V. MEDICAL ASPECTS OF THE IMAGE INTENSIFIER

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In both fluoroscopy and radiography, which may be considered to form the basis of modern X-ray diagnosis, the image intensifier will play a very important part. These two branches of X-ray diagnosis are discussed separately in the present article.

Fluoroscopy

In an X-ray examination the patient is exposed to radiation which is to some extent harmful — a fact which is, fortunately, now better appreciated by doctors employing X-radiation for diagnostic examinations. From the quantitative point of view, fluoroscopy (long exposure at low radiation intensity) produces a very much stronger effect in this respect than radiography (very short, but intense exposure). To reduce the dose required in fluoroscopy as far as possible, the radiologist usually adapts his eyes to a very low luminance level for at least 15 minutes, and to preclude any unnecessary loss of time in re-adapting of the eyes, it is nowadays customary to take all cases requiring fluoroscopic examination one after the other.

In ordinary chest fluoroscopy, involving such adaptation, an X-ray tube current of \(2\frac{1}{2}-5\) mA at 60-70 kV is usually employed to ensure an

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accurate appraisal of the lung structure. Using the image intensifier, the same result is obtained at the same voltage, but without preliminary adaptation and with a current which need not exceed 0.5 mA. Hence the dose is reduced by a factor of 10. A smaller, but nevertheless appreciable dose-reduction is obtained in the case of relatively thicker and more solid subjects (as in lateral fluoroscopy of the abdominal organs).

Experience has shown that such relatively thick subjects necessitate the use of a scatter grid.

Tests carried out on a "Philite" phantom, as designed by Burger 1), for a subject thickness corresponding to that of the human thorax have shown that, at the same X-ray tube voltage, fluoroscopy with the image intensifier produces roughly the same contrast-detail perceptibility at 0.1 mA as ordinary fluoroscopy at 4 mA (see II). A tube current of 3 mA is enough to bring the perceptibility of contrast and detail in intensifier fluoroscopy quite a long way towards the standard attained in ordinary, full-size radiographs. Despite the intensifier, however, this standard will never be equalled in fluoroscopy, since the number of X-ray quanta released during the storage time of the eye (0.1-0.2 sec) is invariably very much smaller than the number effective in radiography (see II). Moreover, the high gamma of the photographic emulsion increases the contrast in the radiograph by a factor of 2^k or 3. In fluoroscopy, the actual contrasts are the same with, as without the intensifier, but with it they are raised to a very much higher luminance level. Observers employing the intensifier for the first time are therefore often disappointed, having assumed from the fact that the fluorescent image is seen at virtually the same luminance level as a radiograph examined in front of an ordinary light box, that the two must produce very much the same impression (high contrast).

Photography

The image quality in photography with the image intensifier is limited not only by the blurring effect of the two fluorescent screens, but also by the grain of the film. Since the viewing screen to be photographed is very bright, fine-grain film of low sensitivity may be employed for single photographs. It is found that the X-ray intensity required to take an image intensifier photograph on Kodak "Micro-File" film using a tandem optical system, each component having an aperture ratio of 1 : 1.5, is only from a half to a quarter of that involved in the taking of an ordinary full-size radiograph of the same subject at the same tube-voltage. Also, the high contrast and very fine grain in such a 35-mm photograph results in almost the same information as a normal radiograph.

Comparing image intensifier photography with ordinary screen photography (fluorography) 2), we find that it has a drawback, viz. the small field of view. On the other hand, it has one or two advantages which should not be underestimated, viz.; the apparatus is relatively small and easy to handle; adjustments prior to taking photographs are readily effected by viewing through the intensifier without any preliminary dark-adaptation; single photographs can be taken on fine-grain 35-mm film giving high contrast and therefore excellent picture-quality: all these advantages are procured with an X-ray dose at least a factor of 3 smaller than that required in ordinary radiography, instead of 3 or 4 times larger as in fluorography.

Cinematography

To all appearances, cinematography with the image intensifier will find a great deal of scope in the future. It is the only method of photographing transient processes in the human body without risk either to the subject (overdose) or to the X-ray tube (overloading). For this purpose, a more sensitive 35-mm film, e.g. Gevaert "Orthoscopix" or Agfa "Fluorapid", is employed. Experience has shown that the dose required to expose a single photograph on such film is less than 1/10 of the dose ordinarily employed in radiography; this at once implies the possibility of cinematography. Several films taken with the image intensifier are already available. Equipment for this type of cinematography is shown in fig. 1; for particulars see Table 1 3).

Table 1. Examples of films made with the image intensifier.

1. Deglutition at larynx level, in lateral projection. 80 kV, 10 mA, 20 frames/sec, duration 15 seconds. 6 m of film, with a total dose of roughly 2 r.
2. Film in frontal projection of the bulbus (entrance of the duodenum). 120 kV, 11 mA, 8 frames/sec, duration 2 minutes. 20 m of film, with a total dose of 50 r.
3. Micturition. 125 kV, 20 mA, 8 frames/sec, duration 56 sec. 10 m of film, with a total dose of 45 r.
4. Cerebral angiography (examination of blood vessels in the brain) in lateral projection. 90 kV, 10 mA, 16 frames/sec, duration 20 sec. 7 m of film, with a total dose of 3 r.

2) See for example, Philips tech. Rev. 13, 269-281, 1951/52.
3) These experiments were carried out in collaboration with J. van der Wal and J. Proper of the Research Laboratories at Eindhoven.
Most of these films were made with an X-ray tube having a 0.3 mm focus, without overloading it. For each of them the distance from focus to screen was 90 cm, since a scatter grid designed for this distance was employed.

Although it is already evident from this table that the dose itself is a more or less minor problem in X-ray cinematography with the image intensifier, this all the more evident from Table II, indicating the dose to the subject in different methods of gastric radiography.

### Methods of diagnostic examination

To show in how far it is practicable to employ the image intensifier in the various methods of diagnostic X-ray examination, a general survey of these methods will now be given.

**Examination of the skeleton and the joints of the limbs**

Because of the importance of minor changes in the bone structure in skeletal examinations, ordinary radiography is still the only effective method. Here, then, the image intensifier cannot supersede the radiograph, although it is very useful in exploratory examination before the actual exposure. Such visual examination facilitates the correct positioning of the object (say, for the projection of joint spaces and small calcifications). Image intensifier fluoroscopy is also useful for locating foreign bodies and for the examination of joints into which contrast medium, or air, has been injected.
Again, the image intensifier is ideal for follow-through examinations to ensure, for example, that
the re-setting of bone fractures, dislocations, etc has been satisfactory. It is in examinations of this
kind that the danger from radiation has so often been underestimated, and many a doctor has injured
his fingers or hands in the course of them. The same applies to the pinning of fractures, that is,
driving a stainless metal pin through the shaft of a broken bone. It is now possible to make sure, by
a check examination in the operating theatre itself, that the pin has been driven into the precise position
selected for it; this eliminates the often enervating delay whilst radiographs are developed, and also
cuts down the overall operating time.

Examination of the spinal column

Although it is now possible to obtain a fairly accurate impression of possible defects in the spinal
column, especially in the region of the cervical vertebrae, with the aid of the image intensifier,
the ordinary radiograph is still the obvious choice for such examinations, at any rate for the time
being, because it enables the bone structure to be assessed correctly. However, there is scope for the
image intensifier in myelography, in which a certain amount of contrast medium is injected into
the canal of the spinal cord and any obstructions preventing the passage of this medium are located
by examining the subject in different positions. Not only the possibility of working in daylight, but
also the small X-ray dose to the patient is important in such examinations, since abnormalities of this
kind usually occur in the lumbar region, where the proximity of the genitals, extremely sensitive to
radiation, necessitates more than ordinarily careful dose control.

Examination of the skull

A simple X-ray apparatus may be very valuable in the consulting room of an ear, nose and throat
specialist, say, as a means of examining an inflammation of the nasal sinuses, visible either by a
swelling of the mucous membrane, or by an accumulation of fluid in the sinuses. The present field of
view of the image intensifier, viz. 13\(\frac{1}{2}\) cm, is ample to enable such a condition to be diagnosed at a
glance (fig. 2). Also, X-ray cinematography of the jaw joint may well be useful to the specialist.

Again, cinematography may be employed in cerebral angiography, that is, studying the circulation
in the blood vessels of the brain by injecting contrast medium into the carotid artery.

Examination of the digestive organs

Because food passes very quickly through the upper portion of the oesophagus, there has been for
many years now a desire to record the movements of the larynx, etc. cinematographically. Holmgren
accomplished this in Sweden as early as 1946 by means of screen cinematography. However, image
intensifier cinematography offers very much better opportunities in this respect by enabling a higher
frame frequency to be employed (fig. 3). Since the passage of food through the lower portion of the
oesophagus, and through the stomach and the small intestine, is much slower, cinematography of these
regions is not essential; however, image intensifier screening of these organs is very useful. Films showing
the movements of the stomach and intestines are undoubtedly spectacular, and eminently suitable
for purposes of instruction.

Examination of the kidneys and genitals

A clear view of the kidney and pelves (filled with contrast medium) and their contractions is readily obtained by fluoroscopy with the image intensifier. In retrograde pyelography, in which the contrast medium is injected through the urinary ducts, the above-mentioned movements can be easily followed.

Cystography usually involves taking single still photographs of the bladder during micturition. Image intensifier cinematography may be employed for this purpose in the future. Owing to the proxi-
mity of the genitals it is necessary to employ only a very small dose of radiation in this examination. This is also the case in hysterosalpingography in which contrast medium is injected into the uterus, usually to ascertain whether the oviducts are clear of obstruction. The insertion and manipulation of instruments can invariably be observed in daylight.

X-ray examination during pregnancy should be kept to a minimum: it is necessary only in some cases during the final weeks, to show the position of the foetus or pelvic anomalies, etc. Here, ordinary radiography is still the best method.

Examination of the lungs and respiratory passages

In serial chest-fluoroscopy the time required for adaptation is virtually immaterial; the use of the image intensifier for this purpose is therefore precluded, at any rate for the time being, by its small field of view. However, the intensifier may well be employed for exploratory examinations of individual subjects; it also deserves consideration as a means of examining local disorders, in view of the high contrast-detail perception in the image. Shadow-producing foreign bodies in the respiratory system are readily located; moreover, image intensifier fluoroscopy is ideal as a means of observing the position of such objects in relation to the instruments inserted to remove them.

Examination of the heart

In heart-catheterisation, the image intensifier enables the X-ray dose employed during the insertion of the catheter, which sometimes takes a very long time, to be reduced considerably.
Cinematography merits consideration as a means of examining highly localised disorders of the heart and adjacent blood vessels.

Whereas the field of view is not large enough to permit of a total examination of the heart in adults, the study of the heart function in children by means of the intensifier has already produced some remarkable results.

Although this summary is by no means complete, the examples given in it show clearly enough the potentialities of the X-ray image intensifier as an aid to medical diagnosis.

VI. INDUSTRIAL RADIOLOGY WITH THE IMAGE INTENSIFIER

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Industrial radiology is now a widely used method for examining materials; in fact, it is one of the most important and reliable of the non-destructive methods of inspection. In the light metals industry, for example, X-rays are employed on a large scale for examining castings for defects fluoroscopically. The relatively low absorptive power of light metal alloys enables X-ray shadow pictures of adequate luminance to be obtained. With an X-ray tube of small focus (e.g. 0.4 × 0.4 mm), an enlarged shadow image can be projected 1), giving unusually good detail-perception.

The situation with regard to the examination of steel, however, is less favourable. The welding of parts normally subjected to heavy loads, for example, parts of boilers, tanks, bridges, ships, etc., usually rests upon a reliable, non-destructive method of inspection enabling the quality of the welds to be properly assessed. Because of the high absorptive power of the iron, however, steel constructional elements cannot usually be examined fluoroscopically; such X-ray shadow pictures are very faint and can therefore be observed only in a darkened room after the eyes have been thoroughly dark-adapted. In many cases, where the particular constructional elements are either too large or too heavy to be conveyed to a screening room, fluoroscopic examination is out of the question for this reason alone. Moreover, fluorescent images of steel parts afford only limited perceptibility of detail; to ensure adequate screen luminance it is necessary to employ thick, coarse-grained fluorescent screens and also high-powered X-ray tubes which preclude all possibility of a small focus. In practice, then, steel is suitable for fluoroscopic examination only if not more than 6 or 8 mm thick. Since in most welded constructions the material to be examined is very much thicker,

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Fig. 1. Industrial radiology equipment using the image intensifier, for experiments and demonstrations. Note the beam exit aperture of the X-ray tube, radiating vertically upwards, behind the lead glass window. Above it is the work to be examined, in this case a welded Y-joint. The image intensifier, mounted in a box on top of the apparatus, is provided with an angled optical system. The two handles seen on the left of the apparatus, are manipulated by the observer to locate the work as required.