

Automation in the laboratory¹

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Every year each incoming President is faced with the choice of a subject for this address. In the past the history and the philosophy, the creators and practitioners, the secrets and the science of laboratory medicine have all been presented. Today I have chosen to speak on 'Automation in the laboratory' not only because this is of considerable personal interest to me, but also because I am convinced that this is a matter of great importance to the practice of our specialty. I should perhaps state at the outset that what I have to say does not necessarily represent the policy of the Council of the Association. If there are any areas of agreement, these are entirely fortuitous and I must accept personal responsibility for any controversial opinions expressed.

No one would deny that today we are living in the age of laboratory medicine. This is largely the result of the 20th century upsurge in both science and technology which has made available a wide range of scientific aids to medical diagnosis. Our specialty, clinical pathology, can be said to have grown out of the resultant increase in the demand for laboratory tests. The broad aims of clinical pathology are, according to Shields Warren, 'the science of obtaining qualitative and quantitative data from patients and the art of so interpreting these data as to establish diagnosis and guide therapy'. There is a widely held view that the second of these aims is being increasingly frustrated by the sheer weight of the first and that inadequacy of space, of staff, and of equipment is making even the provision of a routine service, if not impossible, at least very difficult.

THE WORKLOAD

It has been a pretty general experience that, following the introduction of the National Health Service, there was a significant increase in the number of diagnostic tests carried out in most of our hospital laboratories. This can be attributed to the fulfilment of a need which could not previously be met owing to financial restrictions. A study was made of the workload of our own

laboratory since it was first opened in 1919. The maximum rate of rise occurred immediately following 1948 and thereafter it more than doubled in each subsequent decade.

The factors responsible for this rise are to be found both within and without the medical profession. Within the profession the present demand has its origin in the more scientific orientation of the curriculum of the medical undergraduate. It is reinforced by the postgraduate educational programme which provides up-to-date information on all the ancillary aids to diagnosis. It is amplified by the specialist clinics with their considerable laboratory requirements. It is further promoted by the tendency to monitor medical treatments more closely. It is masochistically increased by the clinical pathologist who, by adapting and introducing the tools and techniques of the basic sciences, has thereby provided a widening range of laboratory tests. This is tantamount to an open invitation to the clinician to make use of the available service. This has perhaps been best summarized by Barnard (1968) in his two patho-Parkinsonian laws, namely, 'where there is a test someone will keep requesting it' and 'the frequency of the request varies inversely with the amount of work the requester thereby involves himself in'. Thus modern training, tools, trends, and techniques have all combined to raise the hospital laboratory workload to its present high level.

The effect of pressure from without the medical profession can be seen by looking at the rise in requests in the four laboratory disciplines. At one time biochemistry was regarded as the discipline with the most rapidly rising workload, but more recently this has been challenged by histopathology. This is largely due to the cytopathology screening programme for cervical cancer in women. This increase has not been dictated entirely by medical considerations but represents a demand from the community, stimulated by planned propaganda.

Requests come into the laboratory from the general practitioner, the hospital, and the community medical services. Throughout the country the proportion from each of these three components shows considerable variation. Although the national

¹The Presidential address given at the Annual General Meeting of the Association of Clinical Pathologists in September 1968.

average for the general practitioner load is of the order of 10%, in some areas this is as high as 20%, and it is likely that the general practitioner will, in the future, make more use of the services of the laboratory.

To attempt to reduce the workload by an attack on the factors responsible for its rise does not appear to be realistic. It would seem, therefore, that we have to accept an open-ended system of uncontrolled requests for service. This does not mean that we can do nothing about controlling the demand. We can exercise an influence by education, by advice, by persuasion, and by propaganda. But if we fail in the end to exercise any influence then we must provide the facilities to deal with the demand.

SPACE

It can be fairly stated that, in the past, the area required by the diagnostic laboratory service has not been fully appreciated by the responsible authorities. At the present moment much of the laboratory work throughout the National Health Service is carried out under substandard working conditions—conditions which would not readily be tolerated in industry or allowed by many craft unions. That most laboratories are able to meet their immediate commitments is in great measure due to the devotion to duty and high sense of vocation of their staffs.

STAFF

The increasing number of tests which are regularly requested has been matched by an increase in their sophistication so that, while it used to be possible to provide a reasonably satisfactory laboratory service without highly qualified staff, this is becoming increasingly difficult. Not only has the need for such staff increased but there is intense competition for the available pool of skilled manpower. The medical laboratory service has to compete for its scientific and technical staff with industry and other fields of technology. Apart from recruitment there are problems created by the technical educational programme, the staff establishment, and the rising cost of salaries and wages. In an effort to widen the catchment area of skilled manpower science graduates are being increasingly recruited, for whom a career structure needs to be more clearly defined.

Within the laboratory service the scientific and technical staff are concerned not only in providing a service but also in refining the methods and the tools, not as an academic exercise but with regard

to their clinical application, for the ultimate aim of all who work in the laboratory service is directed as a cooperative effort towards the care of the sick.

Apart from the reduced availability of skilled laboratory staff, there is the problem of the rising cost of employment. It has been estimated that up to 80% of the revenue cost of running a laboratory can be attributed to salaries and wages. Further, the cost per 100 requests varies very little with the work content. Therefore, in any consideration of laboratory efficiency related to cost, it is the manpower element which is most important. It has been pointed out that to try to solve the manpower problem by delegating the work to less highly qualified personnel will only create similar manpower problems but at another level. Therefore, 'we must consider to what extent mechanical aids and automation can relieve manpower shortages'.

EQUIPMENT

Most studies of the workload of the hospital laboratory have shown that the great majority of tests are of a repetitive nature. The proportion of such tests varies, not only from one discipline to another, but in the same discipline with the passage of time. For instance, when we carried out a study in the haematology division in 1961 we found that the percentage of repetitive tests was 77 but six years later this had risen to 87.

If the efficiency of the laboratory is to be raised it is clear that this can best be achieved by some improved method of dealing with repetitive tests. The first step is the organization of the intake so as to allow of the accumulation of tests into batches and the streamlining of technical work on the assembly line principle. The next logical step is the replacement, as far as possible, of routine manual procedures by machine methods. In 1961 we showed how such an approach resulted in the absorption of a rising workload with a minimal increase in technical staff. We referred to the process as 'automation of routine haematology' although, to be etymologically correct, it should have been called 'mechanization', which is the replacement of a manual manoeuvre by a mechanical process. Automation achieves the same end result as a manual method but does not necessarily imitate the manual manoeuvre involved. Furthermore, automation also infers the possibility of a self-regulating feedback mechanism so that alteration in the performance of the system generates a correcting signal. However, the term 'automation' has become accepted usage for any form of mechanization of laboratory procedures.

First introduced by Skeggs in 1957, the trend of

development of modern scientific instrumentation for the hospital laboratory over the past decade has been very largely dictated by an approach based on the continuous flow analytical system. Progressively the routine biochemical estimations have been carried out by single-channel autoanalyzers, and at a later stage, by the complexes of two or more. At present much of the routine biochemical work throughout the country is efficiently handled by such items of equipment and there is little doubt that the autoanalyzer came just in time to save clinical biochemistry from a possible complete breakdown.

Altogether a considerable body of experience has been gained in the use of this type of equipment and the potentialities of such systems have been extensively exploited. Although used initially for biochemical analyses, the same systems have been adapted for a wide range of laboratory procedures. The limiting factor is the overall analytical speed of 60 specimens per hour.

To overcome this rate-limiting factor, multi-channel analyzers and fixed pattern screening have been introduced. Once complexes of autoanalyzers were in operation, when the request for the estimation of a single substance was received it was simple to put the sample on to a multiple analyzer and to obtain a number of results, including the one which was specially requested. This practice of grouping a number of selected biochemical tests so that when one was requested the remainder were also determined and reported is carried out in a number of centres. It has proved to be an efficient method of working, and the results presented in this form are acceptable by the clinicians.

This kind of thinking led to specially designed equipment which produces, from a single sample of blood, a set of prechosen parameters. The results so obtained are recorded in graphical form with the so-called 'normal' values overprinted on the record. Even with multichannel systems and fixed pattern screening, it has been stated that the continuous-flow analytical system will not be able to deal with future demands.

Whatever the motivation, the stimulus has led to the design of systems with greatly increased speed of analysis. Such discrete chemical analyzers which are designed in modular form should be capable of adaptation to a number of widely different test procedures in a variety of laboratory disciplines.

The appearance on the market of a wide range of mechanical aids and automated systems introduces the need to subject such items of equipment to technical evaluation. There is much discussion as to who should carry out these tests and how exactly this should be done. Much equipment is

currently being tested under what might be called 'field conditions', namely, in a busy service laboratory using their own scientific and technical staff. What is important is that the testing should be carried out in such a way that comparison between individual items or systems is rendered possible. To this end the requirements for evaluation should include tests for the precision or mechanical reproducibility; the accuracy or design of the analytical procedure; the reliability of the equipment, particularly under routine conditions; the simplicity of operation in unskilled hands; and the operational costs in terms of cost per test or multiples thereof.

At the moment a number of professional groups are advising the Ministry of Health on the development and testing of equipment, on the establishment of a central library of information, and also on the introduction of acceptable calibration and other standards. Despite all these measures the ultimate test bed for all equipment is the routine service laboratory where the acceptability or otherwise of the equipment will be finally determined.

THE BENEFITS OF AUTOMATION

The introduction of automation into the laboratory confers certain important benefits. These include an increased speed of test performance, an acceleration in the rate of production of reports, and increased productivity in terms of the number of tests which can be carried out per technician per year. As a consequence this reduces labour costs, leading to a diminution in the cost per test. There is considerable evidence that the accuracy of the results performed in larger automated laboratories is better than those performed in smaller laboratories. There is also increased saving in technical time so that it becomes possible to extend the range of laboratory tests and to include those with a large manual component.

As a consequence the overall laboratory efficiency is increased when this is measured in terms of the range of laboratory tests which can be offered, the quality of the results produced, and the speed with which reports reach the clinician.

THE CONSEQUENCES OF AUTOMATION

The introduction of automation into the laboratory has certain consequences. The first of these is the need to programme the work to ensure that automated equipment is efficiently used and that technical time is not wasted. To this end the samples must be delivered promptly and at a rate adequate to keep equipment working continuously.

The majority of specimens submitted to a laboratory consist of blood samples, and venepuncturing a large number of patients presents a considerable problem. The use of trained teams of venepuncturers has much to commend it, as such teams could start to obtain blood samples early in the day and thus make the programming of automated equipment easier.

The laboratory day usually starts at 09.00 hours and it takes something of the order of one hour to set up present-day multichannel equipment and to run through the controls and calibration standards. Therefore, at 10.00 hours the equipment is ready but, in many laboratories, the first delivery of specimens does not coincide. How can we ensure that the delivery of specimens is integrated into the laboratory programme? A hospital or a closely knit hospital group is best served by an efficient messenger service, preferably by laboratory porters, the collection schedule being determined by the laboratory staff to fit into the work programme. The first collection or a significant proportion of it needs to reach the laboratory before 10.00 hours.

Various attempts to solve the problem of the transportation of specimens by some mechanical means have been tried. There was a short flirtation with the pneumatic tube system which held out some hope, but an organization and methods study in 1963 put this into proper perspective when it said 'a well organized messenger service is more efficient, costs nothing to install, and operates at one-third the cost of the pneumatic tube system'.

At present there is no satisfactory mechanical method of transporting specimens from outlying points to a central laboratory. This should not lead us to accept the *status quo*. The transport of specimens and the transmission of reports are as fruitful fields for study as are the current experiments in analytical techniques.

KEEPING THE MACHINES OPERATIONAL

The great fear of the laboratory technician is that the automated equipment will break down in the middle of a busy day and create chaos. Although this should not often happen it is inevitable that equipment will, from time to time, break down. Therefore speed in rectifying faults is vital.

Equipment can be maintained in a number of ways and involve the manufacturer or his agent, university facilities, or engineering establishments. However, there is virtue in having departmental control of maintenance. A valuable way of achieving this is the appointment of a young and interested electrician as a member of the laboratory staff.

Such a man rapidly acquires facility in the use of testing equipment and develops the necessary skills. More important he can have, as his routine duty, preventive maintenance of the laboratory equipment. Another way is to train the laboratory technician to detect and correct faults. For this the best method of construction is modular and by using a set of simple instructions the defective module can be recognized. Such a procedure will, of course, require the holding of a considerable quantity of spares, or they should be readily available. There is no doubt that such 'do-it-yourself' methods of maintenance have many advantages.

QUALITY CONTROL

With increasing numbers of tests and their increasing automation much more attention must be paid to ensuring that standards of accuracy and precision are not allowed to fall, and that insidious variations in machine performance do not result in gradual deterioration in the quality of results. Automated methods of analysis demand the application of accurate and maintained systems of quality control. Some laboratories use commercial preparations for calibrating instruments and for checking both precision and accuracy. Others prepare their own sera and suspensions to check the precision of already calibrated instruments. In larger laboratories with a big workload, the application of statistical methods, including standard deviation and cusum charts, are considered to be reliable. It is of some interest that in at least one study on precision in hospital laboratories, there was a direct relationship between the accuracy and the workload. This could mean either that the larger laboratories are more aware of the need for quality control, or that automated techniques are in the main more accurate.

Despite the application of quality control systems designed to determine accuracy of analysis, uncontrollable errors can still arise. These may be due to mistakes either in transcription or in translocation. Transcription errors can result from incorrect labelling or incorrectly entering results. Translocation errors can result from the wrong sequence of samples on the sampler plate or the wrong arrangement of punch cards in a pack or the incorrect identification of a peak in a series. Attempts to eliminate such human errors have led to the development of specimen identification systems which greatly increase the expense of laboratory equipment. However, the bigger the workload and the greater the throughput rate then the more essential does an infallible specimen identification system become.

AUTOMATED DATA PROCESSING

The introduction of laboratory equipment, with greatly increased speed of analysis, needs data acquisition and processing equipment of comparable performance. The whole field of automated data processing has been recently reviewed by the A.C.P. Working Party and reported in the *Journal*.¹ Consequently I do not propose to discuss it in any detail although I cannot resist making a few observations arising from personal experience. It seems to me a little incongruous to introduce rapid analytical equipment and to use for data acquisition a skilled technician to watch the chart recorder, to perform analogue digital conversions in his head, and to record the answers with a pencil and paper.

To introduce either a digital display or an automatic typewritten list with sequential numbers may look more impressive but contributes little to efficiency. The results have still to be transcribed onto a report or translated onto another document with the possibility of errors in transcription. The test results in digitized form should produce signals which can be used to operate equipment which produces record compatible reports.

Once the data have been acquired, how is the information to be subsequently manipulated? In our own laboratory we use a simple IBM870 punch card data processing system and with this we have been able to deal quite efficiently with the results obtained in the routine haematology laboratory. This system is not new. It has been known for many years and used in centres from Bethesda to Belfast. Sophisticates may regard it as being still in the 'horse and buggy' age but there is virtue in simplicity. It produces a punch card which is available as a machine retrievable record, suitable for later statistical and scientific analysis.

After the data have been obtained and transmitted in the form of a report, the question of disposal then arises. Is the information to be stored and if so how and where and for how long? No one will disagree with the clinical pathologist's responsibility to maintain laboratory data for a limited period of time. In the first place we must be able to deal with enquiries about the results of tests recently performed and to produce replacement reports if these have been mislaid. This is a short-term storage problem which can be met by retaining the bench book or the worksheet. When it comes to long-term storage there is room for considerable argument. Laboratory data can be stored for three separate purposes—administrative, scientific, and clinical. The administrators like to have some form of annual

report. For scientific purposes the data are important as source material for statistical methods of quality control and for research.

The storage of laboratory data for clinical use requires an infallible patient identification system. The way in which the patient can be identified was under active discussion this morning at a session of this Conference. A number of speakers outlined the various items of information which each regarded as necessary for this purpose. It was accepted that there were three objectives in 'patient identification data'. First the basic information needed to identify the patient within the hospital; secondly the necessary information needed to 'home' the report accurately to the patient's location within the hospital and; thirdly the information necessary to permit linkage with already recorded medical or other relevant information available in the community. The minimum requirement for such accurate identification is a unique personal number which has been mechanically produced. When the data about the patient have been entered manually the possibility of wrongly transcribing the number arises and then corroborative information is needed to assist verification which is often inadequately recorded. In support of this I should quote a pilot study which I carried out in our own laboratory when we found that 45% of requests had addressograph labels with unequivocal patient identification particulars. This meant that more than half of the laboratory reports could not have been accurately filed, by a mechanical system, with other information regarding the patient. In another study when the data had been entered manually, only one record in five had adequate patient identification data.

Furthermore, there seems to be little useful purpose in setting up a separate record system for one part of the information about the patient, namely, the laboratory data. To attempt to use a laboratory computer for this purpose implies the responsibility for the maintenance of an accurate storage system which would not only greatly increase the cost of the installation but increase the computer staff requirements. In other words, I endorse Professor Wootton's view that a small on-line computer is needed in the laboratory for strictly laboratory purposes and that an off-line computer with backing store capability, quick access, and high speed printout is needed in the hospital for record and other purposes.

THE COMPUTER IN THE LABORATORY

As you see it is impossible to discuss automation in the laboratory without mentioning the computer,

¹*Journal of Clinical Pathology*, 1968, 21, 231-301.

for today not to engage in computer language name dropping is not to be scientifically 'with it'. In medicine the digital computer may ultimately have many applications but it has a unique role to play in the hospital laboratory. Here the mechanical handling of the mass of laboratory data would clearly benefit by mechanization. The analysis, storage, and retrieval of the data are ideal functions for the computer. Furthermore, the computer can be programmed to detect and correct for instrumental aberrations, thereby helping to control the accuracy of laboratory analyses. Sophisticated calculations, including statistical methods of quality control, fall easily within the range of its essential mathematical functions.

Not long ago a leading article in a prominent medical journal on the subject of laboratory efficiency stated that 'the proper use of the computer should raise the quality of work, improve the service and increase productivity'. If this is true what then are the difficulties? The first problem is one of access. For various reasons, an on-line computer is necessary in the laboratory. However, even a small computer is expensive to buy and such a capital outlay would only be justified in a large organization. Even if the necessary capital were available, there are very few computers on the market which have been specifically designed for laboratory use.

Having obtained the money and bought the hardware, the computer still cannot perform any operation until it has been instructed, for computers can do no more than they are programmed to do and the major weakness of the computer is the programming. The production of a suitable programme involves a long and frustrating dialogue between the pathologist and the computer programmer. It takes the pathologist time to appreciate the literal mindedness of the computer. It takes time for both to go through the logical steps needed to attain the objective and to make the improvements and modifications which will be inevitable. From my own personal experience it strikes me that there is far too wide a time gap between the acquisition of the computer and its routine use. It is quite unrealistic to expect this to be bridged by asking a busy clinical pathologist to learn computer programming. However, it is appreciated that we are going through a development phase.

At present a number of laboratories are testing out different computer systems. When the results of these studies are available we then should have reliable information as to the best type of hardware. By that time it also may be possible to purchase prefabricated programmes which are compatible for a number of computers and specifically designed for laboratory use.

THE AUTOMATION ANXIETY STATE

What I have so far discussed have been the physical effects which are the immediate and logical consequences of the mechanization of manual and mental activities. What I have not mentioned is the psychological reaction to the whole concept of automation in the hospital laboratory. This can manifest itself in a number of ways which vary from a mild anxiety state to a total rejection syndrome. Basically these manifestations stem from a fear of the machine, a historical hangover from the Industrial Revolution and the Luddite mentality. It is to some extent made more acute by the introduction of the computer, which has moved the apprehension into a new area, for 'the electronic brain competes with those who depend for their livelihood on their mental faculties'.

That automation in the laboratory will change the present practice of clinical pathology is inevitable. Whether this will be to the detriment of the specialty is a matter for philosophical speculation. There is so great and increasing a demand for laboratory tests in modern medicine that redundancy of scientific and technical staffs seems very unlikely. The role and function of the medically qualified clinical pathologist may well change, with a greater emphasis being placed on the clinical, interpretative, and administrative responsibilities at the expense of some purely routine technical work.

The fear that the computer with its vast potential will usurp the functions of the physician is groundless, for the computer is incapable of making decisions, of achieving a mature judgment, or of inspiration, and the capacity to leap across the logical steps and land on new and exciting ground. There will always be in the doctor/patient relationship the need for those essential human qualities of character and integrity, of reaction and human response, and of the comfort of compassionate reassurance. This the computer can never supply and the good physician should. However, there is perhaps some bite in the quip recently current in America that 'any doctor who can be replaced by a machine deserves to be replaced by a machine'.

ORGANIZATIONAL APPROACHES

Two organizational approaches to reducing the pressure on the hospital diagnostic laboratory have been made possible by the introduction of automated equipment. The first of these is laboratory screening for disease.

LABORATORY SCREENING FOR DISEASE The principles and practice of screening for the presence of disease either in the whole population or in selected groups

have been presented in a number of authoritative publications.

From the Värmland project carried out in Sweden, there is information on detecting early disease by screening the whole population of an area. At the Kaiser-Permanente Medical Centre in California a self-selected group of the population offered a periodic health examination has been studied in an automated multitest laboratory.

On the whole I think that screening well populations is too large, too expensive, and too controversial a subject for inclusion in this address. On the other hand, the performance of a selected series of laboratory tests on patients at hospital or attending their general practitioners raises no ethical issues and may well be a justified and economic method of diagnosing disease.

The selection of the hospital population for screening has many advantages. In the first instance it follows a well established procedure in medical diagnosis in which the application of a carefully chosen set of laboratory tests to all patients is a logical extension of a physical examination. One criterion for the success of any such screening programme is that a significant yield of detectable disease is achieved. The hospital population in this respect is obviously a high risk group. Most important is the fact that the application of a screening programme to hospital patients is logistically and technically feasible, although this is not in itself a justification for doing it as some people would appear to suggest.

While the concept of screening has been denounced by many orthodox physicians as a prostitution of the art of medicine, it has been rationalized by its protagonists on the basis of analogy. It is pointed out that, just as a good physician makes a full clinical examination not confining this to one system which the history suggests is primarily involved, so also patient profile screening gives unsolicited information on a number of body organs or systems. It has been stated that screening involves much less venepuncture for the patient, produces the results without clerical work, presents the data in a standardized computer compatible form, and offers a range of laboratory data shortly after the patient has been admitted to hospital. Such an approach should save bed time, increase the rate of disease detection, and achieve all these advantages with multitest equipment which does not significantly increase the need for skilled laboratory staff. The possible disadvantages of a screening programme are the capital outlay necessary for the equipment and the inevitable production of a proportion of results which fall in the twilight zone between so called 'normal' and 'abnormal'. The possibility of

uncovering undetected disease other than that originally suspected and requiring further investigation is an inherent risk of any medical examination but if the condition is treatable is obviously advantageous to the individual patient.

During the past year we have carried out an in-patient admission profile laboratory screening programme in two disciplines, in biochemistry using the Multi 12 and in haematology using the SMA4. We started the programme by approaching the medical staff to seek their cooperation and to ask them to submit samples to the laboratory. The results of the laboratory tests were then returned to the wards, together with a questionnaire which asked four basic questions to which answers were sought from our clinical colleagues.

The findings in the haematology screening programme are of some interest. The number of patients who gave results outside the normal accepted range in any of the six haematological parameters was just under 50% and the incidence of anaemia in the hospital population was 27%. This high rate of disease detection must be considered in the light of the clinical diagnosis already made, and the replies to the question, 'Would you have requested this laboratory test?' We found that in most instances the abnormal results confirmed a clinical diagnosis already made and that 92% of the tests would have been requested in any case. Therefore, as far as haematology was concerned the in-patient screening programme in our hospital was just routine haematology under another name. This view was borne out by a study of the total workload before and after the screening which showed no significant increase. Therefore, our conclusion is that it appears unnecessary to carry out a haematology screening programme for hospital inpatients by setting up an organization separate from the routine haematology laboratory, if this already provides a rapid and efficient service.

The findings in the biochemical screening programme, on the other hand, are less clear cut but the value to the informed clinician is undoubted. The 'biochemical screen' tends to produce a high proportion of unexpected 'abnormal' results which calls into question our present concept of what we tend to regard as so-called 'normal' values. The need to be able to define those results which fall in the borderline between the 'accepted normal' and the findings in disease is of paramount importance.

Our screening study on admission indicates the importance of a few basic requirements which are so elementary that I hesitate to mention them. First, there is need for a period of education of the medical, nursing, and other staffs in the use of

patient screening, otherwise the system will be either misused or abused. Secondly, there is the need to educate laboratory staff, for the whole principle of screening patients on admission depends on the results reaching the wards shortly after the admission of the patient. Unless this is achieved, the test may well be duplicated in both the screening and the routine laboratory. Thirdly, there is need to establish acceptable physiological so-called 'normal' parameters. Until this is satisfactorily solved, the reporting of the laboratory tests in the form of figures with no comment by the laboratory staff as to their significance may be indicated. It is then left to the clinician to interpret the results in the light of the clinical situation, the time when the sample was collected, and other factors known to him. Lastly, the use of different methods of analysis of a given substance in the screening and in the routine laboratory may show a variance which may be 'normal' for the two methods used. However, the disparity in results when reported to the wards creates uncertainty and may discredit the screening programme. Therefore, in any hospital, all the methods of analysis for a given substance should be carried out by the same technique.

We are currently cooperating in a study of the patients attending the general practitioners of one large health centre in the City of Belfast. This has shown that the provision of a screening service by hospital laboratories to general practitioners is feasible. The blood samples are taken by the nurses attached to the Health Centre and are delivered to the laboratory. The findings in the study have not yet been fully evaluated but in the first 1,000 patients screened, 11% were found to be suffering from anaemia, an observation in conformity with other similar studies. We hope to extend our investigation of patient screening to the new outpatient polyclinic which is due to be opened early in the new year. We have planned a programme which should provide us with information on the feasibility of screening selected outpatients and the effect this would have on the medical diagnostic service.

We do not claim to have made any new or startling contributions to the field of screening for disease. As far as haematology is concerned, we have found that, provided there is suitable equipment and speedy reporting, it does not seem necessary to run a hospital patient screening programme separate from the routine service laboratory.

It is most probable that techniques for the detection of disease in the early stage when treatment is likely to be successful will be further exploited. It is apparent that, 'in developed countries largely freed from the present burden of communicable disease and with resources, equipment, and

staff capable of mounting such a programme, the practice of screening will extend'.

We, as clinical pathologists, are in a position to influence the trend of events and to assist in the moulding of both medical and lay opinion in this new field of preventive medicine. We must continue to exercise our professional responsibility in this area.

The second organizational arrangement is the factory laboratory.

THE FACTORY LABORATORY The idea of the factory laboratory has developed as a method of dealing with that considerable proportion of the laboratory tests which are of a purely routine nature. The suggestion has been made that these tests could be processed in a specially designed and staffed laboratory.

This 'factory' laboratory is visualized as a data-producing unit designed to process laboratory tests for medical use. Using multichannel systems and automated methods of data processing such a laboratory could deal with non-urgent samples. By the concentration of equipment the advantages of modern methods of mass production, including systems of self-correcting analysis, could be utilized. To justify the capital expenditure and to achieve the maximum saving in cost per test, it may be necessary to operate the equipment to full capacity. This may require an extended day or even shift work. Such an alteration in working hours might be easier to achieve if the 'factory laboratory operators' were not tied to an existing work pattern or to currently agreed terms and conditions of service. The data emanating from the factory laboratory might either be funnelled through a medically staffed editing station, such as the original referring hospital laboratory, or despatched unedited to the clinician requesting the test.

Because the skills needed to operate the equipment are not medical skills nor, strictly speaking, are they medical laboratory technical skills, it has been suggested that the factory laboratory could be established in isolation geographically at a convenient communication point. Although, in theory, this may have advantages it has not yet been shown to be satisfactory in practice. I hold the view that if the factory laboratory approach is to be tested it should in the first instance be organized within or in association with an existing hospital laboratory complex rather than in isolation, for there is merit in the medical laboratory providing a total service to an area being based on a hospital. It maintains the essential medical orientation of this diagnostic service; it provides the opportunity for intercommunication between specialists in laboratory

medicine and clinical colleagues on a regular and face-to-face basis. It ensures that those who work in the laboratory will not practice this speciality from the ivory tower of intellectual isolation. By being close to hospital patients, it introduces the chastening effect of clinical involvement.

The idea of the 'factory' laboratory to deal with a proportion of the present routine workload appears to be a sensible solution to a current problem. I can see no reason why a clinical pathologist should feel any hurt to his professional pride by subcontracting the work out in this way. He has been doing something quite like this for years by handing much of the work to laboratory technicians.

The proportion of work which could be handled by a 'factory laboratory' is not inconsiderable. In our own hospital laboratories a little over 71% in the biochemistry and 53% in the haematology division are routine tests which can be carried out on two items of currently available multichannel equipment. By shelving this proportion of the routine workload, more time would be created for the existing technical staff and thereby increase the efficiency of the hospital laboratory. Simultaneously it should also provide the clinical pathologist with more time for medical consultations, teaching, and research.

THE EFFECT OF AUTOMATION ON LABORATORY SERVICES

All modern trends in the laboratory are towards mechanization, towards automated data processing, and towards the offloading onto factory or screening laboratories. Many problems have still to be solved, not least being the logistics of sample collection and transportation, the unequivocal identification of the specimen, and the best methods of acquisition, transmission, storage, and retrieval of laboratory data.

Because the maximum benefit from automation comes from centralization, and also because of the high capital cost of equipment, it is inevitable that the expensive automated equipment will be concentrated in fewer but in larger laboratories. These large laboratories are likely to be centred in district hospitals which will create certain transportation and communication problems. There is little point in providing an efficient centralized laboratory with a rapid throughput of samples if this benefit is nullified by delays in the transport of specimens to the laboratory, or of reports back to the clinician. So far we have made little progress beyond the human messenger system, except in providing the messengers with some mechanical means of transport which, within cities, may well be rendered impotent by road traffic congestion. However, some practical

experience in running a central laboratory system for a widely scattered group of hospitals in the somewhat rural area of Northern Ireland indicated that the main cause of delay was more in the transmission of reports rather than in the transport of specimens. Therefore, in any central laboratory scheme the introduction of a rapid method of data transmission is essential, and here the use of telex, teleprinter, or facsimile telegraphy might help to solve this problem.

It is probable that the automated laboratory may require fewer laboratory technicians but will require staff with biomedical engineering skills. This does not mean that the present technical staff establishment should be cut. What it does mean is that rising workloads can be absorbed without the need for a constant and concomitant increase in the technical staff establishment. The introduction of automation should create more time for technical staff to carry out work requiring manual skills or to perform tests which are so infrequently requested that their automation would not be economic. Furthermore, the scientific/technical staff can be usefully employed in the introduction and development of new methods. The total benefit to the laboratory would be considerable. It would lead not only to an improvement in the quality of service, but also to a widening of the range of tests which the laboratory could offer.

While an automated laboratory can function efficiently using the existing staff, it is a matter of debate whether this is the best way to use such personnel. It is certainly not the best way to train student technicians for subsequent work in a multi-discipline laboratory using mainly manual methods. However, there is no special establishment for an automated laboratory. As the equipment so far available is not sufficiently reliable for it to be operated by untrained personnel, qualified laboratory technicians, especially trained in the use of such equipment, are needed. Such operators can detect obvious errors in results and correct instrumental faults during analysis. The presence of an electrician on the staff to maintain equipment is invaluable.

There is no doubt that automation will affect the internal arrangements for a laboratory. Some of the newer equipment is free standing and for access is better sited in the middle of a room rather than at the periphery. This alters our present conception of a laboratory designed on a modular plan with fixed benching arrangements. Flexibility and open planning should be the keynote. Our experience has shown that dust in a laboratory atmosphere has a significantly adverse effect on delicate electronic and flowline equipment. Therefore, consideration should be given to the provision

of special ventilation, particularly in some areas. This environment control will of course be imperative if a laboratory computer is a part of the installation.

Most of us are aware of the need to abandon the traditional methods of doing things. Even in the corridors of power the necessity to experiment with new approaches and new tools is recognized. How can we convert this recognition into reality, this platitude into policy?

To have no plan and no policy will lead to the inevitable rat race with everyone rushing to buy the shiny new toys which the scientific industry dangles before our eyes, with the promise of a performance which in practice is not always realized. The cost of any laboratory automation programme for the whole National Health Service is considerable. If it were uncontrolled it would be astronomical. It has been pointed out that 'whatever the sources of finance, there will always be more that could be done if resources were greater. It is therefore, imperative that the manpower and materials bought with the money that is available, should be used as efficiently as possible'. How can we see that the best possible laboratory service is provided with the available resources?

There is much talk today of the need to streamline the administration of the National Health Service. It has been pointed out that the present administrative structure has remained virtually unchanged for 20 years, and perhaps now is the time to have it reviewed if not entirely overhauled. One of the main reasons for this view is that the administration is divided into three watertight compartments. A unified administrative arrangement under local government has been suggested but has not proved to be acceptable. Instead the Ministry of Health

and the medical profession both favour the creation of health areas based on the population of the 'catchment area of the district hospital'. Within such a region the area laboratory service would need to be reviewed and rationalized. This may require the introduction of some method of centralization. To achieve the best arrangements for the health needs of the area, the Regional Pathology Committee could provide the necessary professional advice. To make the plan effective, the pathology advisory committee would require to have at its disposal adequate monies for the purchase, among other things, of automated equipment for service use. Such a financial arrangement would be similar to that which already operates in respect of radiological equipment in some areas. Thus a more effective laboratory service could be developed without straining the financial resources too far and with a possible saving in revenue cost by a process of administrative rearrangement, by rationalizing the laboratories in each clinical area, by some measure of centralization, and by the provision of more automated equipment.

It is only by improving the efficiency of the laboratory service that clinical pathologists will be able to provide not only the scientific data from patients, but also the consultative service which together form both the science and the art of clinical pathology. More automation is an imperative need in order to achieve the necessary laboratory efficiency. In this modern age the efficient laboratory is a major factor both in care of the patient and in preventive medicine.

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