PHYSICS IN MEDICINE

BY

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This is a summary of four papers read at the September meeting of the Hospital Physicists' Association. The discussion was prompted by the recent publication of an American volume, *Medical Physics*, which, by its comprehensive scope and list of contributors, suggested that physics played a far more important part in American than in British medicine.¹ However, the wider service to medicine which physics can provide is recognized in a recent leading article in the *British Medical Journal*,² which states: "At present the application of physics to medicine is limited to radiology, the electrocardiograph, and the electroencephalograph in diagnosis, and the somewhat empirical use of various forms of radiant energy in treatment; but it is highly unlikely that these represent more than a fraction of the contribution physics might make to human biology." This medical opinion, which recognizes that the possibilities of physics in medicine are very much wider than the present almost exclusive concentration on radiotherapy by x and radium radiations, is widely held by hospital physicists, and has been admirably expressed by Prof. W. V. Mayneord.³ The most natural extension from this field would be the physics of diagnostic radiography, and of therapy by infra-red and ultra-violet radiations, and high-frequency currents, though there are probably many spheres of medical research in which physical measurement can play an important part—as illustrated, for example, by the recent research by Rundle and Wilson⁴ upon the eye signs exophthalmos and ophthalmoplegia.

Historical

The almost exclusive restriction of physics to radiotherapy can be understood from a study of its development in hospitals. The employment of physicists in the London hospitals and medical schools is a comparatively recent innovation. Early in the history of medical schools the lectures in all subjects were given by medical men. At Bart's the first subjects taught by specialists were chemistry and biology. Some time in the 1880's Donald MacAlister, later Vice-Chancellor of Glasgow University, was appointed Demonstrator in Physics. He was succeeded by the late Dr. Womack, immediate predecessor of the present Professor, F. L. Hopwood. Contemporary with Womack were Dr. Fison of Guy's, Dr. Stone of St. Thomas's, and, later, Dr. Lehfeldt of the London Hospital. All of these, it is believed, were on the medical college staff and not on the hospital staff. It seems that the first professional physicist to take up a hospital appointment was the late Major Phillips, Honorary Physicist to the x-ray department of the Cancer Hospital for some years prior to 1914. Prof. S. Russ, on relinquishing a Beit Fellowship, became Physicist to the Middlesex Hospital, later head of the physics department of the Middlesex Hospital Medical College and Honorary Physicist to the hospital. Prof. Hopwood was, in 1919, one of the first physicists to become a paid member of the staff of a London hospital. He had been Demonstrator of Physics at Bart's from 1906, and an Honorary Clinical Assistant in the x-ray department, 1914-15. The immediate reason for his appointment was the contemplated development of deep x-ray therapy, and this was reinforced almost immediately by the establishment of a radium research department to use radium recovered from war appliances and lent to the Medical Research Council by the Government. Somewhat later Prof. W. V. Mayneord was appointed Physicist to the Cancer Hospital, and subsequently such appointments at hospitals with large radiotherapy centres and at the National Radium Centres have become general.

From the first all hospital physicists have been concerned mainly with the x-ray and radium departments, and to a less extent with the electrical and ultra-violet light departments. Prof. Hopwood, especially interested in units and standards, became secretary of the British X-Ray Unit Committee, while Prof. Russ became the first secretary of the Radium Committee of the Medical Research Council, the Radium Commission, and the British X-Ray and Radium Protection Committee. In those early days mercury interrupters, induction coils, and Lodge valves were general, and clinical dosage was based upon

the Sabouraud pastille, Kienböck photographic strips, milli-ampere-seconds, and milligramme-hours. The contrast with to-day is striking. It is probably not too much to claim that the present international units for x-ray and radium dosage, and the international recommendations for x-ray and radium protection, are due chiefly to the labours of the respective British committees.

Routine and Development Work of the Physicist in Hospitals and National Radium Centres

The use of x-ray and radium equipment has so far made the most direct claim on the services of the physicist. He must ensure its physical perfection and detect aberrations before they have affected treatments. The electrical and radiation protection of patients and staff, and supervision of the care of radium needles and tubes and their recovery if lost, are his responsibility. He has developed convenient apparatus for the measurement of x-ray and gamma-ray dosage, with which the output of x-ray tubes and needles can be calibrated, and with the aid of substandards should be able to hold his accuracy near that of the standards of the National Physical Laboratory.

This accuracy is the foundation of control of radiation dosage, and on it have been elaborated methods of computing and mapping the extent of the field of "tumour-lethal" dosage with respect to the tumour and its site. This field is as important in a radiation treatment as the operation field in a radical surgical excision, and is equally relevant to the question of the patient's survival. From a study of cases of frequent occurrence the best arrangement of beams can be chosen, the methods standardized, and the radiation field computed initially for future routine use. Other cases may require individual study. Here particularly the physicist must have sufficient acquaintance with the anatomy and the nature of tumours to collaborate understandingly with the radiotherapist. This knowledge is best gained by first-hand clinical contact, and both can profit much from the partnership; the physicist must relate his calculations and measurements to actual lesions and medical practice, while the radiotherapist modifies his technique towards the more precise ideas of the physicist—so far as human anatomy will allow. The construction of radium moulds with physical measurements to ensure the realization of the desired dose distribution, the determination of dose in interstitial radium therapy, and the planning and assessment of x-ray and radium beam treatments require the closest collaboration of physicist and radiotherapist.

In addition to clinical work, work of a developmental or semi-research nature is an important function of the physicist. Apparatus has been developed for a great variety of purposes—to hold constant the x-ray output of a tube, to measure dose rate and integrated dose under a variety of circumstances, to give mechanical aid in the computation of dose and the summation of radiation fields, beam-direction devices, callipers, jigs, etc. Empirical techniques have been investigated and improvements suggested—e.g., the needling of the larynx and radium treatment of the cervix.

Although, for the reasons outlined, the physicist's work is largely confined to radiotherapy, in a general hospital requests for assistance in other fields are received from time to time. A few random examples are: the supply and calibration of thermocouples for measurement of the rate of recovery of defective circulation of a limb after sympathectomy, and of skin temperatures following other neurological experiments; the installation of monochromatic illuminants for use with the slit microscope in the eye department; assistance with the polarimeter used to test the purity of insulin compounds; the development of pressure gauges to test the recovery of normal function in patients operated upon for cleft palate; apparatus for the drip method of blood transfusion, and for aspiration of bladders and wounds; sound insulation of Wehnelt interrupters; investigation of the protection of goggles from ultra-violet light; and measurement of the heating produced by diathermy.

Teaching

There are advantages in the use of physicists directly concerned in radiological work as teachers of physics courses for the diplomas in radiology. The practical background of the physics of radiology is thus assured, and the first step taken

in the collaboration between radiologist and hospital physicist which is so desirable later. It is also desirable that the medical student should have a better acquaintance with the applications of physics to medical work than can usually be gained from the pre-clinical course, and the University of Leeds now provides a short course of lectures on the uses in medicine to which physics can be put. The practical experience of hospital physicists is also an advantage in the teaching of physics to student radiographers and physiotherapists.

Research

The attractiveness and efficiency of any physics department depend on the atmosphere and facilities for research. The Goodenough Committee contemplates that in a medical college the members of the staff should for half their time be free to pursue research. However, though the implementation of the Cancer Act is bound to exert a profound influence on the role and status of the hospital physicist, a former Minister of Health has stated that it is *not* the function of the authorities responsible for administering the Act to undertake research. There is thus a probability that only at some of the cancer centres will any research be undertaken. It is difficult to draw a sharp distinction between research and development. A great deal of valuable work, perhaps more of the nature of the latter, has been done in radiotherapy centres, but there has been some work of a fundamental character. The provision of *ad hoc* solutions for the succession of practical difficulties which arise in a radiotherapy department, or the development of techniques or appliances at the request of the radiotherapist, should not be regarded as research. Rather it is the investigation of a problem freely chosen by the individual to satisfy his own curiosity, and followed wherever it leads. There is little danger that such problems will not be related to the work of the department in which the physicist is employed, and without the freedom of choice the best men will not find the work attractive.

If time and facilities were available much could be done in a radiotherapy department in tracing the chain of events between absorption of ionizing radiation and the biological effects produced, and this need not necessarily involve elaborate experimental work, as there is a considerable amount of knowledge regarding the processes of absorption of radiation, the energies of the electrons produced, the distribution of ions along their tracks, and the dependence of a number of biological effects on this ion density, which needs sifting, analysing, and studying with special reference to its implications for radiotherapy. Many profitable researches, not requiring great space or equipment, could be undertaken at radiotherapy centres, such as cloud-chamber studies, or chemical and colloid effects of radiations, while the availability of induced radioactive chemicals will open to the hospital physicist a wide opportunity of collaborating in the study of therapy by these chemicals, or in the study of physiology.

However, many recent physical developments likely to have great importance in medicine require space and apparatus of considerable magnitude and knowledge of special techniques. There are machines for the production of beams of the heavier ionizing particles—protons, alpha particles, etc.—notably the cyclotron or ion tube energized by a high-voltage source such as a Van de Graaff machine. These beams may possibly be used directly in therapy or indirectly to produce supplies of induced radioactive chemicals or neutron beams. The betatron is being developed in the U.S.A. to give x rays corresponding to exciting voltages of 100 million volts, while other methods are proposed which should give electron beams of very great energy, able to penetrate to the deepest tumour, so that perhaps the electron beam itself may be used in therapy, rather than x rays produced by the electrons. Radar research has developed means of generating and transmitting radio waves of very short wave-length—the order of centimetres—of energy vastly greater than has so far been available in these wave-lengths. Not only may such waves be superior for the customary purpose of diathermy, since heat could probably be far better localized than is possible in the case of longer waves, but it is also likely that resonance of complex molecules will occur, with an associated biological effect. Lastly, the electron microscope provides a means of “seeing” biological structures far smaller than the resolution of the optical microscope permits.

A noteworthy point concerning these developments is that certain techniques are common to several—e.g., high-vacuum technique, high-voltage technique, the generation and transmission of high-frequency oscillations, the focusing of ion or electron beams, and so on. This suggests that it would be better if they were all tackled centrally, at a Radiological Research Institute, by a team of men, each a specialist in one of these techniques, rather than each separately at a different institution. Such an institute could also undertake the task of the development of more reliable and serviceable x-ray and associated equipment, and investigate desirable standardizations. Many industries have each established a research institute, and there seems good reason why the British x-ray industry should co-operate with the various interested medical bodies for a like purpose. Such an institution should have a hostel attached, so that visiting research workers could spend six months or so pursuing particular researches with the aid of the induced radioactive chemicals or other facilities of the institute. Hospital physicists should spend a period, from time to time, at the institute, assisting in the work, and so return to their hospital abreast of the latest developments and stimulated by association with the other workers there. In addition, a hospital physicist of wide experience should be appointed to the staff of the institute, to provide a close liaison between the institute and the hospitals, and indicate from his experience what techniques, etc., are feasible for routine hospital use.

Summary of Points Raised by the Four Speakers

Physics could play a much wider and more valuable part in medicine than at present, as it is now largely concentrated on radiotherapy.

The extension of physics into other branches of medicine in a general hospital is frequently hindered by points of administration and habit, which are due to the historical close association of radiotherapy and physics.

To be fully effective the physics in a general hospital should be the responsibility of one physics department, directed by a physicist under the general control of the hospital committees.

In order to serve all departments, rather than the radiotherapy departments alone, commensurate staff and laboratory and workshop facilities would be necessary. A common defect in the organization of physics in a hospital is failure to ensure that the physicist spends his time on work of the calibre for which he is paid, by providing adequate clerical, laboratory, and workshop assistance to cope with the mass of odd jobs that continually arise.

Research provides a worthwhile stimulus, and those permitted to do research work should have freedom in their choice of problem and in its development.

The large-scale physical developments of great promise in their application in medicine would be best served by a research institute, with a staff of specialists in the different techniques involved. The x-ray industry should co-operate, so that the institute could also undertake research into the improvement of x-ray and associated equipment, and any desirable standardization.

REFERENCES

- ¹ *Medical Physics*, 1944, ed. O. Glasser, Year Book Publishers, Inc., Chicago.
- ² *British Medical Journal*, 1945, 2, 123.
- ³ Mayneord, W. V., *Brit. med. Bull.*, 1945, 3, 129.
- ⁴ Rundle, F. F., and Wilson, C. W., *Clin. Sci.*, 1942, 4, 385; 1944, 5, 17, 31.

By a new rule of the General Nursing Council for Scotland assistant nurses who had received training for the State Register and had passed the preliminary examination before they were admitted to the Roll of Assistant Nurses will have their course shortened by at least six months if they again start training for the State Register. This concession, which shortens the normal course of three years' training to two and a half years (or less in cases where the General Nursing Council permit), is confined to Scotland. In both Scotland and England, however, men and women who have had two years' experience of nursing in a hospital under the supervision of trained nurses in the Services, the Civil Nursing Reserve, or other organizations can also apply to have their course of training for State registration shortened to two and a half years. Assistant nurses who want to take advantage of this new concession should apply, before they resume their training, to the Registrar of the General Nursing Council for Scotland, 5, Darnaway Street, Edinburgh, 3.