MODERN TRENDS IN DIAGNOSTIC RADIOLOGY

(THIRD SERIES)

Edited by

J. W. McLAREN, M.A., M.R.C.P., F.F.R., D.M.R.E.

RADIOLOGIST, X-RAY DEPARTMENT, ST. THOMAS' HOSPITAL, LONDON; EXAMINER IN RADIOLOGY TO THE EXAMINING BOARD OF ENGLAND AND TO EDINBURGH UNIVERSITY; SOMETIME EXAMINER IN RADIOLOGY, UNIVERSITY OF LONDON AND FACULTY OF RADIOLOGISTS

BUTTERWORTHS MEDICAL PUBLICATIONS

MODERN TRENDS SERIES

ACCIDENT SURGERY AND MEDICINE—Edited by RUSCOE CLARKE, M.B.E., M.B., B.S., F.R.C.S.(Eng.), F. G. BADGER, B.SC., F.R.C.S.(Ed.), and SIMON SEVITT, M.D., M.SC., M.A., F.R.C.P.I., D.P.H.

ANAESTHESIA—Edited by FRANKIS T. EVANS, M.B., B.S., F.F.A.R.C.S., D.A., and CECIL GRAY, M.D., F.F.A.R.C.S., D.A.

BLOOD DISEASES—Edited by JOHN F. WILKINSON, M.D., M.SC., PH.D., F.R.C.P., F.R.I.C.

DERMATOLOGY (Second Series)—Edited by R. M. B. MACKENNA, M.A., M.D., F.R.C.P.

DIAGNOSTIC RADIOLOGY (First and Second Series)—Edited by J. W. MCLAREN, M.A., M.R.C.P., F.F.R., D.M.R.E.

DISEASES OF THE EAR, NOSE AND THROAT—Edited by MAXWELL ELLIS, M.D., M.S., F.R.C.S.

DISEASES OF THE VERTEBRAL COLUMN—Edited by REGINALD NASSIM, B.M., F.R.C.P., and H. JACKSON BURROWS, M.D., F.R.C.S., F.R.A.C.S.

ENDOCRINOLOGY—Edited by H. GARDINER-HILL, M.B.E., M.D., F.R.C.P.

FORENSIC MEDICINE—Edited by KEITH SIMPSON, M.D.,(PATH.)LOND., M.R.C.P.

GASTRO-ENTEROLOGY (Second Series)—Edited by F. AVERY JONES, M.D., F.R.C.P.

GERIATRICS—Edited by WILLIAM HOBSON, B.SC., M.D., D.P.H.

NEUROLOGY (Second Series)—Edited by DENIS WILLIAMS, C.B.E., M.D., D.SC., F.R.C.P.

OBSTETRICS AND GYNAECOLOGY (Second Series)—Edited by KENNETH BOWES, M.D., M.S., M.B., CH.B., F.R.C.S., F.R.C.O.G.

OPHTHALMOLOGY (Third Series)—Edited by ARNOLD SORSBY, M.D., F.R.C.S.

ORTHOPAEDICS (Second Series)—Edited by SIR HARRY PLATT, LL.D., M.D., M.S., F.R.C.S., F.A.C.S.

PAEDIATRICS (Second Series)—Edited by ARON HOLZEL, M.D., D.C.H., and J. P. M. TIZARD, M.A., B.M., F.R.C.P., D.C.H.

PATHOLOGY—Edited by DOUGLAS H. COLLINS, O.B.E., M.D.(L'pool), F.R.C.P.(Lond.).

PSYCHOLOGICAL MEDICINE—Edited by NOEL G. HARRIS, M.D., F.R.C.P., D.P.M.

PSYCHOSOMATIC MEDICINE—Edited by DESMOND O'NEIL, *M.C.*, M.D., M.R.C.P., D.P.M.

PUBLIC HEALTH—Edited by SIR ARTHUR MASSEY, C.B.E., M.D., D.P.H., D.P.A.

SURGICAL MATERIALS—Edited by LEON GILLIS, M.B.E., M.CH.(Orth.), F.R.C.S.(Eng.), F.R.C.S.(Edin.), D.L.O.

UROLOGY—Edited by SIR ERIC W. RICHES, *M.C.*, M.S., F.R.C.S.

PRINTED IN GREAT BRITAIN BY HEADLEY BROTHERS LTD
109 KINGSWAY LONDON WC2 AND ASHFORD KENT

CONTRIBUTORS TO THIS VOLUME

G. M. ARDRAN, M.D., D.M.R.
Radiologist, Nuffield Institute for Medical Research, University of Oxford; Lecturer in Radiological Anatomy, Department of Human Anatomy, University of Oxford; Radiologist, Atomic Energy Research Establishment, Harwell; Radiologist, Atomic Weapons Research Establishment, Aldermaston; Associate Radiologist, United Oxford Hospitals

F. B. COCKETT, M.S., F.R.C.S.
Surgeon, St. Thomas' Hospital, London

J. FRIMANN-DAHL, M.D., SC.D.
Professor of Radiology, University of Oslo; Director, Roentgen Department, Ullevaal Hospital, Oslo

DAVID EDWARDS, M.B., M.R.C.P., D.M.R.D., F.F.R.
Consultant Radiologist, University College Hospital, London

ARNE ENGESET, M.D.
Neuroradiologist, Roentgen Department, University Hospital, Oslo

F. CAMPBELL GOLDING, F.R.C.P., F.F.R.
Director, X-ray Diagnostic Department, Middlesex Hospital, London

RONALD G. GRAINGER, M.D., M.R.C.P., D.M.R.D., F.F.R.
Consultant Radiologist to the United Sheffield Hospitals; Formerly Radiologist, London Chest Hospital, and St. Thomas' Hospital, London

W. G. SCOTT HARDEN, M.B., CH.B., D.M.R.E.
Radiologist, Cumberland Infirmary, Carlisle

C. J. HODSON, M.B., B.S., F.R.C.P., F.F.R., D.M.R.E.
Director, X-ray Diagnostic Department, University College Hospital, London

A. C. W. HUTCHINSON, D.D.S., M.D.S., F.D.S., F.R.S.E.
Visiting Professor in Diagnosis, Northwestern University Dental School, Chicago; Dental Consultant to the Royal Navy; Examiner to the Royal College of Surgeons of Edinburgh and to the Royal Faculty of Physicians and Surgeons of Glasgow; Formerly Professor of Dental Surgery and Director of Dental Studies, University of Edinburgh

J. B. KINMONTH, M.S., F.R.C.S.
Professor of Surgery and Director of the Surgical Unit, St. Thomas' Hospital, London

KRISTIAN KRISTIANSEN, M.D.
Chief, Neurosurgical Department, Ullevaal Hospital, Oslo

JOHN LIND, M.D.
Professor of Paediatrics, Children's Clinic, Karolinska Hospital, Stockholm; Director of Research, Wenner-Gren Research Laboratory, Norrtull's Hospital, Stockholm

THOMAS LODGE, M.B., CH.B., F.F.R., D.M.R.D.
Consultant Radiologist, United Sheffield Hospitals, Clinical Teacher in Radiodiagnosis, University of Sheffield

ÅKE LINDBOM, M.D.
Radiologist, Roentgen Department, Karolinska Hospital, Stockholm

A. J. MINNS
Managing Director, Watson and Sons (Electro-medical) Limited, North Wembley, Middlesex

PER ÖDMAN, M.D.
Radiologist, Hässleholm, Sweden

S. B. OSBORN, B.SC., A.INST.P.
Principal Physicist, University College Hospital; Honorary Lecturer, University College Hospital Medical School, London

J. W. PIERCE, M.D., M.R.C.P., D.M.R.D.
Radiologist, St. Thomas' Hospital; Radiologist, Brompton Hospital, London

ERIC SAMUEL, B.SC.(Wales), M.D.(Lond.), M.R.C.P.(Edin.), F.R.C.S.(Eng.), F.F.R.(Lond.), D.M.R.E.(Camb.)
Radiologist in Charge, Radiodiagnostic Department, Royal Infirmary, Edinburgh; Honorary Senior Lecturer in Radiology, Department of Diagnostic Radiology, University of Edinburgh

FREDERIC N. SILVERMAN, A.B., M.D., D.A.B.P., F.A.A.P.
Associate Professor of Paediatrics and Radiology, College of Medicine, University of Cincinnati; Director, Division of Roentgenology; Associate, Children's Hospital Research Foundation, Cincinnati, Ohio

CARL WEGELIUS, M.D.
Professor of Radiodiagnostics, University of Turku, Finland; Co-director, Wenner-Gren Research Laboratory, Norrtull's Hospital, Stockholm

E. ROHAN WILLIAMS, M.D.(Lond.), F.R.C.P., F.F.R., D.M.R.E.
Director, Diagnostic Radiological Department, St. Mary's Hospital, London; Consultant Radiologist, Queen Charlotte's Maternity Hospital, London; Late Hunterian Professor, Royal College of Surgeons of England

G. R. WOODALL
Publicity Manager, Watson and Sons (Electro-medical) Limited, North Wembley, Middlesex

CONTENTS OF THE FIRST SERIES

CONTENTS OF THE FIRST SERIES

CONTENTS OF THE SECOND SERIES

CONTENTS OF THE SECOND SERIES

INTRODUCTION

DIAGNOSTIC radiology has again made great advances since the Second Series of this book appeared in 1953. This volume attempts to record our knowledge of the advances made in the last seven years. As in the previous Series the articles are by authors of international repute, but it must be remembered that multiple authorship does not necessarily lead to uniformity in outlook. Expressions of opinion in the chapters of this book may therefore be individual. Where translation has been made into English an attempt has been made to keep as closely as possible to the meaning and intent that the author expressed in his own language.

In this volume the method of reproducing the illustrations has been considerably changed as the illustrations have been "bled off", and this allows larger and more illustrations to each article without enlarging the size of the book. In the main, reproductions of radiographs have been made in negative form but in certain instances, either at the author's request or because the detail that the author wishes to depict is more clearly shown, positive reproductions have been made.

My thanks as editor are due to all the contributors to this volume, to my secretary and to the technical staff of Messrs. Butterworths' Medical Department who have always co-operated so well in the production of this Series.

J. W. McLAREN

February, 1960

CONTENTS

CONTENTS

CHAPTER 1

RADIOLOGICAL APPARATUS

A. J. MINNS AND G. R. WOODALL

THE EVOLUTION of x-ray apparatus is a continuous process stimulated by the constantly increasing demands of radiologists and probably to a less extent by progress in methods and materials common to other branches of electrical, mechanical and optical engineering. There is a world-wide exchange of technical information, but developments which are readily accepted in some countries are not invariably adopted in others. Whilst it is not possible to be cognizant with all that is taking place in the x-ray apparatus factories of the world, an attempt is made here to describe briefly some of the equipment known to the authors, which in their opinion indicates future trends.

Almost all x-ray apparatus design is in some way conditioned by the electrical characteristics and physical dimensions of x-ray tubes. Dramatic changes may yet come, but at the present time the upper limit at which rotating anode tubes can be produced to operate satisfactorily appears to have been reached at 200 kVp. Tubes of this rating are in use mainly in Scandinavia; elsewhere 150 kVp. is the top rating. The use of liquid coolants offers the possibility of higher thermal ratings, but at the expense of more complex apparatus, and it seems doubtful whether liquid-cooled tubes will come into general use for diagnostic purposes. Present-day rotating anode tubes have greatly improved thermal capacity and can thus withstand the heavy loading of rapid serial techniques which are being employed to an increasing extent to record movement.

PHOTO-FLUOROGRAPHY

Of the factors affecting the activities of manufacturers of x-ray apparatus in recent years, photo-fluorography ranks high in importance. This is owing to the optical qualities of the mirror camera system which have made possible 70 and 100-millimetre pictures having a diagnostic quality which is adequate for many purposes and thereby makes possible substantial economies in film and in filing space. The use of this system for chest radiography is already widespread, and many users rely on the 100-millimetre photo-fluorograph for the majority of their chest examinations. It is also claimed that the small film can replace full-size radiographs for certain other regions, but there is as yet no wide-scale acceptance of this view.

In some countries photo-fluorography is employed in examinations such as angiocardiography, where basically a rapid series of pictures is required to record a cycle of movement. As many as 40 radiographs can be taken at speeds of from one to six per second, the exposure frequency being pre-set and capable of variation in groups of five exposures. By using a small-size fluorescent screen and a reduction factor of 4:1 for subjects such as cerebral angiography or angiocardiography of children, greater detail can be shown than would be the case if a full-size screen were photographed.

Another development of photo-fluorography is the simultaneous use of two cameras to obtain antero-posterior and lateral views, whilst two cameras have on occasions been used side by side when the need exists to cover a long field as in arteriography. Both the legs and the lumbar region can be included on two films which are joined together after development.

IMAGE INTENSIFIERS

Research on methods of increasing the brilliance of the fluorescent screen image are continuing in several directions and it is reasonable to expect that some of them will, in the not too distant future, become practical and economic tools for the average x-ray department. This will give an impetus to cine-radiography and there will be a substantial reduction in the patient dose during all procedures involving the use of a fluorescent screen.

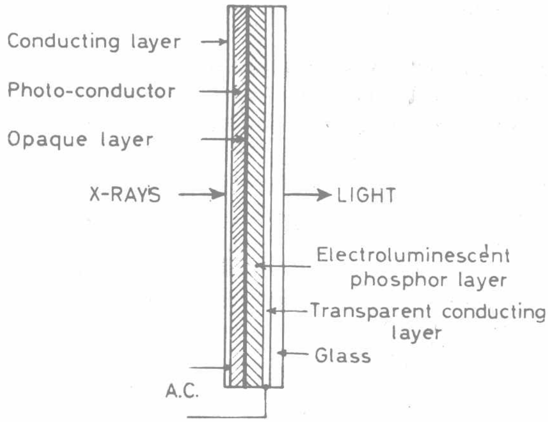

FIG. 1.—Diagrammatic illustration of solid state intensifier.

There are several methods of image intensification, but at the present time, so far as is known, the most widely used is that incorporating an electronic "image convertor" tube as described in the previous series of this book. Since that time the effective field covered has been increased from five to eleven inches in diameter (27 centimetres), but larger tubes are of necessity bulky and expensive.

There are three other systems in course of development. The first of these makes use of a television camera and monitor to increase the brightness of the image on a normal fluorescent screen, and provide a final image on the monitor screen somewhat similar to that of a television receiver.

The second method is usually referred to as the "solid state" intensifier (Fig. 1), so called because it depends on the reaction of solids to external influences, the action occurring within the solid itself. The amplifier can take the form of a flat plate similar in appearance to an ordinary fluorescent screen. It consists of a photo-conductive layer, activated by x-rays, which controls the light output of an electroluminescent phosphor.

In the model described, which was developed by R.C.A. Laboratories, the photoconductor is grooved, and alternate ridges are given D.C. bias of opposite polarity; a 420 cycle A.C. supply of peak value equal to the bias voltage is applied to the phosphor and photoconductor in series via a transparent conductive layer and the common point of the bias circuit. Conduction between the phosphor and photoconductor is limited in order to prevent diffusion of the image and light feed-back is prevented by an opaque layer.

It is claimed that at low input levels the intensifier produces an image having a light output as much as 100 times greater than that of a fluorescent screen. Unfortunately, however, this includes a build-up time of about 10 seconds and a decay time, or afterglow, of 15 to 45 seconds. Thus the system is not at the present time suitable for viewing moving organs, but it is hoped that further research will ultimately overcome these difficulties. On the other hand, the persistent image can be turned to advantage by extending the time during which an image, produced by a short exposure, is available for study. The image can be "erased" by electronic means, in a fraction of a second.

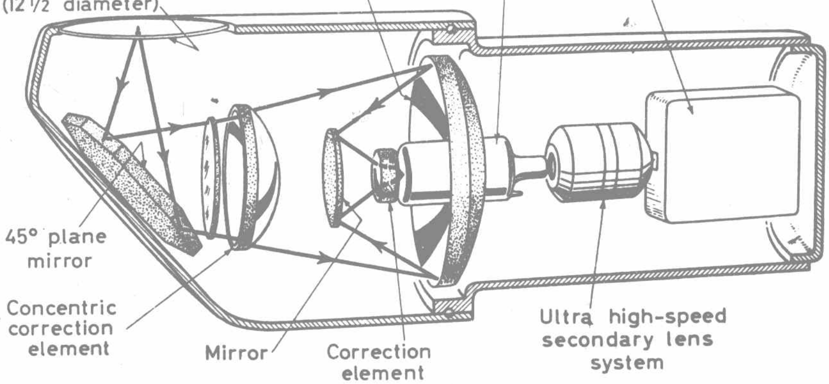

FIG. 2.—Diagram illustrating the Odelca image intensifier.
(By courtesy of N.V. Optische Industrie "De Oude Delft")

A combination of light amplifying tube with a reflecting optical system developed by Professor Bouwers also opens up possibilities (Banks, 1958). A spherical mirror 18 inches in diameter is used to produce a reduced image of the fluorescent screen on a light amplifier tube. The optical system has an aperture of about f/0·7 and makes it possible to collect eight or nine times the amount of light that is possible with an f/1·0 refractive optical system. The image is picked up by the 1:1 lens of a 35-millimetre cine camera. A viewing device is incorporated to enable monitoring to be carried out whilst filming (Fig. 2).

An example of a practical application of image intensifiers is a special heart catheterization apparatus introduced by Philips, which incorporates a two-way viewer enabling the surgeon and radiologist to observe the image simultaneously. Other specialized applications will without doubt be developed as time goes on.

EXAMINATION TABLES

One of the most radical changes in table design, though not entirely new, is that in which the fluorescent screen assembly and x-ray tube remain in the vertical plane whilst the patient is moved by mechanical means in any required direction. This has certain advantages for the radiologist, but the patient must be securely strapped in position and the apparatus is of necessity more complex than the orthodox table. An apparatus of this type, designed by C. H. F. Muller of Hamburg, permits the rotation and movement of the patient in practically every direction. The design lends itself particularly well to use with an image intensifier and cine camera or with a photo-fluorographic camera.

Radiographic tables generally tend towards providing an increased range of tilt up to a full 180 degrees; the best of them have a variable-speed hydraulic drive with automatic deceleration at the extremes of travel so that they come to rest gently. Control of the movement of many tables is by means of a hand lever or press button situated at the front of the fluorescent screen in preference to the foot pedal, although some manufacturers supply both types of control

The "ring mounted" table has made its appearance in the United States of America, but not in Great Britain. The orthodox floor pedestal is replaced by a vertically disposed circular ring in which the table body is supported on its remote side and is free to rotate through 180 degrees. A similar construction is adapted for a cine-fluorographic unit offered by Philips, the x-ray tube in this case being also carried by the large ring, and for the Siemens Universal Planigraph.

Improvements in detail include motor-assisted screen movements, electro-magnetic brakes, reciprocating Bucky diaphragms (which save the need for setting) and facilities for simultaneous antero-posterior and lateral fluoroscopy and radiography. A refinement—sometimes offered as an optional extra—is a motor-operated footrest which saves time and labour in bringing the region under examination behind the fluorescent screen.

Serial changers have improved in operative convenience rather than in principle, and the extent to which their action is automatic is governed by the price. Pneumatically operated changers worked entirely by push-button are becoming increasingly popular. The operating mechanism is more compact than that of the motor-driven type, and less space is therefore occupied beneath the screen so that any necessary palpation can be carried out more readily. On the other hand, pneumatic operation involves the installation of an air compressor.

A departure from the floor mounted or floor-to-ceiling mounted tube-stand is the ceiling-suspended type which is said to offer advantages under certain conditions. It affords unobstructed working space on all sides of the x-ray table, and can easily be arranged to serve more than one table or a table and vertical cassette holder. There is the minimum of obstruction to free movement of the tube, but some models cannot be arranged to direct the beam in an upward direction. A separate under-table tube easily overcomes this difficulty. The installation of this type of tube-stand may present structural problems in some cases, but where floor space is very restricted it has much in its favour.

Table design has, to some extent, been affected by the increasing stringency of protection requirements and various collimating devices have been introduced to confine the primary beam within the area of the fluorescent screen. A variable beam delineator with light-beam indicator is provided by some manufacturers for over-table radiography and this provides a very practical way of reducing the direct radiation hazard. Protection against scattered radiation has been increased in various ways including shutters to close the gap between the table top and the Bucky runners. The lead equivalent of the lead-glass of fluorescent screens has generally been increased to at least 2 millimetres, and the size and lead content of aprons suspended from the screens have also been increased.

THE OPERATING THEATRE

When using x-rays in the operating theatre it is usually accepted that some concessions must be made to radiographic quality and asepsis, and that non-inflammable anaesthetics must be used. This need not be the case, however, and at some British hospitals the operating theatre is equipped with a full-power x-ray installation operable in an aseptic manner and without electrical explosion hazards. The x-ray tube is supported on a wall bracket with a span of 8 feet 3 inches (2·5 metres) to bring it directly over the operating table or alongside it with the tube firing horizontally or at any angle required. The high-tension transformer and control unit are housed in separate rooms, communication with the operator being by means of a two-way communication system incorporated in the bracket. When not in use the bracket folds into a cupboard with a flush door.

In Germany a rotating anode tube has been built into an operating lamp, and in this case, too, it is connected by the high-tension cables enclosed in the support, to a generator in a room above. Manipulation of the lamp with its added weight, is dealt with by the incorporation of five motors which, it is claimed, give delicate control of all movements.

TOMOGRAPHY

Advances in apparatus for body-section radiography continue to increase the diagnostic value of this method, the objectionable increase in radiation dose which it formerly involved being overcome to some extent by the multi-section technique described by Mr. W. Watson in the previous series of this book. This method was slow to find acceptance, but now that several manufacturers have produced multiple cassettes containing graded sets of intensifying screens which give even blackening of all the films in a series of tomographs, it is coming into widespread use.

Another factor having a favourable influence on tomography is the introduction of mechanically propelled and remotely controlled tomographic apparatus which reduces the radiation hazards for the operator and takes the physical effort out of tomography.

Special apparatus for taking tomographs in various planes with the patient in any required position has already been described; a relatively new development is the Rotagraph by Watson & Sons (Electro-Medical) Ltd., for rotary tomography of the skull. This enables a radiograph of both upper and lower jaws from one temporo-mandibular joint to the other to be made in a single exposure on one