Computers in Medicine

Computer-Assisted Diagnosis of Abdominal Pain using "Estimates" Provided by Clinicians

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Summary

This paper reports a comparison between two modes of computer-aided diagnosis in a real-time prospective trial involving 472 patients with acute abdominal pain. In the first mode the computer-aided system analysed each of the 472 patients by referring to data previously collated from a large series of 600 real-life patients. In the second mode the system used as a basis for its analysis "estimates" of probability provided by a group of six clinicians. The accuracy and reliability of both modes were compared with the performance of unaided clinicians.

Using "real-life" data the computer system was significantly more effective than the unaided clinician. By contrast, when using the clinicians' own estimates the computer-aided system was often less effective than the unaided clinician—especially when diagnosing less common disorders. It seems, firstly, that future systems for computer-aided diagnosis should employ data from real-life and not clinicians' estimates, and, secondly, that clinicians themselves cannot analyse cases in a probabilistic fashion, since often they have little idea of what the "true" probabilities are.

Introduction

We have already described the construction and evaluation of a computer-assisted system for use in clinical medical diagnosis[1 2] and shown that it may be more effective than the unaided clinician. But whatever the practical implications and applications of the system described there are clearly two further conceptual problems of interest. Firstly, what are the reasons for the discrepancy between the unaided clinicians' accuracy (79·6% in some 304 patients) and that of the computer-aided system (91·8%)? Secondly, since any computing system is only as effective as the data which it analyses, is it really necessary to provide the computer in advance with data from a large-scale clinical survey or can clinicians' "estimates" of probability be used?—a suggestion raised by several authors.[3–5]

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Concept of Clinicians' "Profiles"

In our computer-aided diagnostic system, as previously described, the computer was initially provided with clinical data via a previously undertaken study of 600 patients suffering from abdominal pain of acute onset[6] (Table I). The ensuing computer-aided system was more accurate than the unaided clinician (by a margin of some 12%). It seemed logical to us to suggest that the increased effectiveness of the computer-aided system might be derived in one of two main ways. Either the clinicians

1. Sex

	Appx.	Divert.	Perf. D. U.	N.S. pain	Chole-cyst.	S.B. obst.	Pan-creat.
Male	60	50	90	40	30	50	50
Female	40	50	10	60	70	50	50

2. Age

	Appx.	Divert.	Perf. D. U.	N.S. pain	Chole-cyst.	S.B. obst.	Pan-creat.
0 - 9	30	0	0	30	0	0	0
10 - 19	30	0	0	30	0	5	0
20 - 29	20	0	10	20	10	10	5
30 - 39	10	5	20	10	30	20	15
40 - 49	5	20	30	5	40	25	30
50 - 59	2	30	20	2	10	20	30
60 - 69	1	20	15	1	5	10	15
70 +	2	25	5	2	5	10	5

FIG. 1—Completed page from individual clinician's "profile book." (Compare this clinician's "estimates" with values from survey in Table I.) N.S. Pain = Non-specific abdominal pain.

TABLE I—*Observed Findings in Large-scale Survey of 600 Patients with acute Abdominal Pain. Figures are Percentages of Groups Studied*

	Males	Females	Age in Years							
			0–9	10–19	20–29	30–39	40–49	50–59	60–69	≥70
Acute appendicitis (100 cases)	60	40	22	33	22	8	5	5	4	1
Acute diverticular disease (100 cases)	39	61	—	—	2	2	10	10	28	48
Perforated duodenal ulcer (100 cases)	85	15	—	4	7	9	26	22	20	12
Non-specific abdominal pain (100 cases)	42	58	14	41	19	7	5	3	7	4
Acute cholecystitis (100 cases)	32	68	—	1	8	4	9	19	26	33
Acute small-bowel obstruction (50 cases)	60	40	2	6	24	6	14	14	18	16
Acute pancreatitis (50 cases)	38	62	—	2	8	6	14	16	30	24

were working from original estimates of probability which were inherently "wrong"—in the sense that they did not reflect real-life findings in a large series of similar cases—or they were working from "correct" probabilities but lacked the ability to handle large volumes of data in a real-life (emergency) situation. We therefore set out to investigate the problem further by constructing "profiles" of clinicians' personal estimates of the symptomatology of abdominal pain. That is to say, we asked the clinicians to estimate values such as those shown in Table I—what proportion of patients with acute appendicitis were male and what proportion female, what was the age distribution, and so on.

Six clinicians participated in this study. Three were relatively junior clinicians of registrar status and three were more senior men of lecturer or senior lecturer status. All were provided with an identical "profile book" and invited to complete the book by filling up the pre-prepared tables on each page. Each page dealt with a separate attribute, and an example of a completed page is shown in Fig. 1. No time limit was placed on the procedure, and usually the profile book was completed over a period of two or three weeks. On completion and return of the book any outstanding difficulties were discussed with the clinician, who was allowed to alter any entry about which he was uncertain before handing in the completed book.

Validation

There seemed to us to be no guarantee whatsoever that the data written down by the clinicians actually represented their "considered opinions," and hence it appeared desirable to institute some form of validation procedure. This was attempted by presenting each clinician (after analysis of his profile book) with a "short-list" of 10 attributes—these being the attributes where that clinician's estimates differed most from the "observed" values in the 600 patients surveyed. These data were presented without comment to the clinician, who was invited merely to re-check them; in practice, however, the data presented were carefully selected. For five out of the 10 attributes we gave back to the clinician values which were identical with the estimates which he had previously given us. In the remaining five attributes the values we gave him were those observed in our previous survey of 600 patients.

The results of this validation procedure were of interest, bearing in mind that the clinicians did not know whether they were reassessing their own estimates or data from our survey (Fig. 2). Most clinicians left their own previous estimates

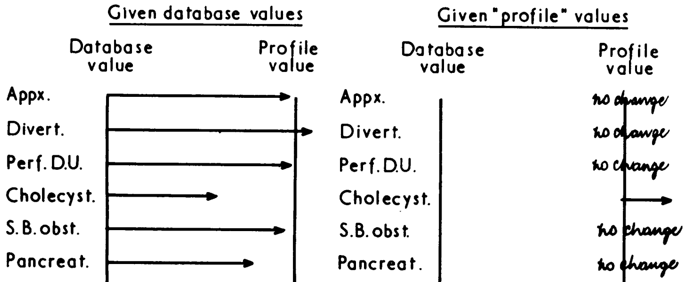

FIG. 2—Results of giving data *back* to clinician for recheck. Where "survey" data is presented (blind) clinician alters towards his previous "estimates." Where previous estimates are presented clinician leaves them largely unaltered.

unaltered, and where observed "survey" data were presented the clinicians altered this so as to approximate once more to their original estimates. This has two implications—firstly, it validates broadly the method of data collection and, secondly, it re-emphasizes the overall (and often considerable) degree of difference between clinicians' confirmed estimates and the observed survey values.

Finally, the clinicians were asked to look again at their individual profile books, and where large discrepancies occurred between estimates and observed survey values these were indicated to the clinicians. For each such discrepancy the clinician was offered three choices—either he could maintain his own (divergent) estimate or he could substitute the value from our observed series or he could compromise in some way between the two. On less than 5% of the instances did the clinician accept the observed survey value outright, and while in a number of instances a compromise was acceptable, in most the clinician insisted on retaining his own estimate of the value in question.

From these individual profile books a composite or group profile was then made up, as indicated in Table II, using for each composite value the mean of the six clinicians' individual estimates. It is this composite or group "profile" which has been used in the comparative studies discussed below.

TABLE II—*Method of deriving Composite "Group Profile" from Six Individual Clinicians' Profiles. Attribute: Males. Figures are Percentages*

Clinician	Appx.	Divert.	Perf. D.U.	N.S Pain	Chole-cyst.	S.B. Obst.	Pan-creat.
A	45	40	85	25	30	50	55
B	60	40	75	20	30	60	35
C	50	35	85	30	20	50	40
D	55	25	75	30	20	65	48
E	50	40	70	50	30	50	60
F	60	50	90	40	30	50	50
Mean	53(47)	38(62)	80(20)	33(67)	27(73)	54(46)	48(52)

Figures for females (in parentheses) are given to facilitate comparison with Table I
N.S. Pain—Non-specific abdominal pain.

Results

Many theoretical comparisons could have been made between our clinicians' estimates and the data from a large-scale survey, but we chose instead to evaluate these in a practical setting. This took the form of a real-time, real-life unselected prospective trial, carried out side by side with that already reported,[2] involving patients admitted to the professional surgical unit of the Leeds General Infirmary between 1 January 1971 and 31 May 1972 with abdominal pain of acute onset. There were 472 such patients; the criteria for admission to the survey have been set out elsewhere, as have details of the computing system used.[1 2] In the present study we established merely another "database" of information on the computing system consisting entirely of values estimated by clinicians. Thus for each patient we were able to produce a computer "diagnosis" using (*a*) the observed values in our series of 600 patients, and (*b*) the estimates given by our group of clinicians. Further comparison was made with the clinician's own "real-life" diagnoses, and these three diagnostic nodes were assessed against the final clinical (usually operative) diagnosis.

OVERALL "ACCURACY" OF DIAGNOSIS

In this context "accuracy" of diagnosis is taken to mean a diagnosis made either by the clinicians or by the computer-aided system which corresponded with the "final" diagnosis made when the patient left hospital, usually established when the patient came to operation. The overall accuracy of diagnosis thus expressed is shown in Table III. In the total series of 472 cases the overall accuracy of diagnoses made "on the spot" by the clinical team was 79·7%, whereas the accuracy of the computer-aided system using values based on 600 surveyed cases was considerably higher (91·1%). This discrepancy broadly maintains

TABLE III—*Overall Accuracy of Diagnosis, Real-time Unselected Prospective Trial January 1971 to May 1972 (472 Cases)*

	Accuracy
Senior clinician	79·7%
Computer using "survey" data	91·1%
Computer using clinician's "estimates"	82·2%

the situation which prevailed at the time of our earlier report[2] and is not commented on further. In the present context, however, it is of interest that the overall accuracy of the computer-aided system using the clinicians' estimates was a relatively unimpressive 82·2%. Tables IV-VI show the outcome of the 472 individual cases when each of the seven possible diagnoses are considered separately.

TABLE IV—*Diagnosis of Senior Clinician to see each Case v. Final Diagnosis. Leeds, January 1971 to May 1972*

		Senior Clinician's Diagnosis							
		Appx.	Divert.	Perf. D.U.	N.S. Pain	Chole-cyst.	S.B. Obst.	Pan-creat.	?/Other
Final Diagnosis	Appx.	106	1	—	12	—	—	—	3
	Divert.	—	7	—	1	—	1	—	1
	Perf. D.U.	1	—	11	—	—	—	—	1
	N.S. Pain	39	—	1	186	3	—	1	2
	Cholecyst.	—	—	—	—	34	1	4	2
	S.B. Obst.	—	—	—	—	—	20	—	—
	Pancreat.	1	2	1	—	1	—	8	1
	Other	6	1	1	2	—	2	—	8*

*4 right, 4 wrong.

TABLE V—*Computer-predicted Diagnosis v. Final Diagnosis. Leeds, January 1971 to May 1972. Computer using Survey Data fom 600 Patients*

		Computer Diagnosis						
		Appx.	Divert.	Perf. D.U.	N.S. Pain	Chole-cyst.	S.B. Obstr.	Pan-creat.
Final Diagnosis	Appx.	120	1	—	—	—	—	—
	Divert.	—	10	—	—	—	—	—
	Perf. D.U.	—	—	13	—	—	—	—
	N.S. Pain	8	—	1	216	2	—	3
	Cholecyst.	—	—	—	—	41	—	—
	S.B. Obstr.	—	—	—	—	—	19	1
	Pancreat.	—	1	1	—	—	1	11
	Other	6	7	1	2	1	1	1

Four "fail-safe" cases excluded; computer made no diagnosis because clinicians unable to agree on symptoms and signs.

TABLE VI—*Computer-predicted Diagnosis v. Final Diagnosis. Computer using "Estimates" provided by Clinicians*

		Computer Diagnosis						
		Appx.	Divert.	Perf. D.U.	N.S. Pain	Chole-cyst.	S.B. Obst.	Pan-creat.
Final Diagnosis	Appx.	111	3	—	7	—	—	—
	Divert.	—	8	—	—	—	1	1
	Perf. D.U.	—	1	11	—	—	—	1
	N.S. Pain	12	3	1	201	1	3	9
	Cholecyst.	—	—	—	—	30	3	8
	S.B. Obst.	—	—	—	—	—	19	1
	Pancreat.	—	2	2	1	1	—	8
	Other	7	5	—	2	—	2	3

Four "fail-safe" cases excluded.

ESTIMATES V. SURVEY DATA V. REAL-LIFE DIAGNOSIS

Further interesting points emerge when (*a*) the computer's performance using estimates supplied by the clinicians is compared with (*b*) its performance using survey data and also with (*c*) the performance of the clinicians themselves in real life. The position is summarized in Figs. 3 and 4. These show the unaided clinician's accuracy and reliability of diagnosis for each of the seven diseases and compare this unaided performance with that of the computer in each of the two modes studied. A "gain" in diagnostic effectiveness occurs if the computer's performance improves on that of the unaided clinician and is indicated by a positive figure. A "loss" in effectiveness occurs if the computer's performance is less accurate or less reliable than that of the unaided clinician and is denoted by a negative value.

There is wide overall variation in the results but certain trends are quite apparent. Firstly, the computer's performance using survey data is considerably more effective than the unaided clinicians' and also considerably more effective than its own performance using clinicians' estimates (Fig. 5). Secondly, there

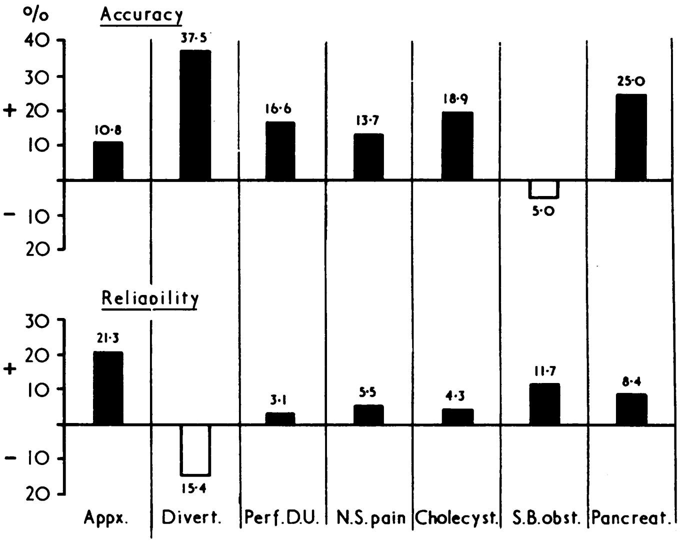

FIG. 3—Comparison of computer-aided diagnosis using "survey" data with real-life diagnoses of senior clinician.

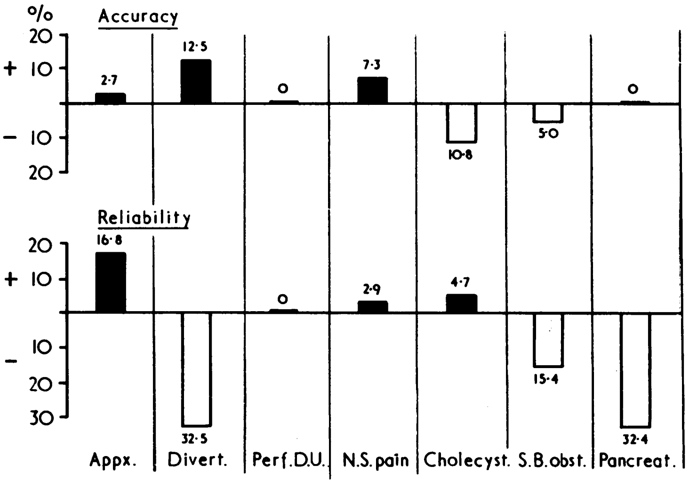

FIG. 4—Comparison between computer-aided diagnosis using clinicians' "estimates" and real-life diagnoses of senior clinician.

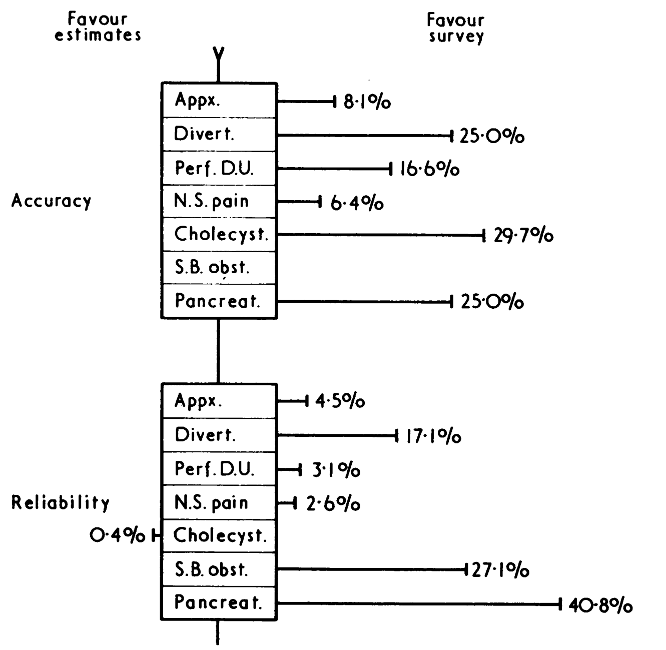

FIG. 5—Comparison of accuracy and reliability of computer-aided diagnosis in two modes.

is pronounced variation by disease—in some instances (appendicitis, non-specific abdominal pain) the computer using estimates was more effective than the unaided clinician, but in others (diverticulitis, pancreatitis) it was much less effective. Thirdly, the effectiveness of the computer using estimates *seemed to be related to the incidence of the diseases under study*. In respect of acute appendicitis (121 cases in 15 months) and non-specific abdominal pain (230 cases) the computer using estimates was relatively effective when compared with the unaided clinician. But for other diseases such as diverticulitis (10 cases) and pancreatitis (14 cases) the computer using estimates proved to be less reliable. In fact, if we compare the number of cases presenting during this series with the gain obtained by using survey data as opposed to estimates we find a trend which just fails to achieve statistical significance at the 5% level ($r_s=0.680$).

INDIVIDUAL CLINICIANS' PROFILES

One major criticism of the studies so far reported is that a "group" profile may be less accurate than estimates obtained from an individual clinician; but two points emerged from the present study which tend to refute this. Firstly, we ourselves have failed to find a clinician whose individual profile is in practice *more* effective than that of the group. Secondly, as Table VII shows, in most instances an individual clinician's profile is noticeably *less* effective than that of the group. We are therefore unable to adduce any evidence from the present study to substantiate the hypothesis that use of individual profiles per se would be any more effective than the type of group profile which we have constructed.

TABLE VII—*Comparison between Clinician C and Computer in Variety of Modes over a series of Real-life Cases*

	Real Life	Computer		
		Survey Data	Group Estimates	Clinician C's Estimates
% Diagnostic accuracy ..	84·2	100·0	89·4	84·2

Discussion

If a computer-assisted system for clinical diagnosis *could* be induced to work effectively using estimates of probability supplied by clinicians[2-5] several advantages would ensue. Firstly, when opening up a new field for study there would be no need to conduct exhaustive surveys; one would merely go to an expert in the particular field and obtain his "estimates." Secondly, many doctors might feel readier to use a system which relied on their own "thoughts" for its data values. They might feel that they exercised more control over such a system than over one in which probabilities were supplied from outside by other, possibly unknown people.

Unfortunately if we measure the effectiveness of a computer-aided system by its diagnostic accuracy and reliability we have not been able to confirm this attractive hypothesis. Despite the utmost care in producing, checking, and validating our clinicians' estimates, when the computer came to use these estimates it was little more effective than the unaided clinician and often it was much less effective. This disparity became more and more pronounced as rarer diseases were encountered. (Moreover, in this instance a "rare" disease such as perforated peptic ulcer or pancreatitis still presented once or twice monthly.) We must conclude, therefore, that it has not been within our capabilities to produce a system using clinicians' estimates showing any marked advantage over the unaided clinician. We suspect that the use of clinicians' estimates of probability may have been a cause of failure in some previous computer-aided diagnostic systems, and we conclude that in future computer-aided diagnostic systems there is no alternative to using carefully collated data from large-scale, real-life surveys rather than clinicians' estimates.

Of course, it could be argued that we were faced with a singularly unco-operative or singularly inept group of clinicians. Both assertions we reject utterly; the former on the grounds that the clinicians spent many hours pouring over the profile books—from the nature and frequency of their queries it became apparent that they were genuinely interested in trying to provide useful data, not least as a matter of personal pride. As regards the latter assertion it is necessary only to point to the overall accuracy of the same clinicians' real-life diagnoses in our current series of 472 patients (79·7%); for this figure compares favourably with other published series.[7]

REASONS FOR DIAGNOSTIC ERROR

Where, however, the system of using estimates has proved extremely useful is in another area—namely, that of research into the diagnostic process itself. Thus the present study enables us to suggest some answers to the query originally posed relating to the reasons for failure to reach a "correct" diagnosis. It is clear from the data contained in Fig. 5 and Table VII that in the present study clinicians failed to analyse the cases in a "probabilistic" fashion for two reasons. They may well have lacked the necessary ability to manipulate in any statistical sense the large amounts of data which they obtained for each patient. But also, and more important, in many instances the estimates of probability from which they were working were well off the mark.

This latter point becomes evident when Table VII is studied. In this instance the data represent a series of 20 or so real-life cases presenting to a single clinician, and Table VII suggests at least one possible reason why clinician C may have failed to make an accurate diagnosis in some of these cases. It is *not* that clinician C obtained insufficient data from his patients, since when using the data he obtained (and comparing it with other values from 600 patients) the computer-aided system made no diagnostic error. Nor can it be said that clinician C failed to make some diagnoses because he could not process data in a probabilistic fashion, since when the computer-aided system used his own probability estimates it was no more accurate than he was in real life. What Table VII does strongly suggest is that clinician C occasionally failed to make the correct diagnosis *because he was working from a set of personal probabilities which were inherently wrong*. (By wrong in this sense we mean merely that (*a*) his personal probabilities differed from those found in our survey and (*b*) that this seemed to have an adverse effect on his diagnostic accuracy.)

Interestingly, in more general terms (Figs. 4 and 5) for "common" diseases like appendicitis the problem seems to be mainly an analytical one. Clinicians work from a reasonably accurate set of estimates but, lacking the ability to manipulate all these data at once, are sometimes still uncertain at the end of their deliberations. At this point other considerations may take over, like a concern for the consequences of error.[8] The clinician thus diagnoses acute appendicitis more readily than non-specific pain and is prepared to accept a proportion of negative laparotomies as a necessary evil.

When, however, patients with rarer diseases present clinicians often fail to make a diagnosis because they have only a relatively small knowledge of the clinical picture which these diseases present. This particularly applies to junior clinicians, who may have seen only a handful of patients, with, say, acute pancreatitis. In round terms (see Tables III-V) we may conclude that up to 3-4% of clinical diagnoses are in error because the clinician cannot manipulate the data adequately, but up to 7-8% of clinical diagnoses are in error because the clinician is inadequately familiar with the clinical picture of the disease in question.

The implications for computer-aided diagnosis are clear. The computer should use real-life data from large-scale surveys and not merely estimates from clinicians. The computer-aided system will sometimes be of use, even in the most common of diseases, on account of its ability to manipulate large amounts of data at once. But it will also be extremely useful as a "data bank" of information about less common disorders with which the clinician can supplement his own personal experience. It can in this respect make available to the junior clinician a level of clinical experience which might take him years to accumulate. We ourselves plan experiments which evaluate this particular hypothesis further in respect of disorders of the large bowel.[9]

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Impressions of Cogwheel

General Practitioner

FROM A SPECIAL CORRESPONDENT

British Medical Journal, 1972, 4, 354–355

To most of those general practitioners who have heard of the Cogwheel report,[1] it is something that "they" are doing in the hospitals. The family doctor I visited, Dr. Cadwallader, was one of these. Even so, as the report points out, "liaison activities with other divisions, with other departments and committees within the hospital group, with general practitioners and with medical officers of health, to name only a few, will form an important part of the division duties."

Dr. Cadwallader runs a modern, well-staffed, group practice. His patients may be cared for in one of four hospital groups and so far there is no sign of liaison between him or his group partners and the various hospital divisions. Dr. Cadwallader charitably wonders whether the early stages of establishing the divisional and executive committee structure within the hospital groups have kept their eyes turned inwards so far. Soon he hopes that they will feel secure and well-organized enough internally to look to their external duties to the community they serve. For he certainly has need of them. His patient, old Mrs. A. B., who is paraplegic, survives at home with three daily visits from home helps. Recently when the Seebohm report[2] was implemented the new local authority social services department took over the home help service. The home help organizer, well known to Dr. Cadwallader, used to be responsible to the county medical officer but now her boss is the director of social services. He says that the budget demands that, as the area is getting much more money than the average, some help must be withdrawn. Therefore it may not be possible to manage Mrs A. B. in her home and she will have to go into hospital.

This presents another problem. The local geriatrician sees his role as caring for illness in the aged. Mrs. A. B. is not really ill, or no more ill than she has been for years, so he may not be able to find a bed for her. In any case Seebohm reported that (in 1968) the cost of one whole time home help was "less than £1,000 per year."[2] Even at today's prices Mrs. A. B. must cost the N.H.S. (though not the local authority) much more in hospital.

At present Dr. Cadwallader has only two or three options. He could go to the local hospital management committee, of which he is a member. But they can only make recommendations. He could have the matter publicized, but there will be other cases and that would give diminishing returns. He could, and does, use the "old boy net." He is able to do this because he is a friendly, long-established, public-spirited G.P. who knows a lot of people, and has done many good turns for others. Some G.P.s have other gifts which, while making them good doctors, do not create an old boy net like Dr. Cadwallader's. What are they to do for their Mrs. A. B.s?

Divisions For G.P.s?

Dr. Cadwallader's solution to this type of problem would be to have Cogwheel divisions of general practitioners. The second Cogwheel report[3] mentions that a few have been set up—some apparently for general practitioners using hospital beds, others (more what Dr. Cadwallader has in mind) to provide a more broadly based link with community health services. Dr. Cadwallader himself would not regard it as practicable to belong to a division of general practitioners in each of the hospital groups to which he sends his patients, and so he suggests that the divisions could be organized by the members of the local medical committee. In his area, this statutory body has about 30 members. Each member is elected by the general practitioner in his "constituency." They represent the G.P.s on the executive councils and the same organizations will be retained to represent the G.P.s on the area health boards after the N.H.S. reorganization in 1974. They used to select trainers and trainees in general practice but this function will be taken over by the regional general practitioner advisory committees. As Dr. Cadwallader sees it, the members elected for the areas covered by each of the four hospital groups could form the division of general practice. They would elect their own divisional chairman, who would then sit on the hospital group medical executive committee.

A problem like Mrs. A. B.'s, Dr. Cadwallader thinks, would then be discussed by the general practitioners, and, with any luck, the community physicians and representatives of the department of social services (who would not be doctors). An