IMPROVED TEST METHODS FOR SCANNER EVALUATION

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We have explored the possibility of using patterns of one-dimensional sources to evaluate scanning equipment. These patterns offer certain advantages which make them useful adjuncts to the point sources and three-dimensional sources which are now recommended by the IAEA and others (*1–6*). Two patterns of one-dimensional sources are described here, and the results of their application to a 10-crystal, 10-channel rectilinear scanner are shown.

METHODS

Line sources were made by placing a radioactive solution in the type of glass capillary tube commonly used for micro-hematocrit determination. Two of these sources were positioned under the scanning machine at specified intervals by a jig made of a 1-cm thickness of plastic. The jig was 4 cm wide by 25 cm long. V-shaped notches, spaced at 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0 and 5.0 cm intervals, were cut to hold the capillary tubes. The jig is shown with the sources in place in Fig. 1. A second pattern resembling an astigmatism chart was also made. Sixteen line sources were mounted in a radial pattern on an aluminum plate 1 mm thick. The capillary tubes were secured to the plate by epoxy resin cement as shown in Fig. 2.

The capillary hematocrit tubes have an inside diameter of 1.1–1.2 mm, a wall thickness of 0.2 mm, and a length of 75 mm. The average volume is 0.1 ml/tube. Line sources containing 20 μc each were prepared from a solution of 200 μc/ml. Each tube was loaded by capillary attraction with 0.1 ml of this solution. The radionuclide used was ^{99m}Tc because we wanted to correlate the test patterns with brain-scanning potentialities.

RESULTS

The linear source pattern was scanned with a commercial 10-crystal, 10-channel scanner.* The spectrometer was set to include energies from 93 to 187 kev. Three different collimators were used with focal lengths of 3½, 4 and 5 in. The focal length was used as the source-to-collimator distance in each case. The 5-in. collimator (Fig. 3A) clearly visualized the 2.5-cm space. The 2-cm space was slightly visible.

The resolving power in terms of lines per meter can be obtained by dividing 100 cm by the width of the space between the lines. Thus the 2.5-cm space between the lines corresponds to a resolution of 40 lines/meter. The 2.0-cm space is equivalent to 50 lines/meter. An average of the two gives an estimated resolution of 45 lines/meter for the 5-in. collimator. The 4-in. collimator (Fig. 3B) clearly resolves the 2.0-cm space and suggests the 1.5-cm space. This indicates an estimated resolution of 60 lines/meter. The 3½-in. collimator (Fig. 3C) clearly resolves the 1.5-cm space and gives a slight suggestion of the 1.0-cm space. The resolution is clearly better than the 67 lines/meter indicated by the 1.5-cm space; 75 lines/meter seems reasonable.

The collimators used with this scanner are of an unsymmetrical construction (*7*). The possibility therefore exists that the resolving power might be better in one direction than in another. A test for astigmatism was made with the radial line-source pattern. At their focal distances all of the collimators gave a uniform resolution pattern. The pattern for the 3½-in. collimator at 3½ in. source-to-collimator distance is shown in Fig. 4A. As the source-to-collimator distance was increased, a slight astigmatism appeared in all three collimators. The worst case is shown in Fig. 4B. This pattern shows the response for the 3½-in. collimator at 4½ in. distance.

DISCUSSION

It is common practice to evaluate scanning machines with three-dimensional phantoms (*1–3*).

* Picker-Nuclear Dynapix.

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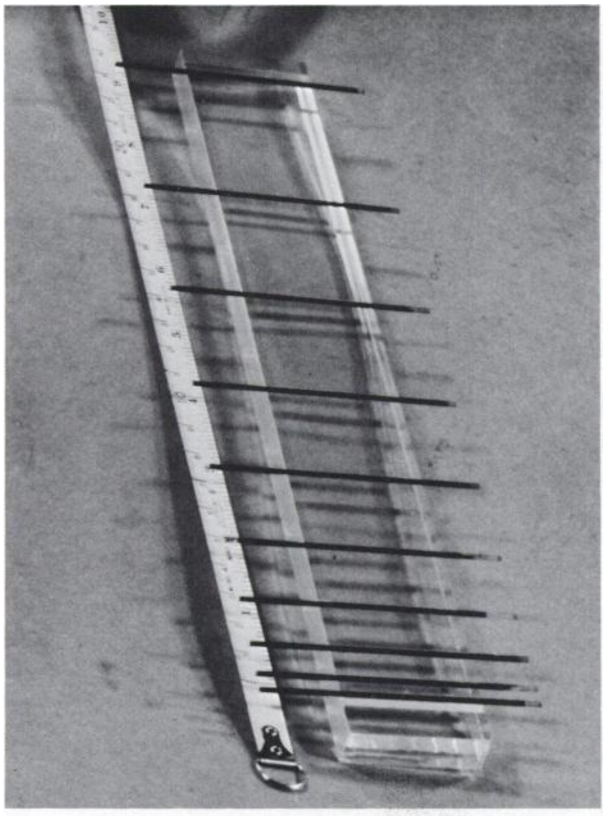

FIG. 1. Linear jig with line sources in place for determining resolution.

higher-energy radionuclides have an increased interseptal penetration, they give rise to reduced resolution. In the clinical situation scattered radiation from the tissues of the patient may reduce resolution. This is particularly so with low-energy radionuclides such as the one used in this study. The spectrometer settings of 93–187 kev, used to scan the 140-kev radiation from the ^{99m}Tc sources are insufficient to eliminate a great portion of scattered radiation. One could possibly improve the resolution slightly by omitting the plastic and aluminum backing from behind the sources to reduce scattering.

The linear test pattern used in these experiments has been interpreted as resolving power in terms of lines/meter. This method is analogous to resolution in lines/mm used in photography. Photographic tests have been made of the ability of resolving power, expressed in lines per millimeter, to reflect image quality (*8*). When an imaging system has the ability to resolve more than 10–20 lines/mm, the resolving power as expressed in lines/mm correlates poorly with image quality. Additional criteria are needed to indicate the capability of the system. If an imaging system is of limited ability so that its resolution is less than 10 lines/mm, resolving power correlates well with image appearance. Because scanners are instruments with low resolution, resolving power in lines per unit length should give an excellent indication of scanner performance. It is suggested that lines/meter be used as an indication of scanner performance. If resolving power in terms of lines per unit length is accepted as an important feature

However, these phantoms are difficult to correlate visually on the two-dimensional plane presented to the viewer by the scanner. Moreover, the three-dimensional objects also complicate attempts at mathematical analysis.

A point source has also often been used in scanner evaluation (*3,4*). Visual evaluation of the image of a point source, or group of point sources, also taxes the ability of the observer. A line source is obtained by integrating a point source in one direction. As a result, the line source provides a one-dimensional test object. In practice, replacement of a point source by a line source also yields a great increase in the amount of radiation available for measurement. The image of a line source, or pattern of line sources, provided by a scanner offers easy correlation of the scanner image with the original pattern. The mathematical analysis of such a one-dimensional pattern is also much easier. Line-spread functions and modulation transfer functions can be estimated from line-source images.

In considering the resolution figures presented, several limitations must be pointed out. The resolution of a given collimator depends to some extent on the energy of the radiation incident upon it. Because

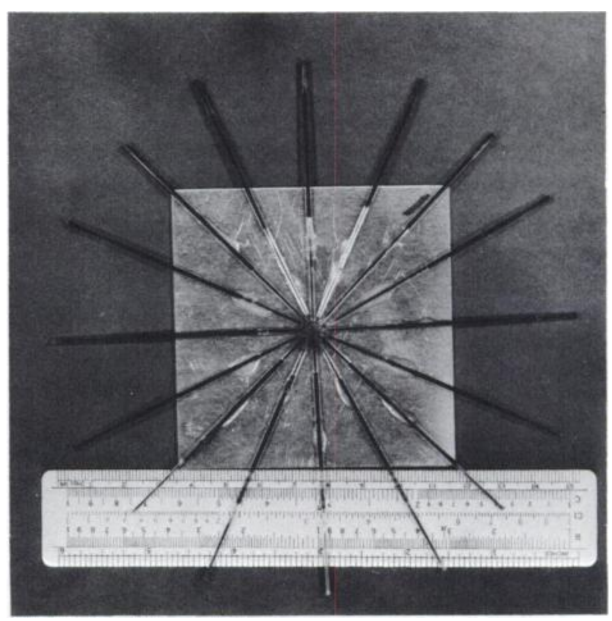

FIG. 2. Radial line-source pattern for astigmatism tests.

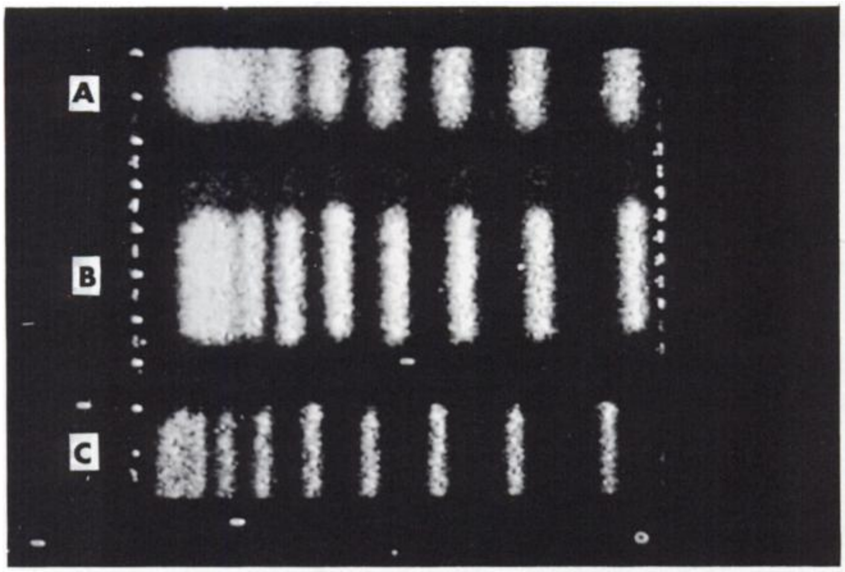

FIG. 3. Images of linear test pattern. A is made with 5-in. collimator. B is made with 4-in. collimator. C is made with 3½-in. collimator.

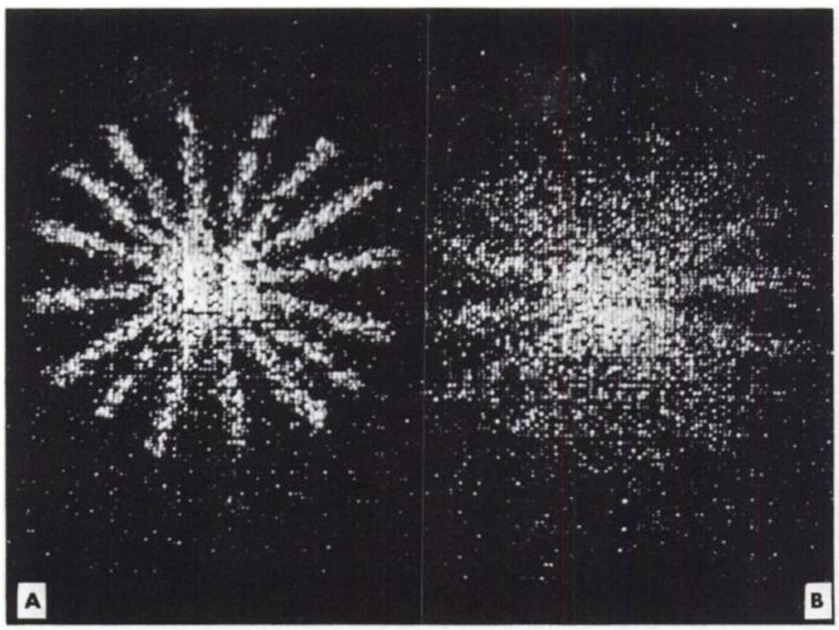

FIG. 4. Image of radial test pattern made with 3½-in. collimator. A is made at 3½-in. distance. B is made at 4½-in. distance. Note astigmatism in B.

of image quality, this system has the following advantages:

1. Resolving power can be expressed in easily comprehensible terms.

2. Resolving power allows system performance to be expressed as a single number.

3. Resolving power in terms of lines/meter can be determined easily by using spaced line sources.

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