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Research Article

Evaluation of Performance of different display systems used in Nuclear Medicine Imaging

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Abstract : Display is a key component of medical imaging systems as it serves as the final element of the imaging chain. A proper understanding of the display system of an imaging unit is very essential in order to fully utilize its diagnostic capability. Observer's visual response to the display plays a vital role in the final outcome of the imaging procedure. In this study we made an attempt to evaluate the performance of various different display systems used in the nuclear medicine imaging. The method of constant stimuli was used for measuring the response of observers. The concentration ratios have been determined for i) Display records on transparent film ii) Display records on computer screen (chromatic) iii) Photographic color display records. A background intensity that is commonly encountered in routine imaging was used for the study. A cylindrical phantom, 25 cm in diameter and 21 cm in height, was filled with Tc^{99m} and sufficient time was allowed for the uniform distribution of the tracer in the phantom. The study was carried out with three spherical targets of varying diameters i.e. 0.75 cm, 1.0 cm and 2.0 cm filled with Tc^{99m}. A series of 60 display records were produced. Ten of the display records did not have any target in them. The visual response to these different display records was elicited from a group of five observers each viewing the 60 scans on five different days. It could be seen that the concentration ratio increases as the size of the target is decreased, as reported. Transparent film detected, at lower concentration ratio 4 for a 0.75-cm target as against 4.7 for digitizing computer image and 6 for photographic color image. Even in the case of 1 cm and 2cm targets, the concentration ratio required for detection was lower in photographic film as compared to color digitizing computer screen and color photographic image. It has been brought out that large abnormalities were detected at lower concentration ratios than the small abnormalities. Of the three types of display systems compared, the photographic transparent film is superior in the detection of abnormalities as compared to digitizing color computer screen and color photographic record.

INTRODUCTION

Image from gamma camera is displayed on computer color monitor having the facility of processing and smoothing the image. A permanent record may be obtained by photographic film, photographic record on Polaroid film or transparent film. A display is a critical component of medical imaging systems as it serves as the final element of the imaging chain [1]. A proper understanding of the display system of an imaging unit is an essential to utilize its diagnostic capability fully. The good display is not only a function of the hardware and displays medium. The software and user interface are also important [2]. Therefore, Observer's visual response to the display plays a vital role in the final outcome of the imaging procedure. In the process of detection of abnormality, the relation between physical attributes of the stimulus and the psychological behavior of the observer is significant. The human visual system is an essential component of all medical imaging system; by far the most complex, but equally the least understood. Usually, performance is measured concerning what the observer can detect. In this context, to detect a signal and to observe its presence, but not necessarily to specify its form. Detection also depends on the amount of risk undertaken by the observer in deciding the existence or absence of the target. Detection is only one aspect of performance and other issues such as identification and recognition are equally important. Size & shape of the target, duration of the scan, size of the background, Pulse Height Analyzer (PHA) window settings, collimator resolution and energy of the gamma radiation are some of the physical factors which affect the abnormality.

A fundamental limitation on the recognition of abnormalities is the random fluctuation associated with radioactive distribution. In the scanning procedure as a whole, the observer ability to detect lesions in the scan is an objective measure of the efficiency. An understanding of the parameter that effect observer detection performance will make it possible to use the system effectively. In this study, we attempted to evaluate the performance of various display systems used in the nuclear medicine imaging.

MATERIALS AND METHODS

The method of constant stimuli was used for measuring the response of observers. The method of constant stimuli consists of producing a set of scans for showing the abnormalities with various target intensities such that in some scans the defect is visible while in others is difficult.

Experimental Set Up

The concentration ratios have been determined for i) Display records on transparent film ii) Display records on a computer screen (chromatic) iii) Photographic color display records. A background intensity that is commonly encountered in routine imaging was used for the study. A cylindrical phantom, 25 cm in diameter and 21 cm in height, was filled with Tc99m and sufficient time was allowed for the uniform distribution of the tracer in the phantom. The study was carried out with three spherical targets of varying diameters, i.e., 0.75 cm, 1.0 cm and 2.0 cm filled with Tc^{99m}.

Concentration in the Targets

Having known the concentration value regarding KBq/ml in the background, the concentration values in the targets to be filled was arrived at by trial and error method initially. We took 70, 90, & 110 KBq/ml in 2-cm target and the scans were taken. The target containing 90 KBq/ml was judged to be visible in all the ten display records. The scans were done ten times, and in all the scans the target was visible. Hence this value of concentration in the target was chosen as C_1. In between the values are divided into four equal values, having known the concentration in the background C_b regarding KBq/ml. Hence the values C_1, C_2, C_3, C_4, and C_5 were arrived at. The Same procedure was repeated for 1 cm and 0.75 cm diameter targets. All the three targets were kept at different places for one set of concentration values, and ten display records were taken in each case by varying the positions of targets within the scan area.

A series of 60 display records were produced. Ten of the display records did not have any target in them. The other 50 were divided into 5 groups of 10 display records, in each group the 10 display records had the same mean target intensities but were different samples of this image. The target intensities were chosen such that at the lowest values of the target intensities practically none of the targets were detectable. The positions of the targets in the display were chosen randomly. However, positions close to the edges of the phantom were avoided since these are likely to produce different visual effect [3].

Targets Positions

The positions of the targets were so varied in the ten display records that at no time the targets remained at the periphery of the scan area. After the display records were taken the positions of the targets were noted on the paper by assigning the number to the display record, so that the correct positions of the targets are known at the time of analysis. First we took the 6 sets of display records, each set having 10 display records, 5 sets having targets at different positions, one set with only background radiation. Later these images were taken on transparent photographic film (8"X10" Konica) through multi-format camera, and on color film (35 mm Konica) through color imager attached to the system.

Visual Response

The visual response to these different display records was elicited from a group of five observers each viewing the 60 scans on five different days. Well experienced observers were chosen. With each set of 60 display records every observer was first given a trial run to allow him/her to learn how to apply the decision criterion. The observers were at first given training so as to read the display and to locate the targets in their true positions. They were told about the size of the targets.

The following procedure was adopted to determine the visual response curve from which the value of concentration ratio required for detection of the target was derived. Out of the total 60 display records for each imaging system, 10 contained no targets and each of the rest has three targets of variable concentration, randomly arranged with in the uniform background. True positions of the targets were there on the paper as per serial no. of display record. The observers were instructed to give positive response to a display record only if he/she was absolutely certain that the target was detected i.e. a strict decision criterion was used [3-4]. If the response to a particular display record was positive, he/she was asked to point out the exact position of the target seen. Each time scans were arranged randomly.

By comparing the response of the observer with the true values, the response could be classified as true +ve, false +ve, false -ve. True +ve meant that the presence of the target was confirmed in its true position. A false +ve could be either the presence of target is reported when none in fact was present or the presence of a target is reported but in the wrong position. The total duration for the presentation of all the 60 display records was approximately 90 minutes. Finally an observation sheet was filled indicating the size of the target, concentration value and the type of the display system to which the response was shown. These results were plotted on graph indicating the percentage of visual response against concentration ratio (the ratio of the activity concentration in the target to that in the background). As strict criterion was used the false +ve rate was in fact 0%.

Each series of 60 display records for a particular target size was seen by 5 different observers and by each observer on 5 different days. The visual response curves for each observer for different display system and for different targets are plotted by taking the percentage of visual response along Y-axis and concentration ratio along X-axis. The mean value of the visual response of five observers for each display system and for each target was taken and the curves were plotted. It is from these averaged curves the 50% visual response value is taken for each curve, as a measure of the performance of the display. The target concentration ratio, which produces a 50% visual response is found.

RESULTS AND DISCUSSION

Whether or not a lesion will be visible on a scan depends upon number of parameters including collimator resolution & sensitivity, concentration of pharmaceutical in the lesion, the size & location of the lesion and how effectively the final image is displayed. Lakshmanan [5] has measured the effect of the size of an abnormality on its detectability under the influence of various concentration ratios and background count densities.

Different types of test patterns were used to analyze display systems. These were either anatomical type of kidney or liver phantoms with 'cold' voids [3, 6-7] or uniform background with hot targets such as those used by Mallard and Wilks, Sharma and Fowlerand Sharp [8-10]. The choice of anatomical phantom might seems to be realistic but it was very difficult in practice to choose the right type which represented the average patient since the normal variations were large. In addition to the varying background, such as those found in anatomical phantoms, the visual appearance of the target will depend upon its position in the phantom. The problems were avoided by using the 2nd type of test distribution i.e. uniform background and a single or multiple targets of increased radioactivity.

The main advantage of choosing a simple set up was that the results obtained represented the best that is possible under ideal conditions, it will provided us with the limits below which we can't hope to detect any abnormality in a practical clinical situation.

The nature of the visual response curves and the variations observed in these curves due to different observers were similar to those reported by Lakshmanan, Sharp and Mallard [4,10].

Expressing the results in terms of concentration ratios required for detection of a target for the comparison of display systems has been followed. The concentration ratio values for 3 sizes of the target used for different display systems could be compared with each other.

The concentration ratio value, which produced a 50% visual response, was found from the averaged response curves for each target, for each display system (Figure-1). From these results the variation in concentration ratio for screen color display, color photographs and transparent films with each target size was determined, as well as the concentration. Ratio values needed for detection for each target in different display systems used.

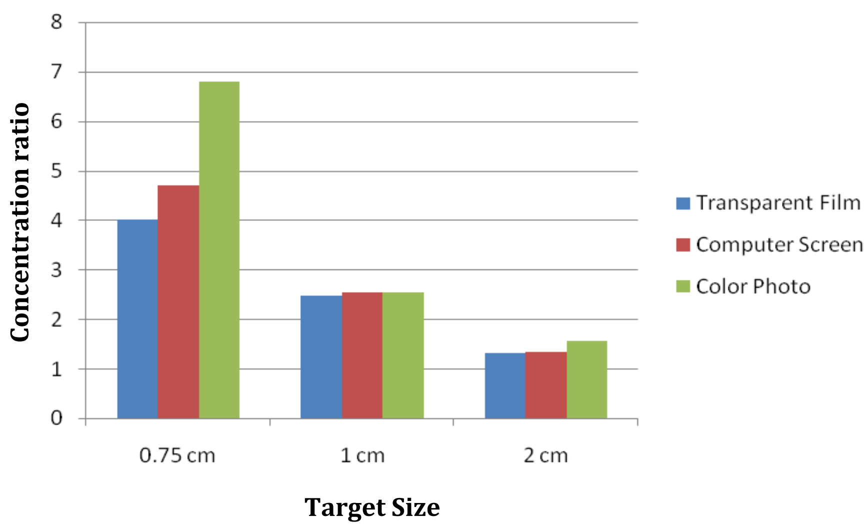

Figure 1: Concentration ratio (for 50% Response) for different display systems for various sizes of the targets

It could be seen that the concentration ratio increases as the size of the target is decreased, as reported by Lakshmanan [5]. Transparent film detected, at lower concentration ratio 4 for a 0.75-cm target as against 4.7 for digitizing computer image and 6 for photographic color image. Even in the case of 1 cm and 2cm targets, the concentration ratio required for detection was lower in photographic film as compared to color digitizing computer screen and color photographic image. Viewing image on computer screen has a number of disadvantages in terms of inherent image quality, including limited luminance range, poor resolution, high reflection, and high veiling glare [11]. Therefore, it is better to evaluate the image on transparent film.

CONCLUSION

It has been brought out that large abnormalities were detected at lower concentration ratios than the small abnormalities. Of the three types of display systems compared, the photographic transparent film is superior in the detection of abnormalities as compared to digitizing color computer screen and color photographic record . The concentration ratio required in detection of small target in the case of transparent film and color computer screen doesn't have much difference but for color photographic image it is considerably higher (only for smaller target size). Of the various attempts made to compare the imaging systems, comparison in terms of concentration ratio needed for detection is definitely advantageous. If the concentration ratio of different types of tumor could be evaluated from animal experiments the adoption of such criterion becomes even more useful.

From an examination of the visual response curves, it was observed that there is a variation in response produced by different display records even though they have the same background count density and the target count density. Response given by single observer varies day to day. There is variation in response among different observers. There is variation in response among different target sizes.

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