex self-learning data base that may be used (a) for taking and analysing a standard history, (b) predicting the likely causes of symptoms, and (c) linking the results of IgE tests to the patient's history so that a valuable interpretation of the patient's symptoms can be used by the general practitioner as a basis for referral to an allergy specialist.

This work would have been impossible without either the assistance of Josephine Merrett in processing the IgE tests or the support of the Post Office and Civil Service Sanatorium Society.

Requests for reprints should be addressed to T O Merrett, RAST Allergy Unit, Benenden Chest Hospital, Cranbrook, Kent TN17 4AX

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Contemporary Themes

Availability of computed tomography for the management of head injuries in England and Wales

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Abstract

Senior neuroradiologists or radiologists of 42 hospitals with computed tomography available for NHS patients in England and Wales were contacted by postal questionnaire about the use of this facility in the management of patients with acute head injuries. Replies were obtained from 39 hospitals. Requests for computed tomography from general surgeons or physicians and staff of accident and emergency departments received positive responses for scanning with only half to three-quarters the frequency of responses to requests from neurosurgeons. Continuous computed tomography facilities were available generally to neurosurgeons. The combined effect of partial responses to requests and the availability of the computed tomography service meant that only 44% of hospitals gave a continuous service for general surgeons or physicians. The percentage of hospitals giving a continuous service to accident and emergency departments was 54%. It appeared that computed tomography scanning was being used most often as a diagnostic/

management instrument after clinical selection among patients with head injuries rather than as an instrument to be used in primary assessment.

Introduction

Bartlett and Neil-Dwyer¹ have argued that the clinical efficiency of computed tomography and its role in the management of head injury requires improved access to this facility. Deployment of screening facilities to general hospitals with major accident and emergency departments could lead to satisfactory assessment and treatment of most head injuries without transfer to special units. Jennett and MacMillan,² however, considered that these scanning facilities would be underused because of a small flow of patients and that for any lesions found there may be an absence of the necessary surgical expertise. They favour quicker referral of larger numbers of patients with head injuries to neurosurgical units.

The effect of scanning in reducing mortality and morbidity has not yet been clearly shown in comparison with other forms of managing head injury. At the same time there is lack of agreement as to whether computed tomography should be part of the initial diagnostic/management response to the presentation of a patient with head injuries or whether diagnosis and assessment should be made on clinical grounds and selected cases transferred to neurosurgical units for further investigation including scanning and further management. This paper reviews

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