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H4.SMR/773-11

College on Medical Physics:
Radiation Protection and Imaging Techniques

5 - 23 September 1994

Radiation Protection & Quality Control in Nuclear Medicine

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Nuclear medicine uses small quantitites of radioistopes in diagnostic procedures which are now very widely applied. Benefits to the patient are remarkable, the status and functions of organs deep into the body can be investigated. With in-vitro radioactive techniques, information can be obtained for the analysis of hormones, vitamins, drugs, etc. etc.

Because of the low levels of radioactivity the radiological hazard is very limited, provided simple but important measures and "good sense" in handling the radioisotopes are applied. The radioactive materials used in nuclear medicine are usually short-lived, and there are well established procedures for transporting, storing and using them. In this field "protective clothing" means no more than an ordinary laboratory coat and the use of disposable gloves. In-vivo nuclear medicine radioisotopes have to be stored in shielded places and some shielded tools must be used. The radioactive wastes are of low level and when necessary may be stored at the hospital until their activity is negligible.

Risk for the patient lies either in "interpretation" errors, or in measurements made with defective or poorly functioning equipment. Faulty diagnosis may then lead to ineffective or damaging treatment. Even in advanced countries this is a difficult problem, requiring sophisticated and well-dsiciplined procedures for quality control. In developing countries, where working conditions are less favourable, the difficulties are much greater. Just providing equipment is not enough, training and quality control programmes are very important. The checking procedures of the images and of the equipment are in a way a "self learning" process; the users will get to know the equipment better and will use it in a proper way.

One of the essential differences between X-ray and nuclear medicine diagnostic investigations is that the X-rays are more or less limited to the irradiated area, while with in-vivo techniques the administered radioisotope spreads in the body acccording to its biochemical characteristics, and later on in the environment.

Consequently, evaluation of the internal dose in nuclear medicine is more complex and requires the help of sophisiticated analysis. Considering the major possible damage which ionizing radiation causes to children and pregnant women, nuclear medicine investigations have to be carried out only when no alternative investigation is available and only in case of absolute need. Therefore, it is advisable to evaluate the dose and the risk in advance.

It is very important to avoid a repetition of the investigation for erroneous interpretation, because of the repeated dose to the patients and the waste of resources.

Attention has to be given to the selection of robust and proven equipment, and to factors contributing to early breakdowns, such as unstable electrical supply or bad climatic conditions. Devices to protect against these have to be supplied with critical pieces of equipment.

Quality assurance procedures developed by the Agency for checking analysis in radioimmunoassay have been demonstrated in training courses and are in widespread use. Training is also given in the use of phantoms and other testing devices for checking the quality of images generated by gamma cameras and other diagnostic devices.

In case of treatment with radioisotopes the problem of radiation safety is different, according to the different administered activity. The problem of handling radiopharmaceuticals and wastes is, of course, heavier but always at a "reasonable" level. Depending on the total activity of the waste, deposit tanks may be required.

When NM techniques are used the influence of radioisotope wastes in the surrounding environment is to be considered according to the national and international rules.

On the whole the rules for safe use of radioisotopes in medicine can be summarized as follows:

- appropriate radiation protection infrastructures
- appropriate tests to check the equipment performance
- appropriate instrument, compatible with the conditions
- appropriate radiopharmaceuticals in order to keep the amount of radioactivity as low as possible.
- correct interpretation of the examinations.

The IAEA TEC-DOC 602 is a very comprehensive guide for performing all the calibration tests.

Basic Radiation Protection Requirements include:

- Construction of the department
  - Washable floors and walls with rounded corners,
  - Appropriate storage facility (hot room),
  - Appropriate air ventilation system,
  - Appropriate layout.
- Good work practice
  - Protection at every point when radioisotopes are handled,
  - Protection of the body and the extremities of the workers,
  - Optimized times and procedures;
  - Prompt availability of soap, decontamination liquid, paper towels, etc.,
  - Adequate shielded containers.
- Waste storage
  - Accurate division of radioactive wastes,
  - Accurate labeling,
  - Appropriate organization.

The following points have to be considered:

Minimal detectable organ effects do not occur at radiation doses less than 200 mSv (except for the testes)

Clinically significant observable effects do not occur at less than 500 mSv.

Correspondingly, whole body doses of less than 50 mSv are not detectable and clinically significant effects are not observed at less than 100 mSv effective dose.

Most diagnostic tests involve activities much less (relative small risk).

Administration (particularly Iodine) to women breast feeding can result in considerable dose to the child.

Misadministration: Wrong activity, wrong radiopharmaceutical being given to the wrong patient by the wrong route.

- human errors
- non-calibrated equipment

* Diagnostic dose differing from the prescribed figure by more than 50% and a therapy dose by 10%.

* 390 incidents of diagnostic misadministration were reported to the NCR in 1985..

* Total figure for the USA is about 3 times.

Misadministration of Radioactive material:

1972-1980

* The number of nuclear medicine studies has doubled,

* Reduction in the radiation dose for procedures and in total dose,

* Due to the shift from I-131 to TC 99,

* For thyroid imaging the gonad dose has increased by a factor of 4 (use of TC 99).

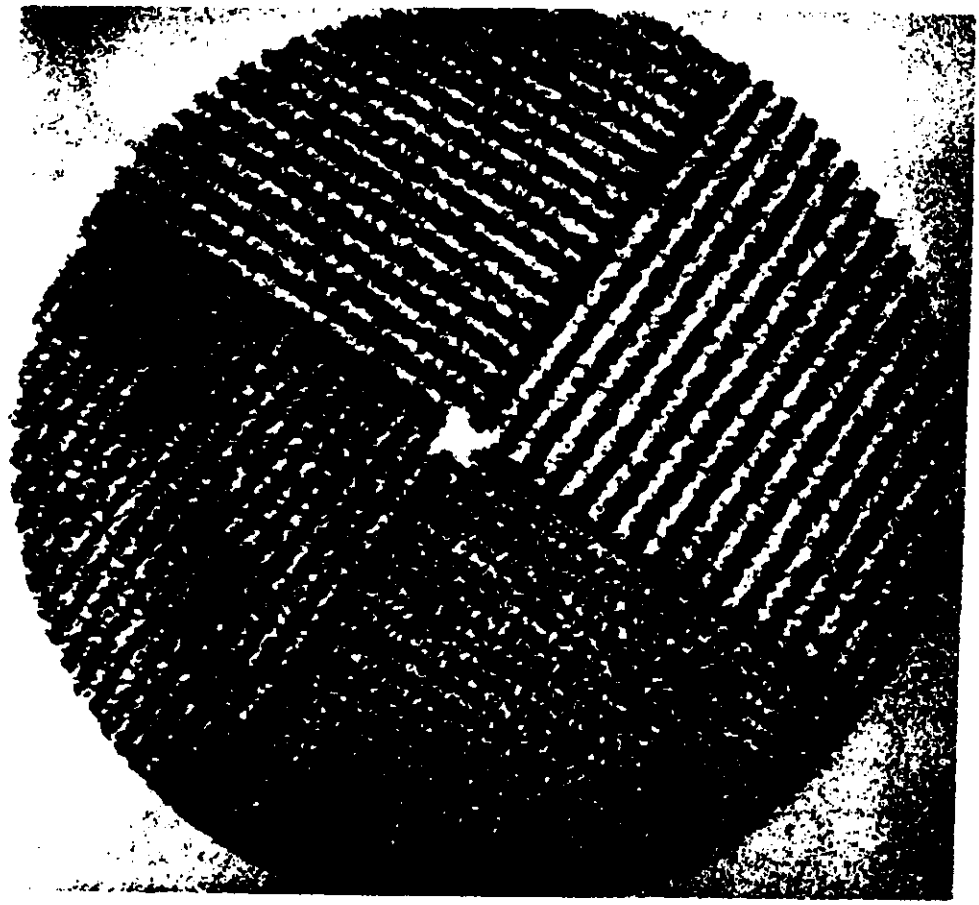

Figure 30-6 Image of a Test Object Used to Measure the Resolving Ability (Amount of Blur) of a Gamma Camera

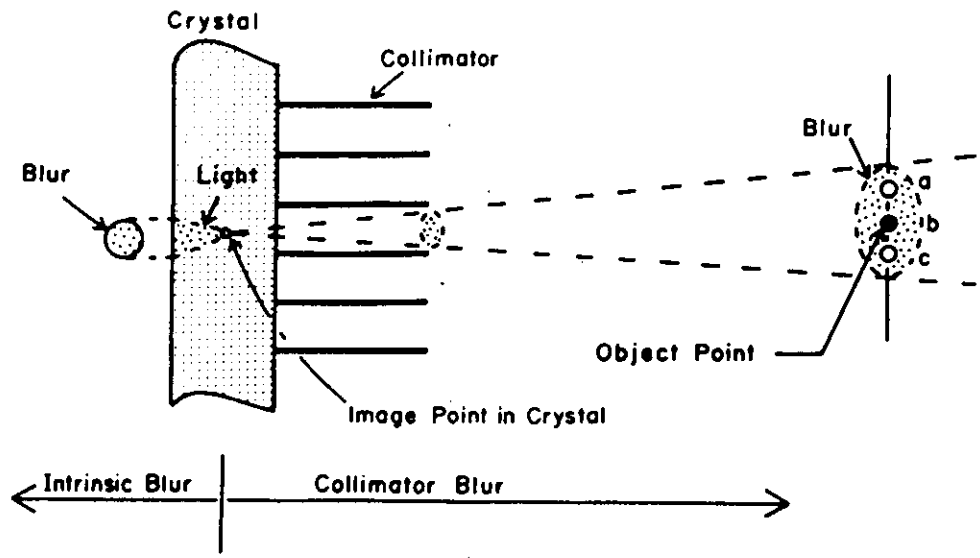

Figure 30-7 The Two Basic Components of Gamma Camera Blur: Intrinsic Blur and Collimator Blur

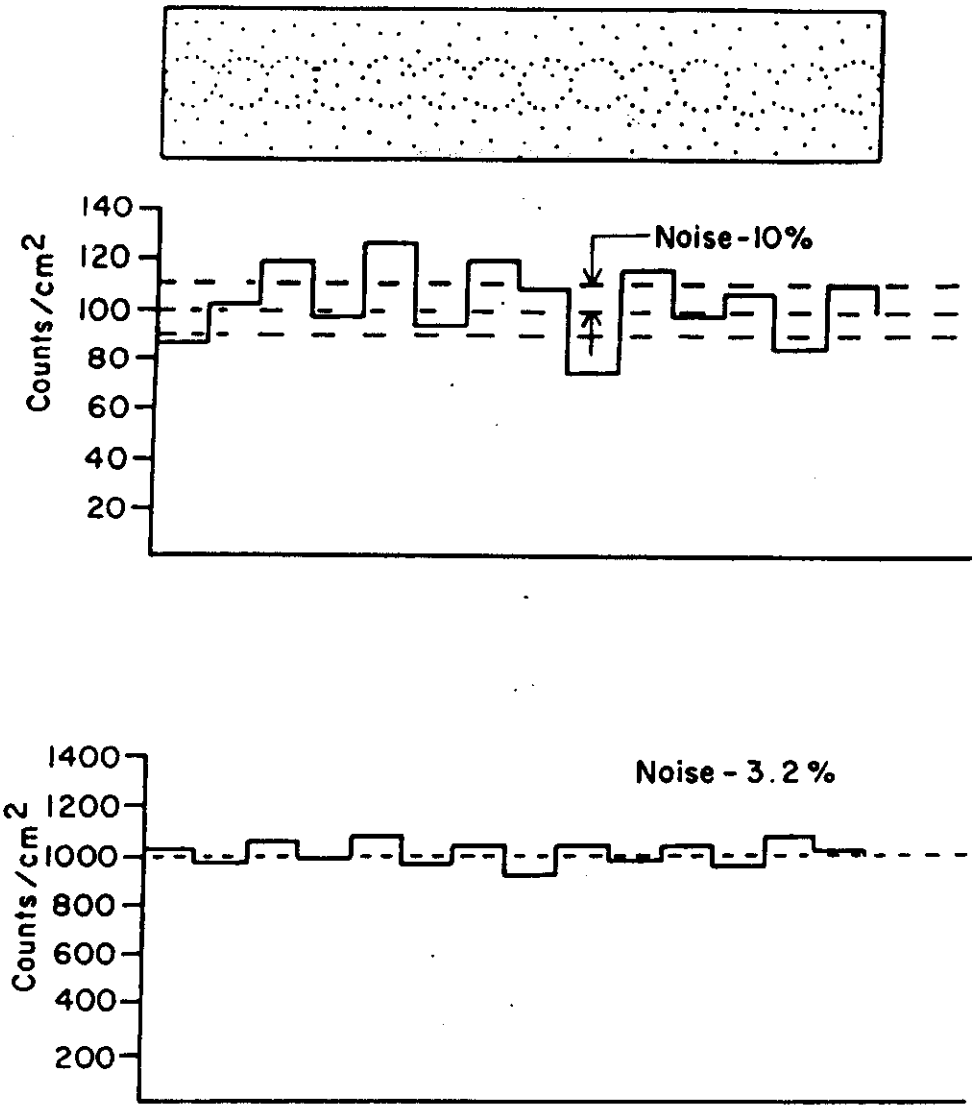

Figure 30-12 Area-to-Area Variation in Photon Concentration for Two Average Count Densities

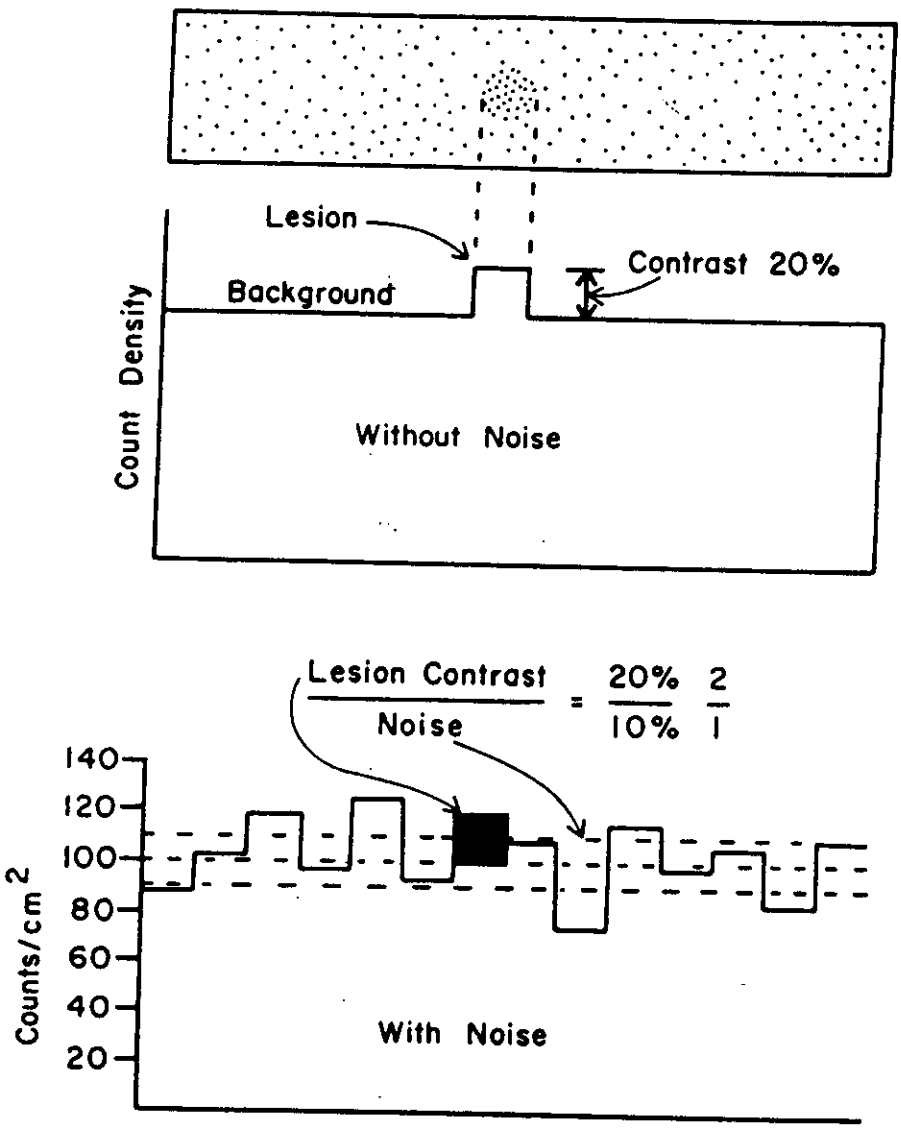

Figure 30-13 Relationship of Lesion Contrast to Background, Both with and without Noise

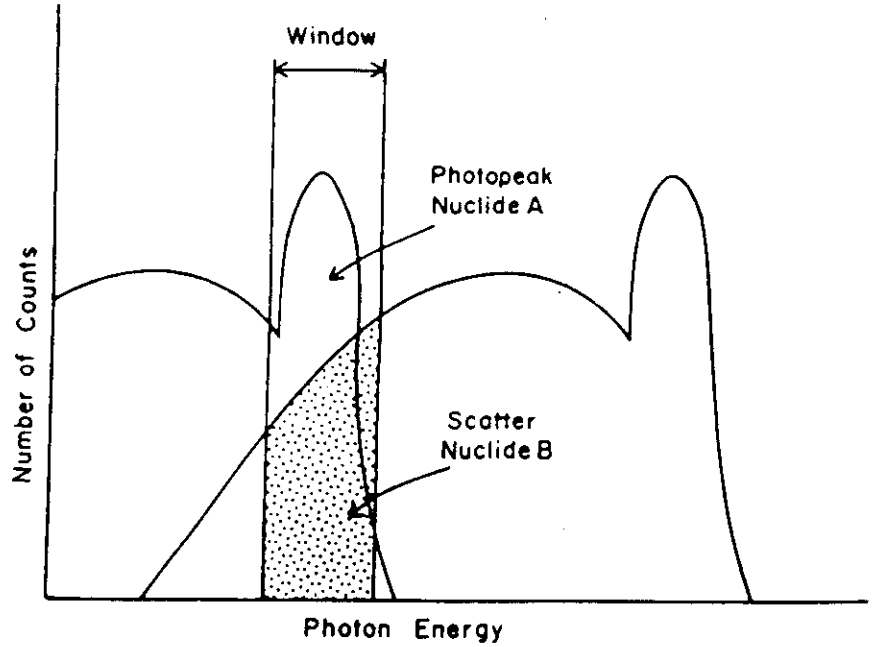

Figure 30-4 Overlapping of the Energy Spectra of Two Nuclides

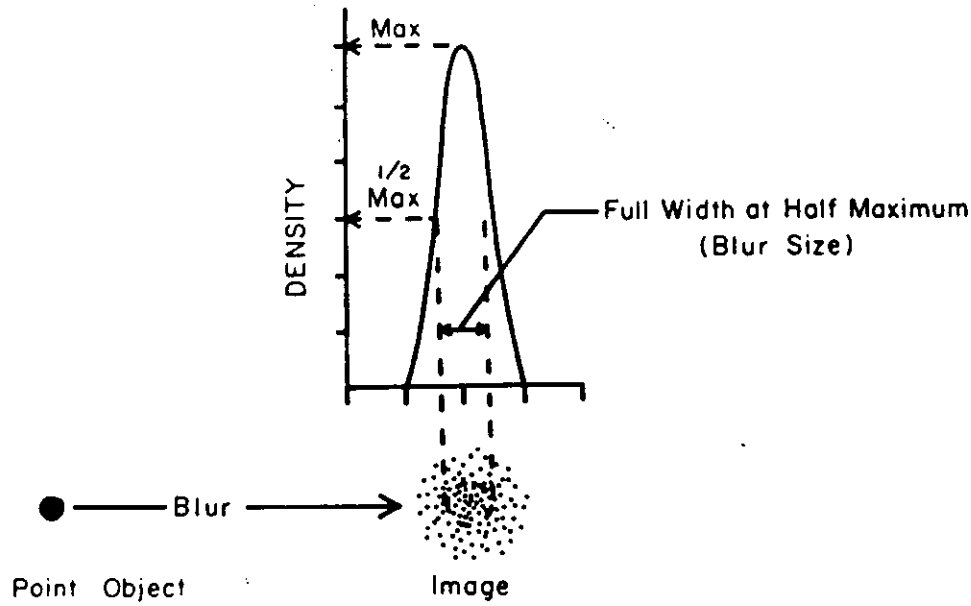

Figure 30-5 Profile of the Blurred Image of a Small Object (Radioactive Source)

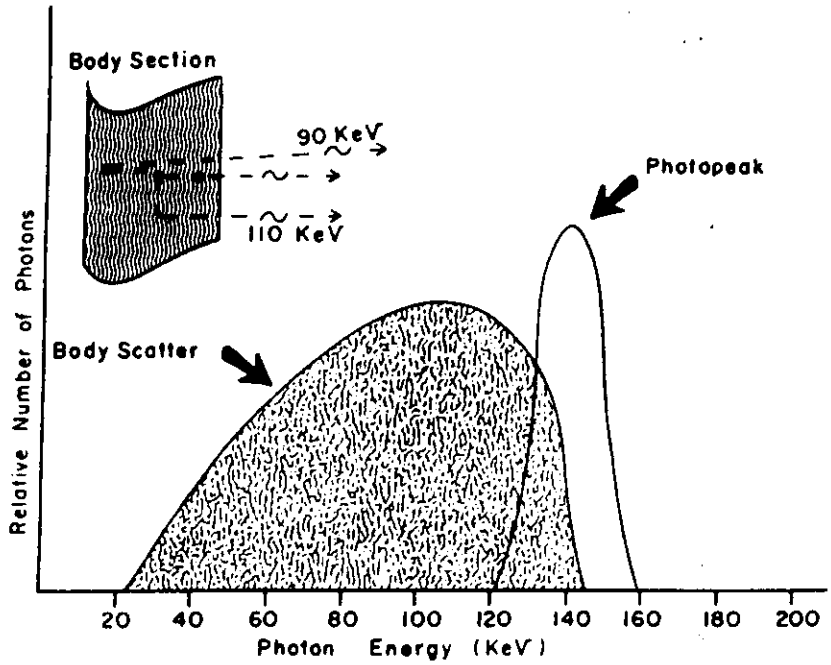

Figure 29-14 Spectrum Component Produced by Compton Interactions within the Body

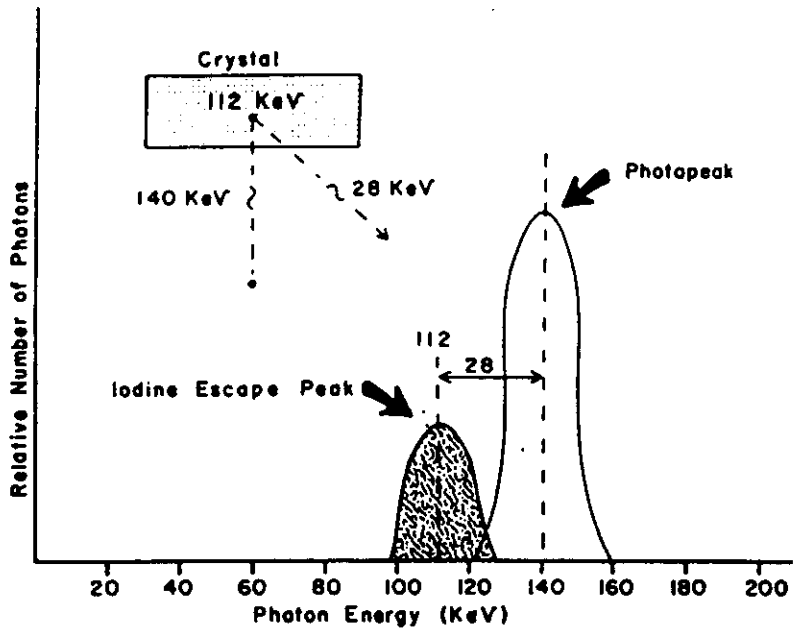

Figure 29-15 Spectrum Component (Escape Peak) Produced by X-Ray Photons Leaving the Crystal

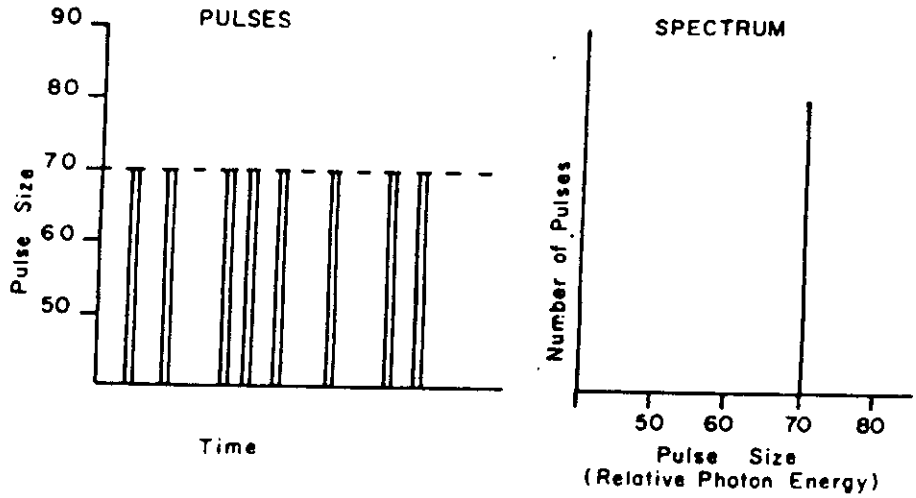

Figure 29-11 The Pulse Spectrum That Would Be Produced by a Monoenergetic Radiation Source and an Ideal Detector

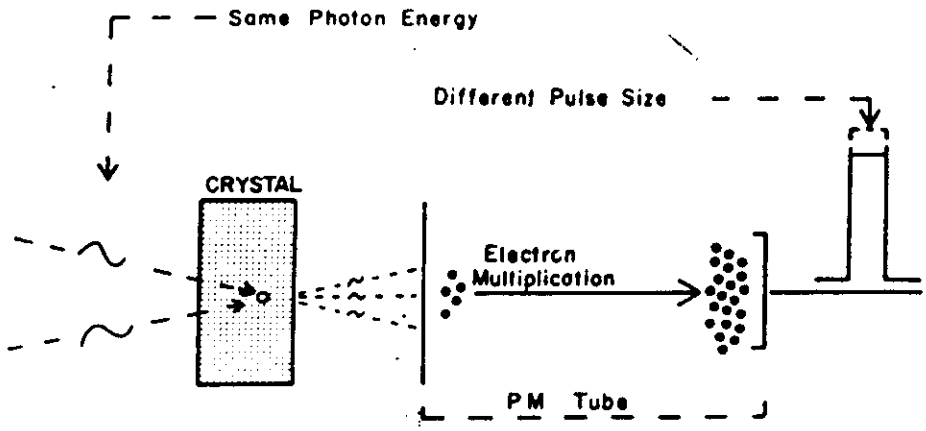

Figure 29-12 Factors That Produce a Variation in Detector Pulse Size

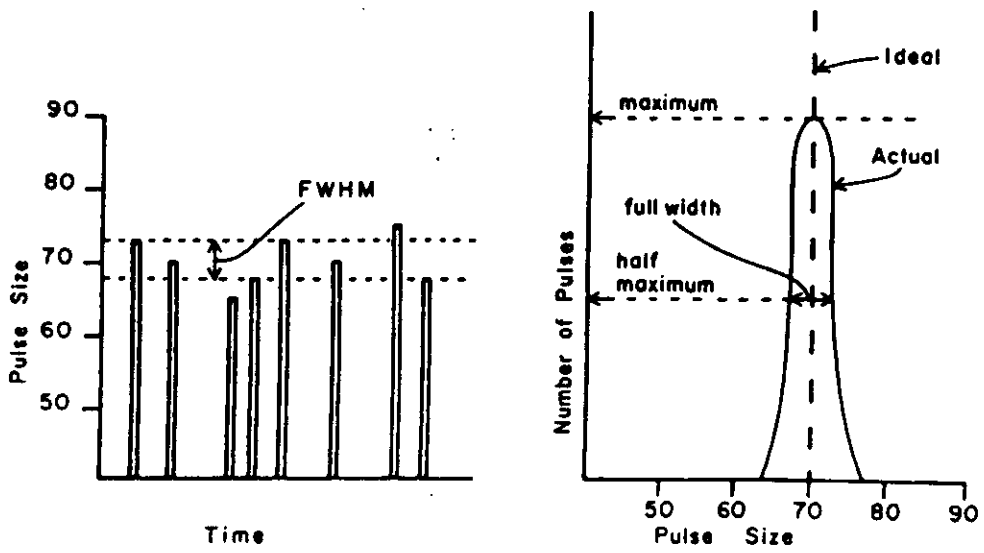

Figure 29-13 Pulse Spectrum Produced by a Monoenergetic Radiation Source and a Typical Detector

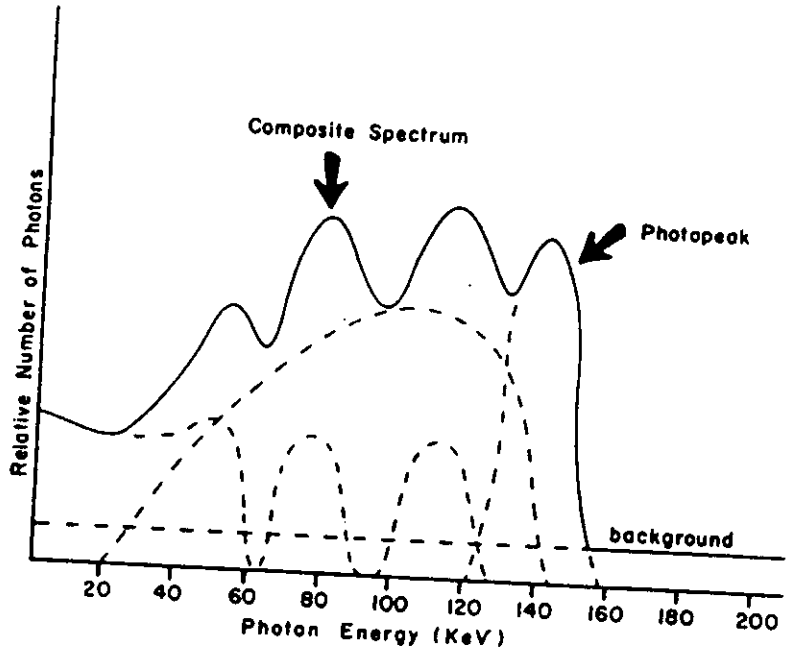

Figure 29-16 Composite Spectrum Produced by Adding the Different Spectral Components

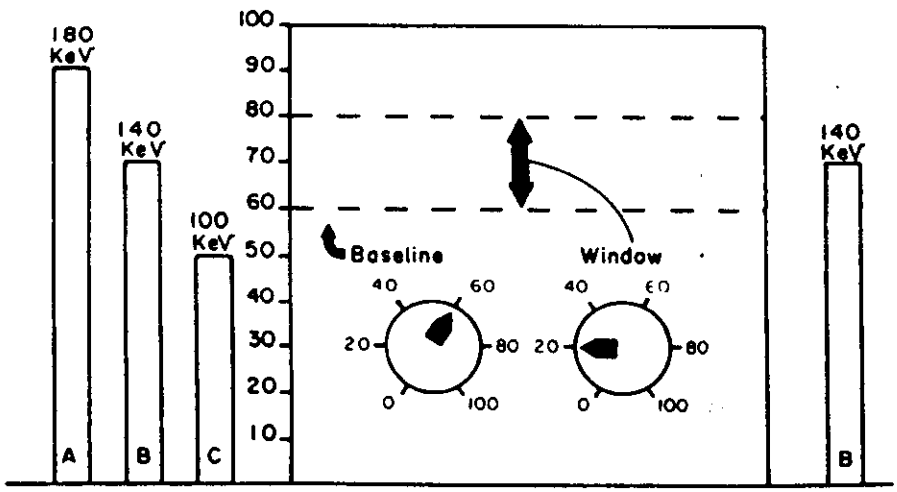

Figure 29-17 Basic Function of a Pulse Height Analyzer

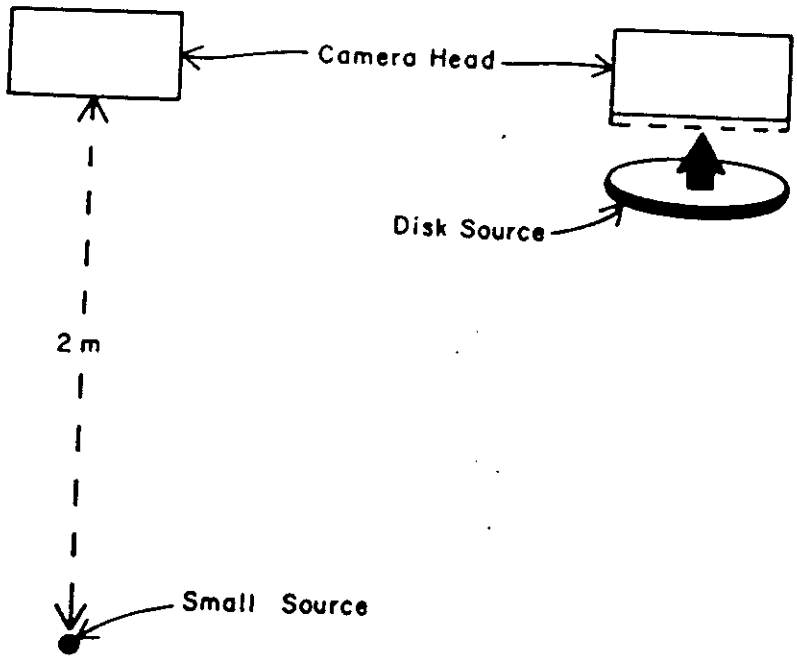

Figure 30-14 Radioactive Sources Used to Test a Gamma Camera for Uniformity Over the Image Area

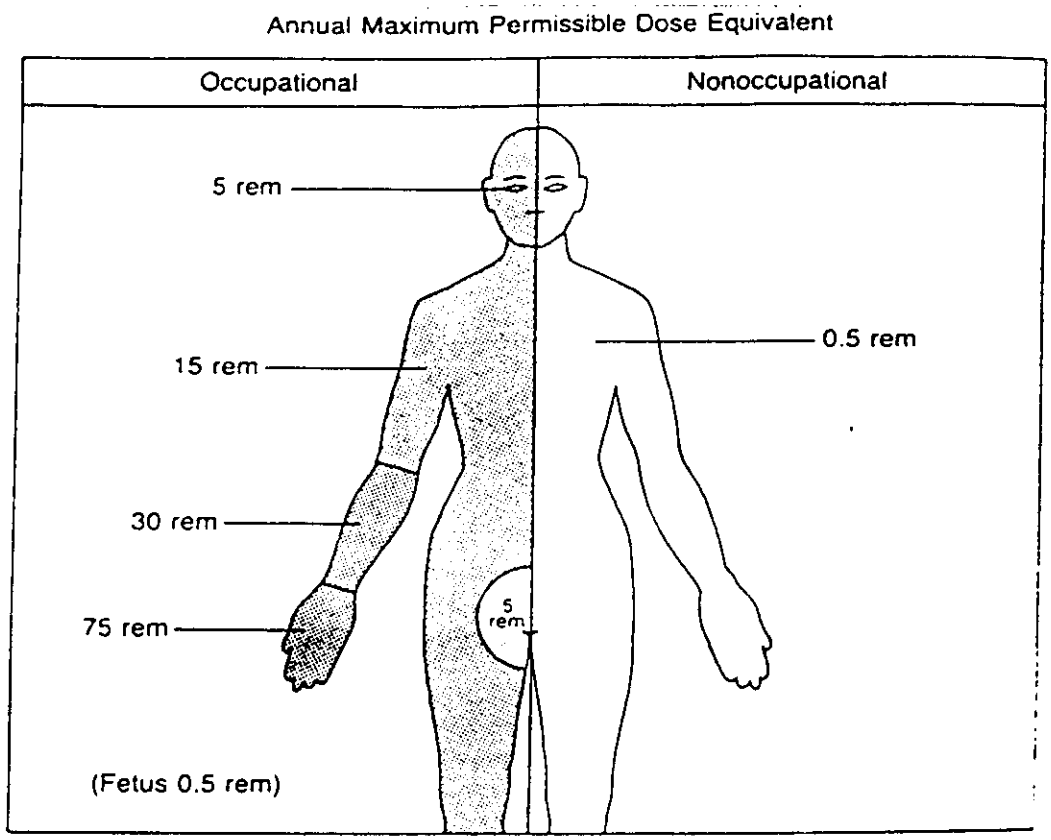

Figure-1 Maximum permissible dose equivalent (MPD) values

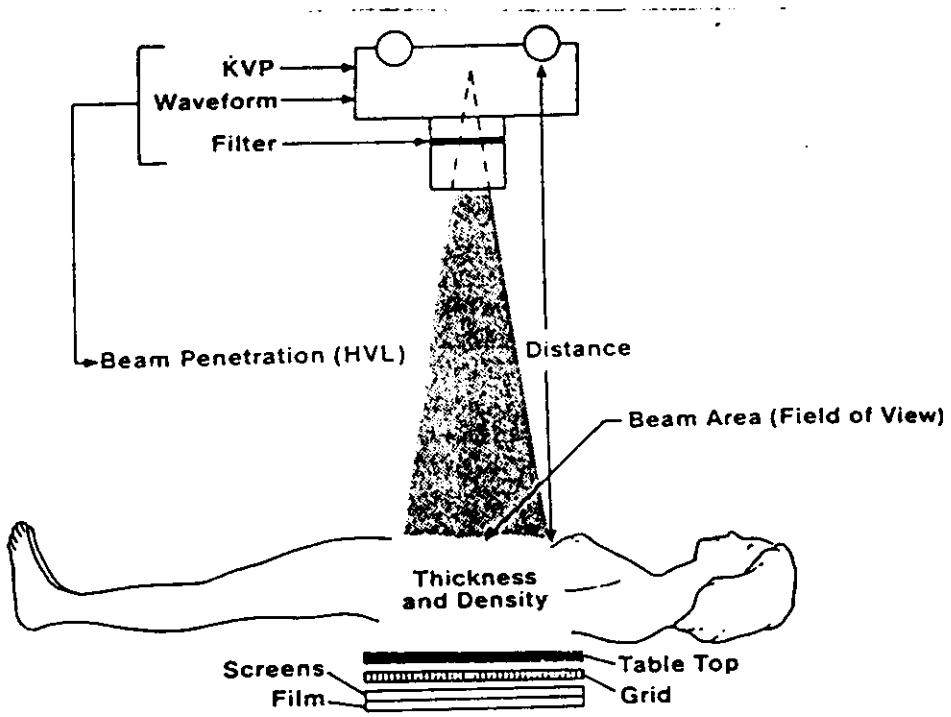

Figure-2 Factors that affect patient exposure in a radiographic procedure

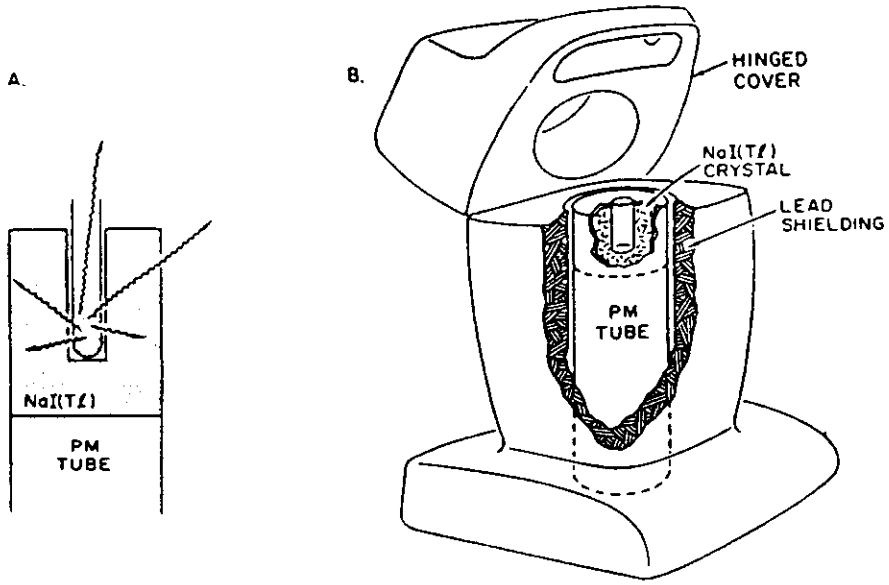

Figure-6 (A) Cross-sectional view of a well counter detector. (B) Detector and shielding

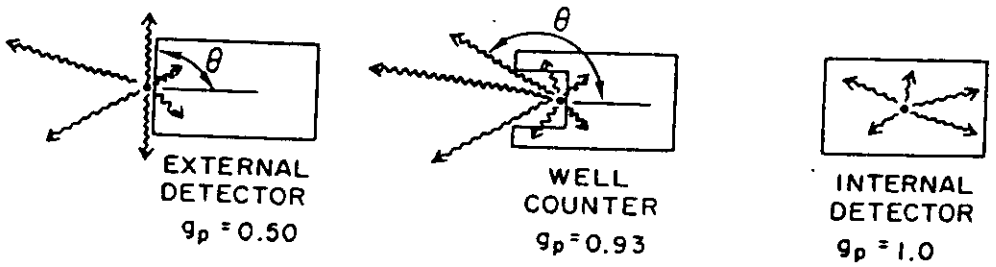

Figure-7 Examples of geometric efficiencies for different source detector geometries

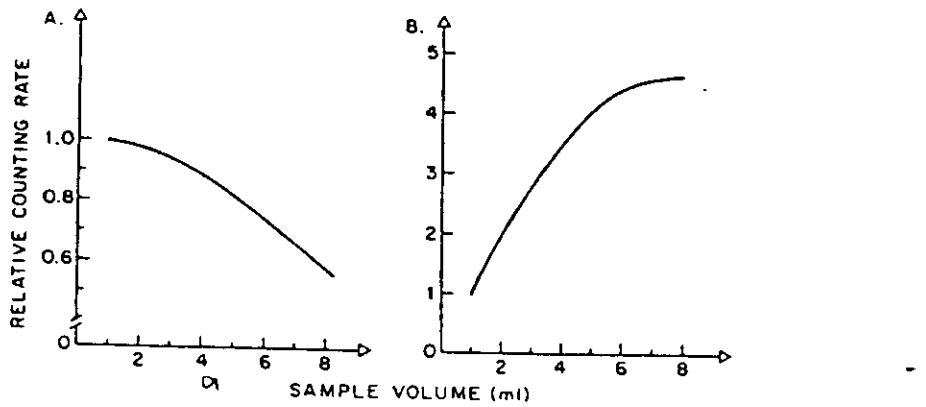

Figure-8 Change in counting rate (A)With constant activity. (B) With constant concentration.

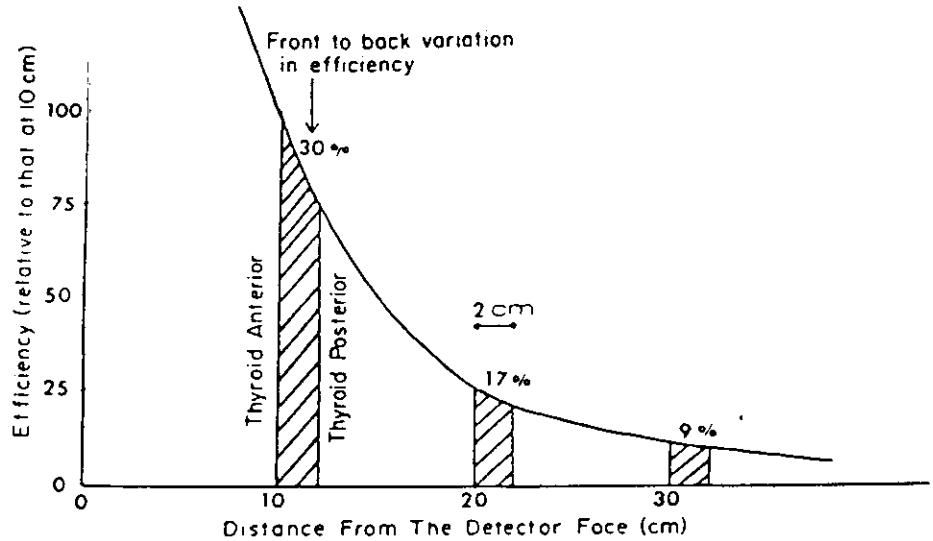

Figure-12 Variation of the efficiency of a thyroid probe as a function of the distance of the thyroid from the probe. The efficienc drops by a factor of 9 when the distance is increased from 10 to 30cm but the uniformity of response within the thyroid (2cm thick) improve

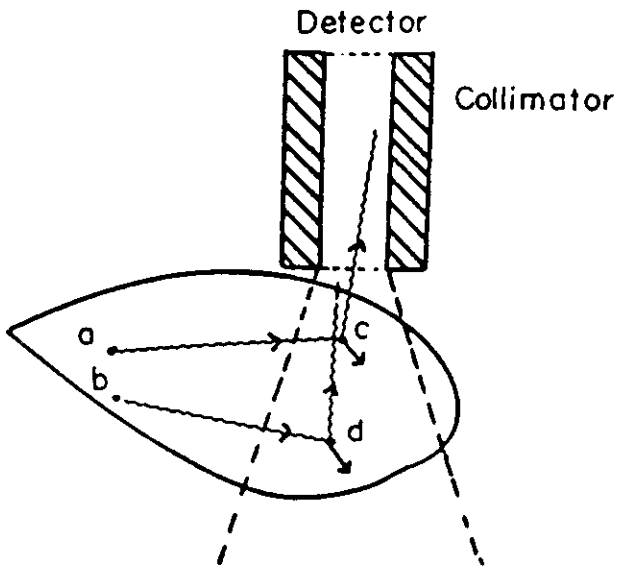

Figure-13 Compton scattering of gamma rays interferes with the function of a collimator. Gamma-rays originating outside the field of view from points a and b are able to reach the detector as a result of compton scattering at points c and d respectively.