Effect of Background Radiation Change on Measurements of Iodine by X-Ray Fluorescence Technique

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Energy spectra from a thyroid fluorescence scanner demonstrate inherent background radiation (excitation beam scatter), which interferes with the detection of characteristic iodine x-rays and influences imaging and iodine quantitation. The amount of scattering material within the beam field is one factor that varies the counting rate detected in the iodine peak region. The technique of constant background subtraction, which is found in conventional radionuclide scanners, is suboptimal because a variable correction is required. A fluorescence scanning system that continuously monitors and subtracts background from the iodine peak region (dynamic background subtractor) was evaluated and found to make appropriate background corrections while scanning. Radionuclides administered before a fluorescence scan produce image artifacts and erroneous quantitation of iodine results, using either background subtraction technique.

Thyroid fluorescence scanning is a technique for imaging and quantitation of stable iodine in vivo, introduced by Hoffer et al. in 1968 (*1*). Presently, several commercial instruments are available for this purpose. We describe the problems that are related to the interference of background radiation with characteristic iodine x-ray peaks and the effect that change in background has on the final measurements. To measure the specific radiation of iodine fluorescence, semiconductor detectors, which possess good energy resolution, are used to separate energy peaks of fluorescent x-rays from those of the excitation source and background. Combination of a focused excitation beam and a semiconductor detector with a scanning instrument enables the simultaneous recording of positional and quantitative measurements of stable iodine. An energy spectrum obtained with a fluorescence scanner using an excitation source of 59.7-keV gamma radiation (Am-241) demonstrates both fluorescent iodine x-rays and the excitation radiation (Fig. 1).

Materials and Methods

The commercial instrument evaluated was a Kevex Scan II adapted to a Picker Magna-Scanner II (Fig. 2). The excitation beam is produced by collimation of the 59.7-keV gamma radiation from a 10-Ci Am-241 source (Fig. 3). The detector system is a high-resolution, silicon-lithium drifted semiconductor with an active area of 500 mm^2.

Electronic components of this instrument (Fig. 4) are amplifier, multichannel analyzer, two single-channel

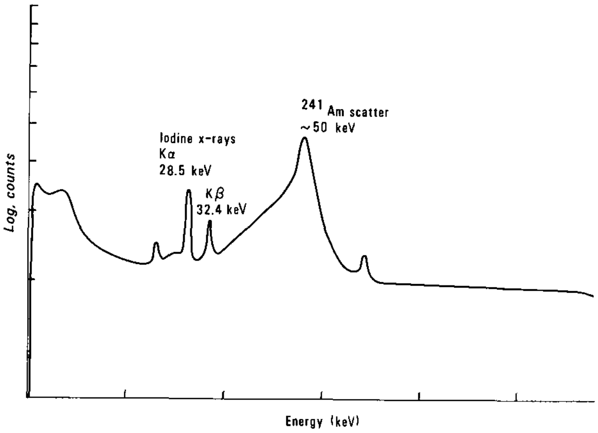

FIG. 1. Energy spectrum obtained with thyroid fluorescence scanner showing characteristic x-rays of iodine and scatter peak from excitation source beam. Note relative peak heights and proximity of fluorescent and excitation radiation.

FIG. 2. Thyroid fluorescence scanning instrument, including multichannel analyzer and patient bed.

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analyzers, two scalers, timer, and dynamic background subtraction module (Kevex model 4840). The dynamic background subtraction module has a unique function in this system: it produces an output signal with a rate equivalent to the difference of the input rates from two single-channel analyzers.

The events indicating the presence of iodine and selected for photorecording and scaling are the net count events of fluorescent iodine x-rays. Detection of a net count event is signaled by the dynamic background subtraction module when the additive input originates from one single-channel analyzer set for an energy window of fluorescent iodine x-rays. The subtractive input comes from the second single-channel analyzer with an energy window selected to be equivalent to the background counting rate within the selected iodine energy region. Energy spectra were obtained with the multichannel analyzer and used for selection of both energy windows.

Scanner controls were selected to complete a scan area of 100 cm², representing the anterior portion of the human neck, in 20 min. Patient and phantom studies were performed with a constant scan speed and line space. A Picker thyroid phantom was used to evaluate the effects of Tc-99m and I-131 within the scanning area.

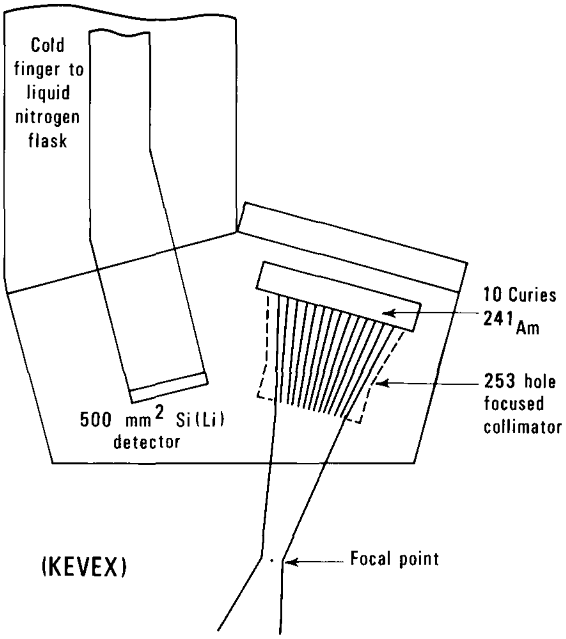

FIG. 3. Schematic drawing of excitation source, collimator, and detector assembly.

Results and Discussion

Energy Spectra from Human Neck Tissue. Energy spectra were obtained from a normal control subject at three locations in the anterior part of the neck (Fig. 5). Differences noted are due to the presence or absence of iodine, the amount of scattering material within the beam path, and the beam detector response to source distance. The spectrum obtained over the thyroid gland demonstrates the peaks corresponding to the Kα and Kβ iodine x-rays. The most prominent peak, however, is the Compton scatter peak of the 59.7-keV americium gamma radiation. A spectrum obtained over the trachea (outside the thyroid gland) demonstrates the absence of iodine and a slightly different scatter pattern. A spectrum obtained over the lateral neck outside the thyroid region demonstrates the minimal amount of scatter expected during scanning. These curves demonstrate that a constant background correction would be inappropriate because the background in the iodine energy region

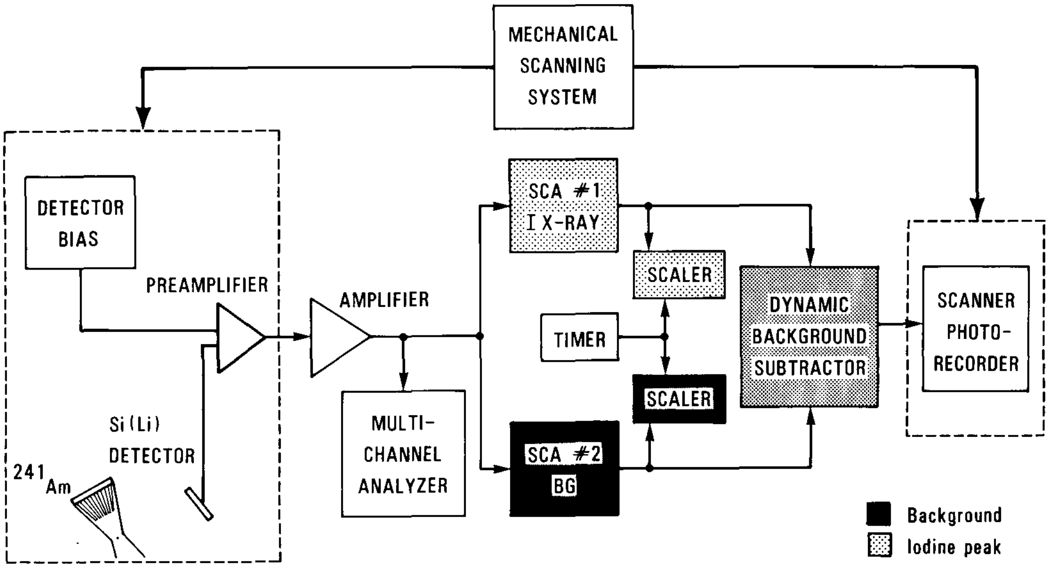

FIG. 4. The electronic components of a thyroid fluorescence scanning system.

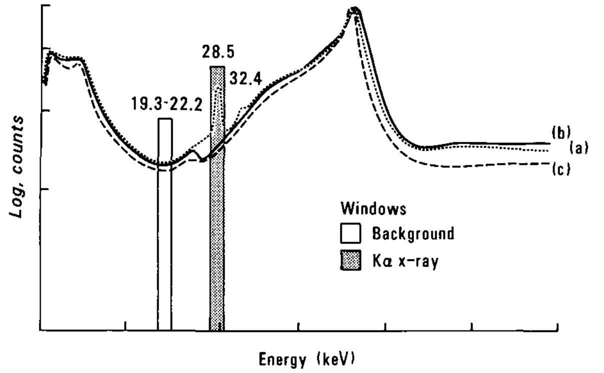

FIG. 5. Energy spectra obtained from normal control subject. Curve *a* was obtained over thyroid gland, curve *b* over trachea outside thyroid gland, and curve *c* over lateral neck outside thyroid region. Energy windows selected for Kα iodine x-ray and representative background are shown.

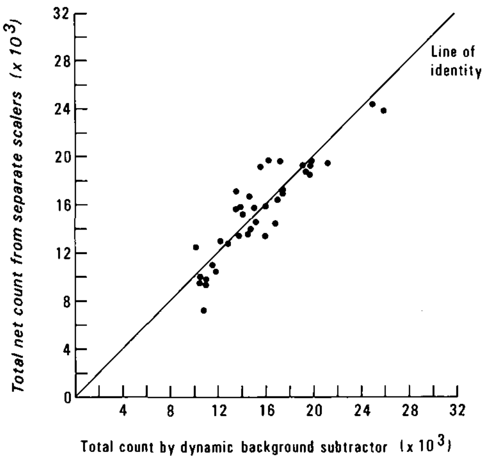

FIG. 6. Plot of data comparing total count result obtained by separately scaling background and iodine counts with total count obtained by dynamic background subtraction. Line of best fit was not significantly different from line of identity.

varies within one transverse scanning section and throughout the scanning area.

Selection of Window Settings. Based on these observations, the iodine x-ray energy window was selected to be a 1.5-keV window around the 28.5-Kα x-ray. The Kβ x-ray at 32.4 keV was rejected for counting because of the predominance of scatter events and the degree of slope within this energy region. The energy region representative of background within the Kα energy window was selected to be between 19.3 and 22.2 keV. The basis for selecting this region was counting rate equivalence to the iodine window under varied scattering conditions and the absence of a slope in this spectral region. As a control, when two athyroid patients were scanned, the counting rates obtained from the iodine peak window and the background window differed by +4.5 and −1.5%.

Comparison of Background Subtraction Modes. The net count sum obtained by separate scalers was compared with the count obtained by the dynamic background subtractor (Fig. 6). The line of best fit, calculated by least-squares regression, was not significantly different from the line of identity, and attests to the proper function of the dynamic background subtractor. These data also confirm that the selection of the background window did not result in excess reduction of the count rate, since this would result in an intercept significantly below zero.

Alterations in Background Spectra By Other Radionuclides. An energy spectrum obtained with Tc-99m (without the beam shutter open) demonstrates the characteristic x-rays at 20.7 and 18.3 keV (Fig. 7). The 20.7-keV peak falls within the preselected background window. As a result, technetium in the thyroid will produce falsely low imaging information and measurements of iodine quantitation. Technetium-99m in phantoms containing potassium iodide reduced the iodine quantitation by 0.4 mg of iodine per microcurie present. An energy spectrum obtained with I-131 (with the beam shutter

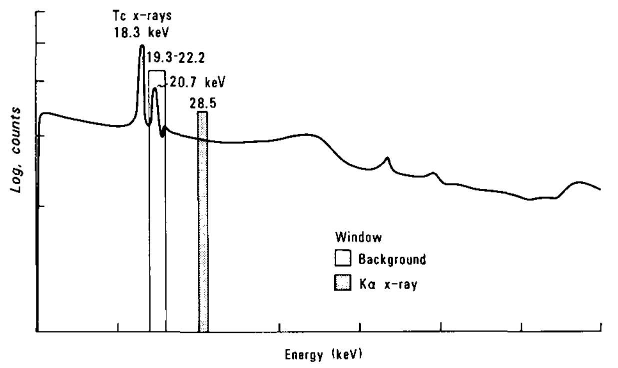

FIG. 7. Energy spectrum of Tc-99m obtained with fluorescence scanner having excitation beam shutter closed. Characteristic x-rays of technetium are shown.

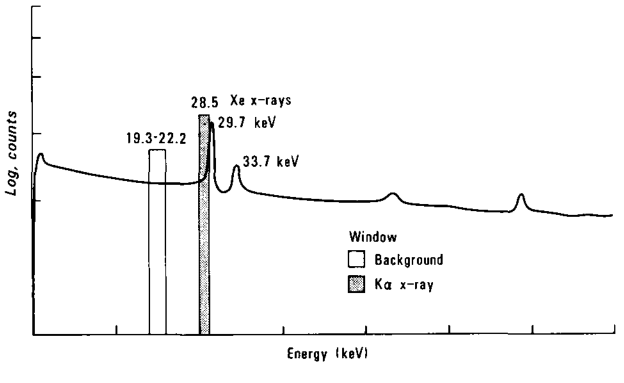

FIG. 8. Energy spectrum of I-131 obtained with fluorescence scanner with excitation beam shutter closed. Characteristic x-rays of xenon are shown.

TABLE 1. Comparison of Calculated Imaging Characteristics Using Dynamic Background Substraction (DBS) and Iodine Peak Only (I)

Thyroid iodine content	Total scan counts			Average information density*		Scan contrast†		Scan count variation, percent‡	
	I	BKG	DBS	I	DBS	I	DBS	I	DBS
High	46,305	26,833	19,907	264	113	0.86	1.0	0.5	1.4
Normal	34,106	23,596	11,855	223	77	0.78	1.0	0.5	2.0
Low	26,109	23,863	2,947	169	19	0.31	1.0	0.6	7.6

$$^{*}\text{Average information density} = \frac{\text{counts for complete scan}}{\text{scan speed} \times \text{line space} \times \text{time}}.$$

$$^{\dagger}\text{Scan contrast} = \frac{\text{count rate maximum}-\text{count rate minimum}}{\text{count rate maximum}}.$$

‡Count variation for iodine peak only = $I^{1/2}/I \times 100$ and count variation using dynamic background subtraction = $[(I + BKG)^{1/2}/(I\text{-}BKG)] \times 100$.

closed) shows the characteristic xenon x-rays at 29.7 and 33.7 keV (Fig. 8). The lower energy tail of the 29.7-keV peak falls within the Kα iodine x-ray window. As a result of the presence of I-131 in the thyroid, imaging and iodine quantitation measurements are falsely high. Iodine-131 in phantoms increased the results of iodine quantitation by 0.3 mg of iodine per microcurie present. Images obtained with either radionuclide present showed poor resolution, inasmuch as they were detected without collimation.

Background Subtraction and Image Display. The effects of the dynamic background subtraction technique on average information density, scan contrast, and count variation were calculated for scans on patients with high, normal, and low content of thyroid iodine (Table 1). The results, with and without background subtraction, showed that the background subtraction technique decreased average information density and increased scan contrast and count variation. This was also true when the constant background subtraction technique was used. The effect, however, did not demonstrate the loss of information but demonstrated the misleading effect of including background in these calculated values. For this reason, imaging characteristics calculated for comparison of scanning techniques should be made with background subtraction.

Thyroid scans of subjects with a normal content of iodine showed marginal improvement when the dynamic background subtraction technique was used. However, for instrument setup, the increased contrast in counting rates over thyroid and nonthyroid tissue was helpful. Because image contrast is increased, dynamic background subtraction is probably a better technique for imaging thyroid glands that have a low iodine content.

Summary

In fluorescence scanning, high-resolution energy spectrometry is necessary to accurately separate the specific iodine Kα fluorescence peak from background radiation. Changes in the background energy spectrum were observed when scans were performed over and around the thyroid gland and when Tc-99m or I-131 was present as a contaminant, perhaps from previous diagnostic procedures. The constant background subtraction technique present in commercial scanning devices is not optimal for fluorescence scanning. With the use of the dynamic background subtraction technique of the Kevex II equipment, improved background subtraction can be performed but the presence of Tc-99m or I-131 in the thyroid gland still leads to erroneous results.

Acknowledgments

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Reference

1. Hoffer PB, Jones WB, Crawford RB, et al: Fluorescent thyroid scanning: A new method of imaging the thyroid. *Radiology* 90: 342–344, 1968