The use of contrast media and serialographic examinations, as well as other recent advances in the field of diagnostic radiology, reported here, is leading to greater diagnostic acumen and therapeutic advances heretofore unsuspected.

Developments in Diagnostic Radiology

By THEODORE F. HILBISH, M.D.

EVER since the discovery of the X-ray by Roentgen in 1895, the utilization of this invisible ray as a diagnostic adjunct in the field of medicine has increased by leaps and bounds. Not only has the use of the X-ray beam increased, but the development of accessory materials, such as the newer contrast media, has widened the horizon of diagnostic application of this ray. Furthermore, the engineering of special radiographic equipment, including the designing of miniature film X-ray units—for 35-mm., 70-mm., and 4- by 5-inch films—and the application of the principle of phototiming, has made practical the screening of the general public for the detection of tuberculosis, heart disease, lung carcinoma, and of other major diseases.

The purpose of this brief presentation, however, is to direct a few comments toward some of the recent trends and developments in the field of diagnostic radiology. As a matter of convenience, some of the early experiences in the operation of the Diagnostic X-ray Department of the Clinical Center at the National Institutes of Health, Public Health Service, will be mentioned since these experiences are pertinent to this discussion.

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This review is based on a paper presented by Dr. Hilbish to the Maryland Radiological Society at its second annual meeting, May 1954, in Hagerstown.

Serialographic Ureterograms

One of the new radiographic methods investigated at the Clinical Center is that of obtaining serialographic ureterograms. This study is a direct outgrowth of our numerous discussions with radiologists, gynecologists, and urologists concerning a common problem, the radiological detection of minimal ureteral strictures. Many female patients seek gynecologic consultation because of symptoms of costovertebral pain or because of some other manifestation which suggests partial urinary tract obstruction. Yet, our routine intravenous pyelographic films almost invariably fail to demonstrate evidence of pathology. Largely because of the interest of the urologist at the Clinical Center in this sub-

ject, we decided to attempt a solution to the problem by using some of the new diagnostic equipment at the Clinical Center. We believed that the most logical approach would involve a physiological study of the urinary system. An overdistention of the urinary tract by retrograde pyelography or the introduction of a foreign body, such as a ureteral catheter, was certain to disturb the physiology of the urinary tract. As a result of much discussion and planning, the procedure described below was adopted.

After the patient to be examined has been moderately dehydrated, she reports to the X-ray department where she is given an intravenous injection of 50 cc. of 70 percent urokon, a dye used as the contrast medium. This injection is given rather slowly through an 18-gauge needle. It is immediately followed by approximately 300 to 400 cc. of 5 percent glucose in water, which is administered through the same needle from an intravenous flask.

Following administration of the glucose solution, which usually takes about 8 to 10 minutes, serialographic films of the urinary tract are made with a Sanchez-Perez serialographic X-ray unit. They are taken at the rate of 1 film every 2 seconds for a total of 12 films. The quantities of urokon and intravenous glucose to be injected, as well as the rate of serialographic filming to be followed, were determined as the result of preliminary experience. The method described, which is currently in operation at the center, was found to be the most effective so far as demonstration of evidence of pathology in the ureters is concerned.

Films which have been obtained in this manner are first studied radiographically by placing them on an X-ray film viewbox in serial order. By so doing, it is possible to visualize and evaluate carefully every section of the urinary tract. The X-ray films may then be placed in register and photographed with a motion picture camera. The films so obtained are then projected on a screen so that the physiological action of the urinary tract can be evaluated. Our experience indicates that more reliable information can be obtained, however, by carefully evaluating each X-ray film in serialographic order when it is on the viewbox. Films obtained with the Sanchez-Perez unit reveal

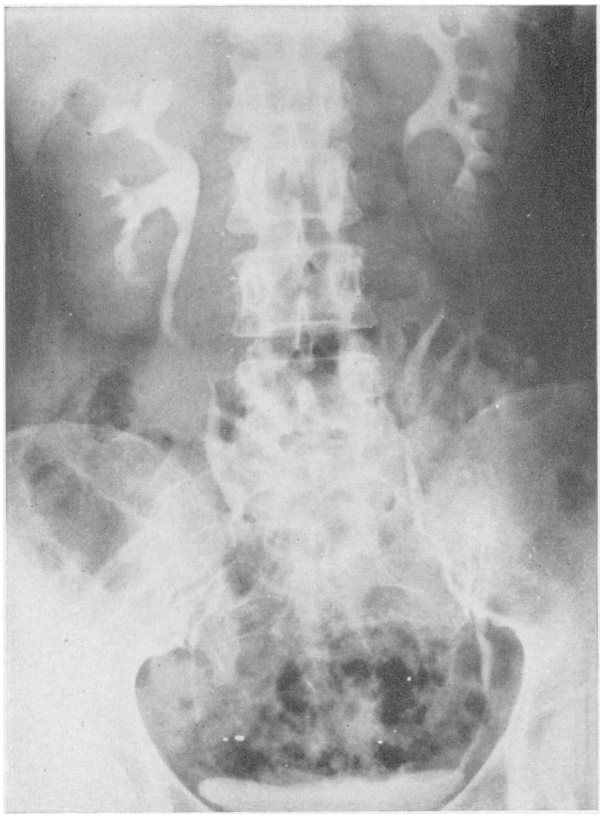

Figure 1. Ureterogram showing contraction of the ureters with passage of contrast substance down the ureters.

ureteral peristalsis as the contrast medium passes down the ureters. This is clearly demonstrated on the original films and may be seen in the illustration (fig. 1). A composite illustration (fig. 2) demonstrates the passage of the urokon down the ureter.

This method of serialographic examination of the ureters and kidneys is relatively new. So far as can be determined, this type of examination has not been performed in this manner elsewhere. A recent review of the literature reveals that Johnson (*1*) used the Sanchez-Perez apparatus in his study of ureteral peristalsis in 1952. In his initial work, Johnson used 40 cc. of 35 percent diodrast as the contrast medium but did not administer the 5 percent intravenous glucose. Likewise, 8 serialographic films, rather than 12, were obtained.

Since this method of examination is relatively new, the procedure is still in the stage of evaluation. As of the present, however, with the use of serial uretography we have discov-

ered two patients with minimal ureteral strictures that were not detected by routine intravenous pyelographic studies. Likewise, by means of serial uretography, it has also been possible to exclude the presence of a kidney tumor in a physician examined at the center. In that instance, the intravenous pyelogram demonstrated what appeared to be a defect of the right kidney pelvis. Serialographic films obtained according to the method described revealed filling of the right renal pelvis as well as good contraction of this segment of the collecting system.

The Schönander Unit

Within the past decade, the use of contrast media and of serialographic examinations has attracted a great deal of interest. The improvement of the diagnostic acumen of physicians who are using angiocardiographic studies and the advances in cardiac surgery during this period have made possible corrective therapy in selective cardiac abnormalities. Congenital heart lesions, such as tetralogy of Fallot, and many vascular aneurysms are now amenable to surgical treatment.

A Schönander biplane angiocardiographic unit, which is especially designed for biplane roentgenology, is in operation at the Clinical Center for detailed study of cardiac abnormalities by radiological methods. Since this is one of only two units of its kind in operation in this country at present, it is considered of sufficient interest to present an illustration of the apparatus as well as to portray a few early results obtained with it.

The Schönander biplane angiocardiographic unit and its two filming areas, the one horizontal and the other vertical, are pictured in figure 3. The same unit in conjunction with a radiographic table, which is placed horizontally over the filming area to support the patient during angiocardiographic study, is shown in figure 4. The table is entirely portable and is moved out of the way when it is not in use.

The Schönander unit makes possible many combinations of filming which we are finding most useful. Films may be taken independently in either plane, at any sequence desired, or films may be taken in both planes simultaneously, at a rate of as many as six films a second. They are 14- by 14-inch cut film and are transported independent of the cassette-holders or film frames.

Aortograms, splenograms, and cerebroarteriograms (figs. 5, 6, and 7) are examples of special studies which can be successfully performed with the Schönander angiocardiographic unit.

In the first instance (the aortogram, fig. 5), the patient was a white woman who had been admitted to the Clinical Center with a history of shortness of breath, ankle edema, as well as other manifestations of cardiac failure. Angiocardiographic films obtained by the retrograde insertion of a catheter into the femoral artery

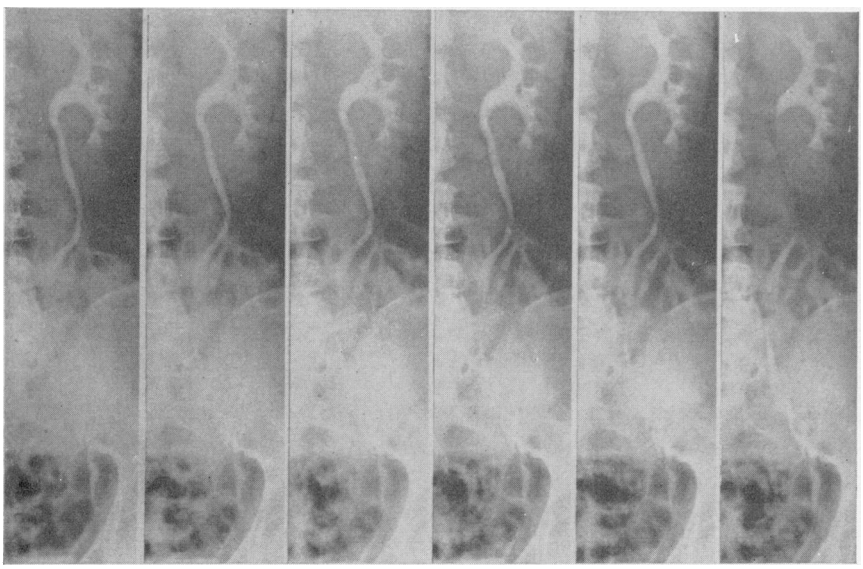

Figure 2.

Composite illustration showing ureteral peristalsis and passage of dye down the ureter. These serialographic films of the ureter were taken at 2-second intervals.

show a large aneurysm of the ascending aorta, which is partially filled by contrast substance. The extremely thick wall of the aneurysm is well demonstrated in the film pictured. When the subsequent operation was performed on the patient, this thick wall was found to be the result of thrombus formation.

A splenogram, shown in figure 6, was performed on a 50-year-old white woman, who had been admitted to the center with a history of hepatic enlargement and several episodes of hematemesis. This study was undertaken in order to rule out the possibility of portal obstruction and the possibility of resulting esophageal varices. As can be observed from the illustration, the presence of portal obstruction could be entirely excluded by this examination.

A cerebroarteriogram was performed on a 27-year-old white man who had been admitted to the center because of epileptic seizures of several years' duration. The examination in this study combined cerebroarteriography and pneumoencephalography. It can be seen from figure 7 that there was a considerable quantity of air within the ventricular system as a result of the preceding pneumoencephalogram.

These cases are reported as examples of how the Schönander unit has been used at the Clinical Center. The taking of films in both planes simultaneously reduces the number of injections and the quantity of injected material by one-half, an improvement which results in considerably less discomfort to the patient and likewise appreciably reduces the hazards associated with examinations of this type.

Image-Intensifying Tubes

As might be expected in a research institution such as the Clinical Center, various research investigators have presented new diagnostic problems to the Diagnostic X-ray Department. For example, a preliminary study was recently directed toward the cineradiography of a contrast substance within the aorta in an effort to study the flow pattern in this vessel. In order to accomplish a study of this type, obviously some special instrument must be provided which will intensify the fluorescent image to such magnitude as to permit photography on a motion picture film. This we attempted by using a Phillip's fluorescent image-intensifying tube.

Figure 8 shows this apparatus in use during the first attempt at consummating the procedure

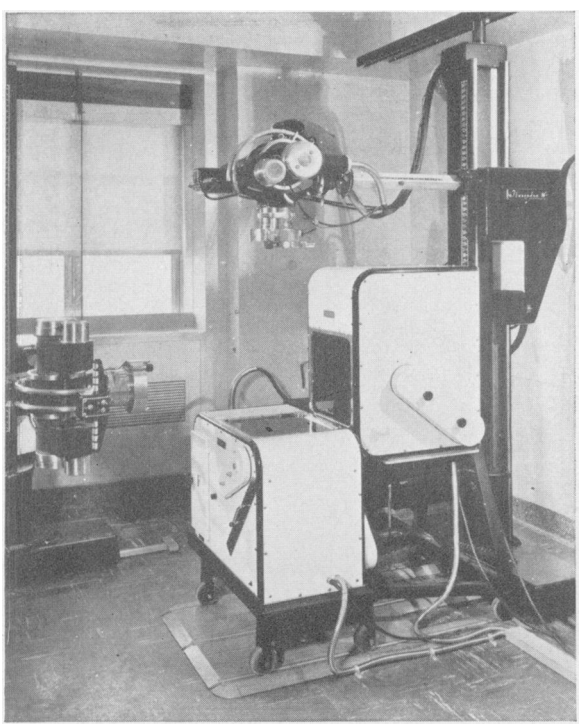

Figure 3. The Schönander biplane angiocardiographic unit. Horizontal and vertical filming areas can be seen.

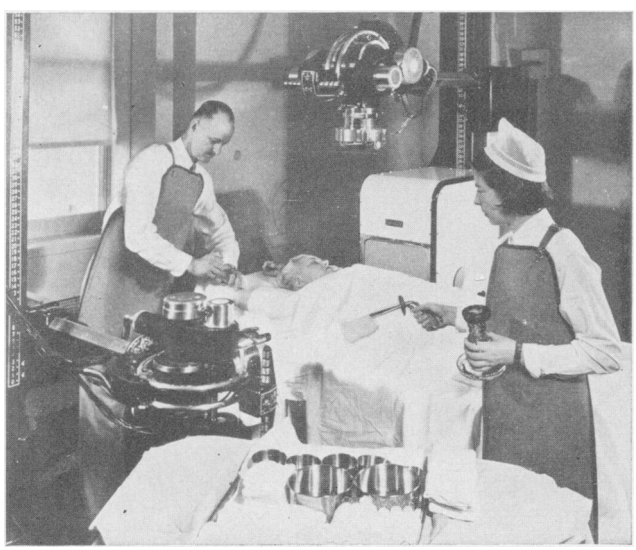

Figure 4. Patient lying on radiographic table for angiocardiographic study. Note X-ray tubes for anterior-posterior and lateral filming.

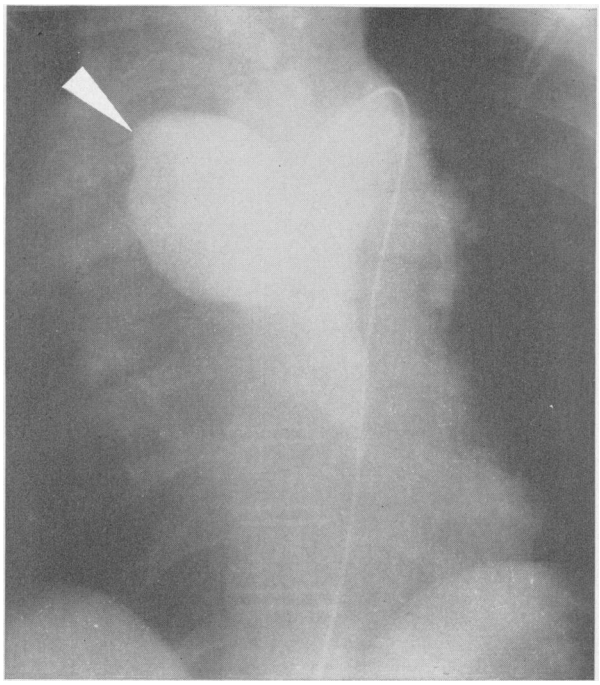

Figure 5. This retrograde aortogram reveals a large aneurysm of the ascending aorta.

just outlined. This particular image-intensifying tube provided an intensification factor of 1,100 times. The preliminary study was accomplished by instilling drops of iodochloral into the aortic arch of a dog by means of a retrograde catheter inserted into the femoral artery.

From this experience, it was learned that the contrast medium could be readily seen in the aorta, but owing to its extremely rapid course down this vessel it could not be followed by the human eye. The next attempt at consummating this examination will involve the photographic recording of the oil droplets in the aorta and then the slow motion projection of the films obtained in order to study the course of the oil droplets in their passage down the aorta. The purpose of this study is to delineate the etiological factors responsible for arteriosclerosis and other changes occurring in the large vessels of the human body. Still in its infancy, this work has yet to advance to a degree that will provide useful information.

The Phillip's fluorescent image-intensifying tube has been studied in the Diagnostic X-ray Department in connection with its use in general fluoroscopic examinations. It was found that with this apparatus patients could be fluoroscoped at one-quarter to one-half milliampere. In its present form, however, this particular image-intensifying tube is not practical since it requires binocular vision and it is quite unwieldy.

The Westinghouse X-ray Corporation has produced a more maneuverable unit of this

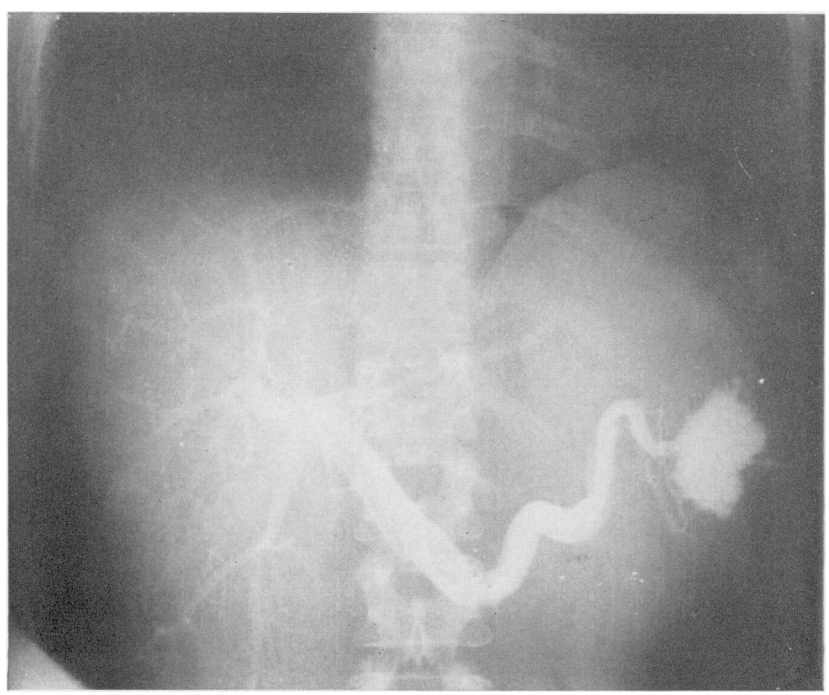

Figure 6.

A splenogram in which the contrast medium can be seen in the spleen, splenic vein, and portal system.

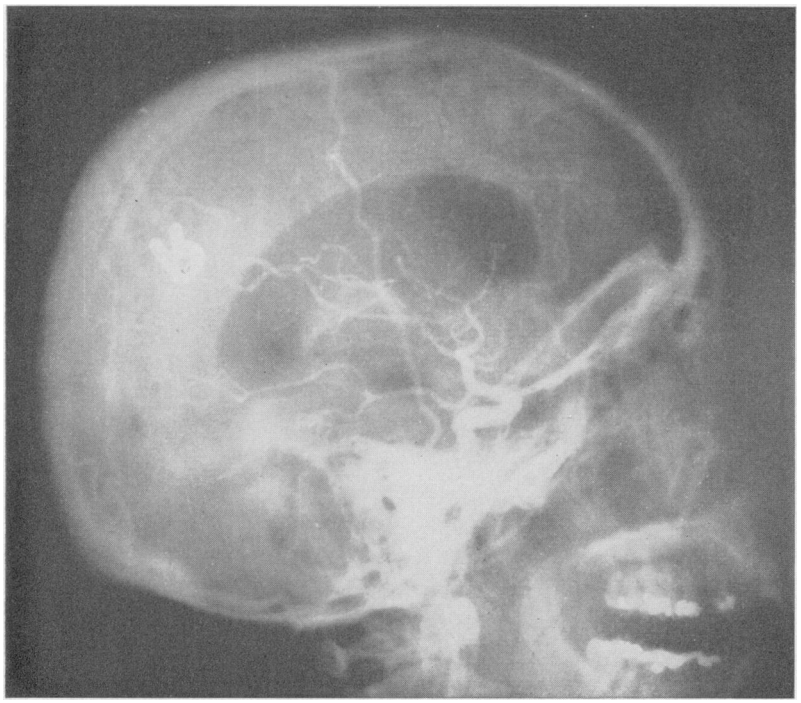

Figure 7.

This combination cerebroarteriogram and pneumoencephalogram shows air in the ventricular system and the contrast medium in the cerebral circulation.

type; it has a 5-inch viewing screen and is commercially available. But the Westinghouse unit like the Phillip's tube has definite limitations from the standpoint of maneuverability. Although fluorescent image intensification is still in the developmental stage, the process will undoubtedly play an extremely important role in diagnostic and experimental radiology within the next few years.

Other Developments

Another relatively new development in diagnostic radiology is the use of a bronchoscope as a means of passing a needle under direct vision through the carina and into the left atrium. The needle is used to determine the left atrial pressures. After pressure studies have been made on the patient, a contrast substance, such as 70 percent urokon, is injected directly into

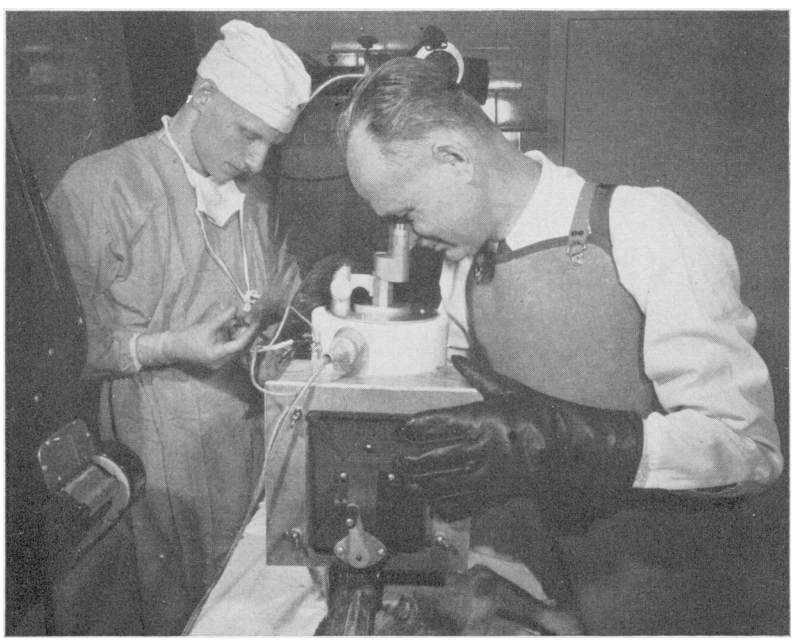

Figure 8.

A fluorescent image-intensifying tube shown in conjunction with the performance of a retrograde aortogram.

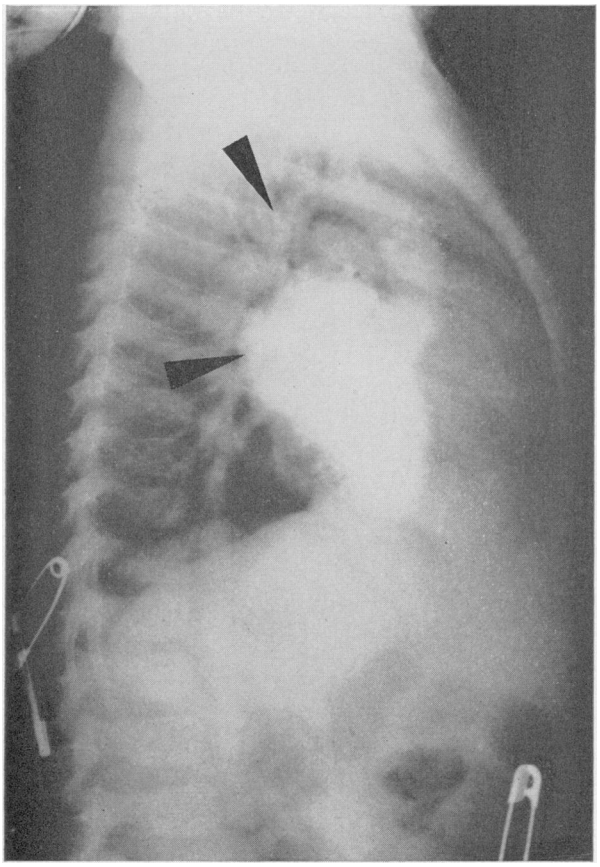

Figure 9. Angiocardiogram demonstrating a large left atrium with stagnation of the contrast substance and with an associated coarctation of the aorta.

the left atrium, and films are taken to determine the size of this cardiac chamber as well as to attempt the differentiation between mitral stenosis and mitral insufficiency. Although this procedure has been used in England, in this country its use is relatively new. In our limited experience with the method at the Clinical Center, no serious complications have occurred. On two occasions, a small quantity of the contrast substance was inadvertently injected into the pericardial sac, thereby resulting in transitory precordial pain, but there were otherwise no harmful effects.

Because of recent advances in cardiac surgery, a great deal of interest has been shown in another trend in diagnostic radiology—the use of angiocardiographic studies as a method of differentiating mitral stenosis from mitral insufficiency. The knowledge as to whether he is dealing primarily with mitral insufficiency or mitral stenosis is of extreme importance to the surgeon when he is planning surgical treatment. Angiocardiography is one method used at the Clinical Center for differentiating these two conditions. Since a decided difference of opinion still exists as to how reliable the method may be, it is hoped that a definitive answer to this question will be forthcoming soon.

The current opinion is that there is a greater stagnation of contrast substance and less dilu-

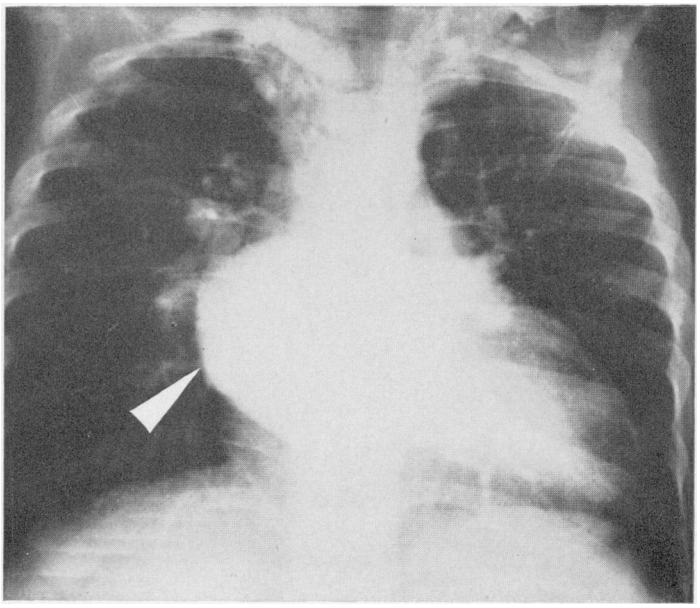

Figure 10.
Angiocardiogram demonstrating a large left atrium and stagnation of the contrast medium in this chamber.

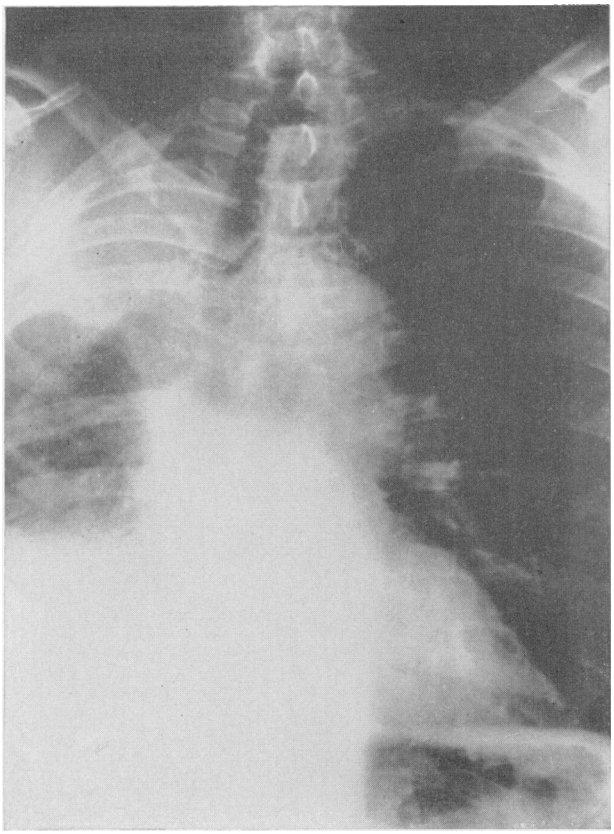

Figure 11. This film taken with conventional radiographic kilovoltage fails to reveal a tumor invading the left side of the trachea.

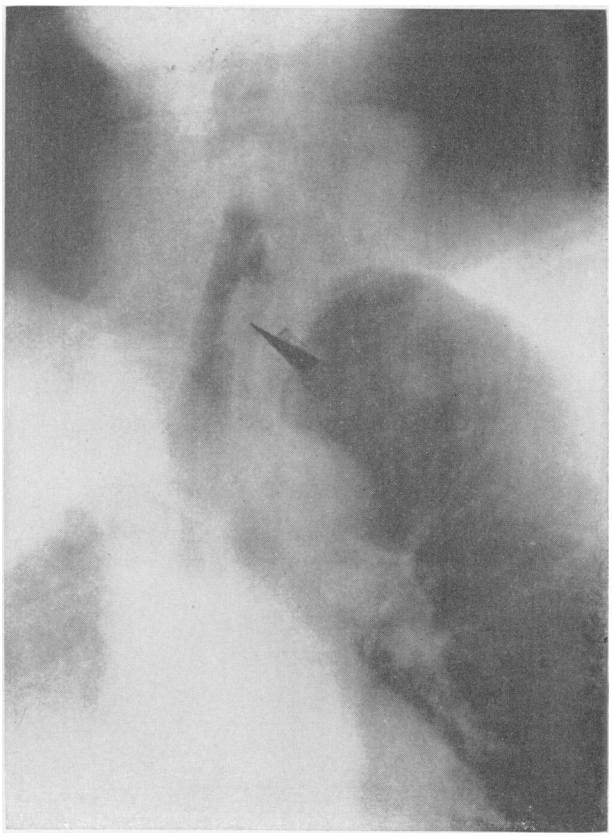

Figure 12. But use of 1-million volt equipment demonstrates that the patient has a carcinoma which is not visible in figure 11.

tion of the substance in the left atrium in cases of mitral stenosis than in cases of mitral insufficiency.

The two cases described below will serve to illustrate the use of angiocardiographic studies in differentiating these conditions.

As shown in figure 9, the contrast medium tends to pool in the left atrium. This study was conducted on a 2½-year-old white boy who had been admitted to the Clinical Center with a history of shortness of breath on exertion and of cyanosis about the lips. In the angiocardiogram, the contrast medium remained in high concentration within the left atrium throughout a period of 15 seconds. Based on angiocardiographic studies as well as on cardiac catheterization and clinical findings, the diagnosis in this case was that of predominant mitral stenosis with an associated coarctation of the aorta.

In the X-ray film pictured in figure 10, the patient studied was a white male child, aged 6 years. He was admitted to the center with a history of a systolic murmur which had been detected when he was 3 months old. In this contrast study, the left atrium was proportionately larger than in the preceding case, the contrast substance was diluted more rapidly, and it remained in the left atrium a shorter period of time. The opinion with respect to this patient was that of predominant mitral insufficiency. Clinical findings, cardiac catheterization, and angiocardiographic studies determined this diagnosis.

From recent experience at the Clinical Center, however, we have come to doubt seriously the reliability of angiocardiography as a method of differential diagnosis.

The use of high kilovoltage X-ray equipment as a means of determining the presence of tum-

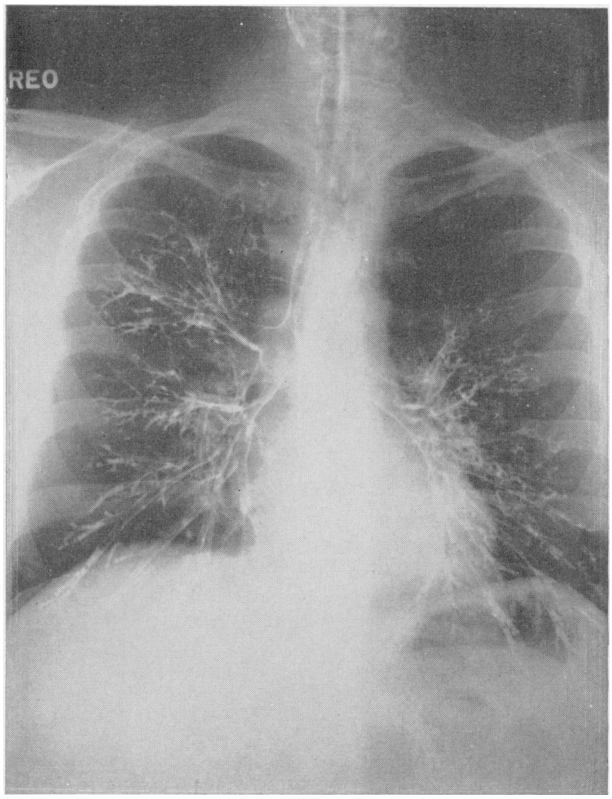

Figure 13. A normal bronchogram performed with dionosil. A new trend is the use of contrast media readily eliminated from the lungs.

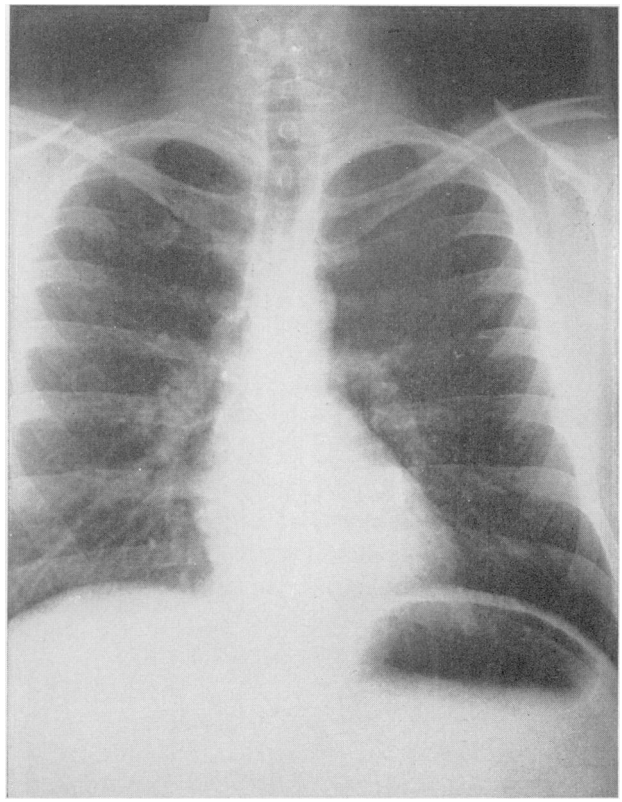

Figure 14. Twenty-four hours later. The contrast substance has been almost completely eliminated from the lung fields.

ors, particularly in the mediastinum, is creating interest, too. The term "high kilovoltage equipment" refers to apparatus providing at least 1-million-volt radiographs. X-rays produced at this voltage level will penetrate the dense structures of the body almost as readily as the soft tissues. Thus, a tumor situated in the mediastinum now becomes discernible, while previously with the use of conventional diagnostic kilovoltages, it most likely would have been obscured by overlying bony densities. This fact is demonstrated in figures 11 and 12, which are X-ray illustrations of a 50-year-old woman, who on admission to a hospital (in Philadelphia) complained of cough, shortness of breath, and hemoptysis. The X-ray film (fig. 11), which was obtained with normal radiographic kilovoltages, failed to demonstrate the tumor involving the left side of the trachea, but a film (fig. 12) taken with 1-million-volt equipment demonstrates a carcinoma.

It should be pointed out, however, that the use of laminography, and in selected instances, arteriography, to delineate tumors of the mediastinum, will produce comparable results. However, hospitals where million-volt equipment is available should consider the diagnostic possibilities of equipment of this type.

Using Contrast Media

Another recent trend in diagnostic radiology—particularly in the United States—is the use in bronchography of contrast substances which are readily eliminated from the lung fields. However, bronchography employing water soluble media has been practiced for several years in Europe, especially in England and Sweden. In a study of this type undertaken several years ago at the Johns Hopkins Hospital in Baltimore, some success was obtained with a product containing diodrast, suspended

in a 0.75-percent solution of methyl cellulose. The preparation, however, was quite irritating and difficult to retain in the bronchi long enough for satisfactory radiography. Recently, a product called dionosil, which consists of 30 percent iodine suspended either in water or oil, has been found to be an efficient agent for bronchography. Dionosil has the advantage of being readily eliminated from the lung fields and has the further property of being evenly dispersed along the bronchi without pooling in the alveolar spaces. It does have, however, a disadvantage similar to that of diodrast, namely, that it is more irritating than the ordinary oily substances commonly used for bronchography, such as iodochloral or lipiodol.

An excellent bronchogram performed with dionosil in Baltimore is portrayed in figure 13. As can be seen from a second illustration (fig. 14), which was taken 24 hours after the initial bronchogram, the material has been almost entirely eliminated from the lung fields.

The next step, of course, is to develop a method of micronizing powder to such extent that the material can be dispersed along the bronchial tree by nebulization, thus eliminating the time-consuming and, at times, difficult problem of introducing the contrast substance by intratracheal catheter. A low surface-tension agent such as tween 80 would be necessary to help disperse the material into the terminal bronchi. It is hoped that these potential simplifications of bronchography may be further evaluated at the Clinical Center.

Xeroradiography

Mention should also be made of the development of xeroradiography by Dr. John Roach, chief radiologist at the Albany Hospital, Albany, N. Y., and Dr. Herman Hilleboe, New York State health commissioner. This new procedure is still under investigation by its originators and may eventually serve a very useful purpose in public health. It involves the use of a chemically coated aluminum plate, which is charged electrostatically and then exposed to radiation. The charge is dispersed by the radiation in direct proportion to its intensity, which, in turn, is governed by the density of intervening tissues. Next, a fine powder is dusted on the charged plate. The powder adheres in greatest quantity to those areas carrying the greatest charge, hence, the formation of the X-ray image.

Color Radiography

During, and shortly after the First World War, much interest in color radiography was stimulated by a French investigator. However, upon careful investigation, the initial claims proved to be somewhat of a hoax and were never proved to have practical application. Recently, however, interest in color photography has been restimulated, and further claims have been made relative to its application. However reliable or beneficial will be the results of the recent experiments in this field—most of which have been conducted in Canada—remains to be seen. On a theoretical basis, color radiography should be useful both as a teaching method and as a means of improving diagnostic acumen.

Radioactive Isotopes

Final mention should be made of two isotopes—thulium-170 and xenon-133—which have recently been utilized on a limited scale as sources of energy for diagnostic radiology. Portable sources of X-ray energy containing thulium-170 and weighing less than 7 pounds have been constructed at the Argonne National Laboratory in Illinois. The radiant energy is self-contained in a lead shield and is released through a shutter which is remotely controlled.

These portable X-ray units have an output of 75 roentgens an hour at a distance of 1 inch. In their present stage of development, they are practical only for the X-raying of small extremities. It is anticipated that a new thulium source will be developed which will have an output of approximately four times that of thulium-170. With this new source of energy and high speed X-ray screens, it should be possible to obtain diagnostic X-ray films of small extremities with exposure factors of 1 to 3 seconds.

Undoubtedly, thulium units will never replace diagnostic X-ray equipment, but it is conceivable that these small, portable X-ray units

may have some practical value in localities where X-ray equipment is not available. Both thulium-170 and xenon-133 have been used in England as an intraoral source of energy for radiography of the teeth and mandibles. The quality of the films obtained, however, does not compare favorably with that obtainable with ordinary radiographic units. Thulium-170 has a half life of 129 days, which considerably limits the practical use of this isotope in radiography. However, thulium-170 may well serve as an excellent source of constant radiant energy for diagnostic and research investigations such as, for example, in electrokymography.

The preceding discussion has touched on some of the current highlights insofar as recent trends and developments in radiography are concerned. The almost constant improvement of electronic devices and equipment will inevitably alter the future diagnostic, and for that matter, therapeutic, applications of radiographic equipment. For example, with the so-called "storage tube," which may ultimately be used in diagnostic radiology, it is possible to examine fixed objects by using very short radiographic exposures and then to store the resulting picture on the grid of the storage tube. The X-ray unit may then be switched off, and the picture may be subsequently examined as long as is desired. In this manner, the possibility of radiation exposure to a patient may be greatly reduced.

REFERENCE

(*1*) Johnson, T. H.: Peristalsis of the upper urinary tract as demonstrated by new X-ray technic. A preliminary report. New York J. Med. 52: 189–196 (1952).

NOTE: Illustrations were provided through the courtesy of Dr. Eugene P. Pendergrass, University of Pennsylvania (figures 11 and 12) and Dr. James K. Wilson, Johns Hopkins University Hospital (figures 13 and 14).

Commissioned Corps Reserve To Be Expanded

Expansion and reorganization of the Inactive Reserve of the Public Health Service as part of an intensified civil defense program in the Service is announced by Surgeon General Leonard A. Scheele.

The new program calls for the recruitment of an additional 5,000 Reserve Corps officers during the next year and a half—2,000 by June 30, 1955, and an additional 3,000 by June 30, 1956. Dr. Scheele called on all commissioned officers and key civil service personnel of the Service to assist in the recruitment program.

Expansion and reorganization of the Inactive Reserve is part of an intensified civil defense program in the Service resulting from presidential approval of a Federal Civil Defense Administration delegation to the Department of Health, Education, and Welfare.

Under this delegation, the Public Health Service has new responsibilities for developing technical guidance for the States and directing Federal civil defense activities concerned with detection and control of communicable diseases. the public health aspects of chemical and biological warfare, and other public health hazards.

"Ultimate objective of the plan," Dr. Scheele said, "is the creation of a pool of trained physicians, sanitary engineers, nurses, and associated professional health personnel who can be immediately mobilized and selectively deployed to reinforce State and local health forces in times of emergency. Experience during World War II and since leaves no room for speculation as to the need for a well-organized Inactive Reserve, large enough to be effective, adequately trained, and ready for rapid mobilization."

As the expansion gets under way, field training courses will be instituted for both present officers of the corps and newly recruited officers. The initial emphasis, Dr. Scheele said, will be on the recruitment and training of physicians, nurses, and engineers.

Inquiries concerning commissions in the Inactive Reserve should be addressed to the Surgeon General, Public Health Service (P), United States Department of Health, Education, and Welfare, Washington 25, D. C., or to the nearest regional office of the Public Health Service.