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LAWRENCE RADIATION LABORATORY
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ABSTRACT

We propose a camera for the laminographic imaging of the thyroid without administration of radiopharmaceuticals to the patient. An external source of gamma-rays is used to excite the characteristic x-rays of natural iodine in the patient's thyroid, source geometry limiting excitation to well defined planes. The camera consists of a parallel hole collimator and a xenon-filled proportional wire chamber with digitized readout of coordinates. Pulse height selection is provided to limit events in the image display to a selected energy range.

The system obtains high resolution laminography for local exposures on the order of 1 rad, with exposure times of a few minutes for each laminogram.

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I. INTRODUCTION

We describe a special purpose imaging system that combines the advantages of well established and new techniques to obtain high resolution laminographic images of the thyroid.

The camera for thyroid imaging employs a technique developed by Hoffer et al at the University of Chicago,(1) which uses characteristic x-ray excitation and a scanning device. The scanner contains an ^{241}Am source which excites the natural iodine in the thyroid. The characteristic x-rays are detected by a solid state silicon crystal which scans the thyroid region in a raster pattern with a focused collimator. The detected density of characteristic x-rays is recorded as in a conventional radioisotope scan.

Our proposed instrument also employs the excitation principle in order to provide thyroid imaging at extremely low patient exposures, which are limited to the region of interest. Instead of using a scanning device with the source moving in unison with the detector, as is done in Hoffer's device,(1) a different principle of activation is utilized, in which we activate only a well-defined and selected plane within the patient's neck for each image of the thyroid. By exciting characteristic x-rays from a series of well-defined planes, a series of high resolution tomograms may be obtained. The x-rays are detected by a xenon-filled multiwire proportional chamber with delay-line readout of coordinates.(2) A parallel hole multichannel collimator limits detection of x-rays to those with perpendicular orientation to the plane of the chamber.

The laminar excitation thyroid imaging device is expected to offer large improvements in quality and information content of thyroid images.

1. Increased spatial resolution in images to about four millimeters (FWHM) with ultimate capability of about 1 mm FWHM.

2. Reduced patient exposure to radiation by limitation of radiation exposure to specific thyroid regions and duration of the image formation.

3. Laminographic thyroid imaging evaluation of palpable nodules without interference by superimposed thyroid tissue with different functional characteristics from the nodule.

4. Ability to image suppressed thyroids: This method of thyroid imaging will depend upon tissue content of iodide rather than the functional activity of that tissue. Thus, thyroids whose function is fully suppressed will still be susceptible to imaging by examination of their iodide content (principally hormone stores). The method will thereby offer several types of information which are inherently different from those obtained by conventional thyroid imaging with radioactive iodide or pertechnetate.

5. Low system cost: The proposed instrumentation may be constructed for a total system cost which would be acceptable for a special purpose instrument that provides the listed advantages and improvements over existing techniques.

II. THE LAMINOGRAPHIC EXCITATION CAMERA

A line ^{241}Am source, collimated to irradiate a plane, is used to activate the volume of interest. The 60 keV gamma-rays from this source will excite the emission of 28.6 keV rays that can be detected with the collimated wire chamber imaging system. (See Figure 1.) We had considered the use of a position sensitive solid state detector for locating the x-rays of interest, but these devices are not useful at energies much below 500 keV. Thus, the proportional chamber is uniquely suited for this camera.

1. The Multiwire Proportional Chamber.[3] This detector will have an active area of 11 x 13 cm^2 and consist of

three wire planes, with the central plane held at a positive d.c. with respect to the outer two. The plane to plane separation is 1-cm. The outer wires are placed at 90 degrees with respect to each other, with the center plane at 45 degrees. The wires will be spaced at 5 wires/cm, allowing for a spatial accuracy of location of 0.14 cm FWHM.

The volume between the planes will be filled with a 92.5% xenon - 7% CO_2 - 0.5% Freon 13B-1 mixture. This will allow for a 10% detection efficiency of the 28.6 keV radiation (including window attenuation), with approximately 10% FWHM* energy resolution. We are presently considering pressurizing the chamber to two or three atmospheres, with a corresponding increase in detection efficiency. The numbers given in the text correspond to atmospheric pressure, unless otherwise indicated.

Coordinate readout will be accomplished by placing an electromagnetic delay-line close to the wires of the outer grids. This proximity couples the delay-line capacitatively to the wires, so that voltage changes in these wires induce signals in the wires that can be read out for determination of coordinates of events in the chamber. A time-to-height converter or a 200 MHz digitizing scaler can be used to obtain analog signals suitable for a CRT display. The signal from the center plane will be coupled to a single channel analyzer that will gate the CRT, thus providing the necessary pulse height selection of events.

2. The Collimator. We propose a 10 x 12 cm^2, 2.5 cm-thick multi-hole collimator. The holes will have a 0.208 cm diameter and will be placed in an hexagonal array, with a separation between centers of 0.238 cm.

This configuration will allow for a geometric resolution of 0.3 cm and 0.5 cm for objects on the collimator surface and 2.5 cm away respectively (these numbers include the effects derived from the finite thickness of the detector). The geometric efficiency of the collimator will be $G = 2.9 \times 10^{-4}$, where G is the fraction of gamma-rays emitted by the subject that pass through the collimator holes.

3. The Excitation Source. We have chosen ^{241}Am for the purpose of exciting the characteristic line of iodine. The 60 keV gamma-ray used will allow for a quite uniform irradiation, and the general availability and long life-time of this radio-

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*Note added in proof. The use of a tin filter placed between the patient and the collimator can reduce this value to a 5% FWHM effective energy resolution.

isotope make ^{241}Am a very attractive choice. We favor a symmetrical arrangement of two "line" sources (Fig. 2), since this maximizes uniformity of excitation. Each source will consist of a 0.1 cm diameter, 15 cm-long wire containing 3.5 Ci of ^{241}Am. As shown in Figure 3, the isotope will be shielded and collimated by lead plates so that the source will be approximately 20 cm away from the patient. A filter consisting of 0.025 cm of Cu will be used to eliminate lower energy photons. (This will decrease the effective source strength to about 2.5 Ci.)

Figure 3 shows the counting rate along two cuts, AA' and BB', of a typical thyroid with an iodine content of 5×10^{-4} g/cm^3. The pair of sources is located symmetrically about the patient, yielding about 650 counts/cm^3/min. Radiation exposures (limited to the excited area) will be of the order of 1.3 rad/min. This is equivalent to a sensitivity of about 500 counts/cm^3/rad. These rates will make possible the acquisition of high quality laminograms in a few minutes. For instance, for a 0.5 cm thick cut along AA', one will obtain about 400 counts/cm^2/min. This will allow for collection of 1600 counts/cm^2 in four minutes, yielding a contrast of about 12% over a distance of 0.5 cm. By use of a variable aperture, laminograms of 0.1 to 2 cm depth will be possible.

III. CONCLUSION

The system described here offers the potential for the laminographic imaging of the thyroid. Table I summarizes some of its relevant parameters.

Table I

Relevant Parameters of the Laminographic Excitation Camera

Sensitive Area: 10 x 12 cm^2

Intrinsic Resolution of the Wire Chamber: 0.14 cm FWHM

Collimator Resolution at the Surface: 0.3 cm

Collimator Resolution at 2.5 cm: 0.5 cm

Detection Efficiency: 2.9×10^{-5} (8.7×10^{-5} *)

Energy Resolution: 10% FWHM (approximately 5% with a tin filter)

Source Strength: 7.0 Ci of ^{241}Am (Effective Strength: 5.0 Ci of ^{241}Am)

Laminographic Cut: 0.1 to 2 cm

Typical Counting Rate: 650 counts/cm^3/min (1950 counts/cm^3/min *)

Maximum Counting Rate: 3×10^7/min

Typical Sensitivity: 500 counts/cm^3/rad (1500 counts/cm^3/rad*)

* Parameters for a chamber pressurized to 30 psi above atmospheric pressure.

FOOTNOTE AND REFERENCES

This work was done under the auspices of the U. S. Atomic Energy Commission.

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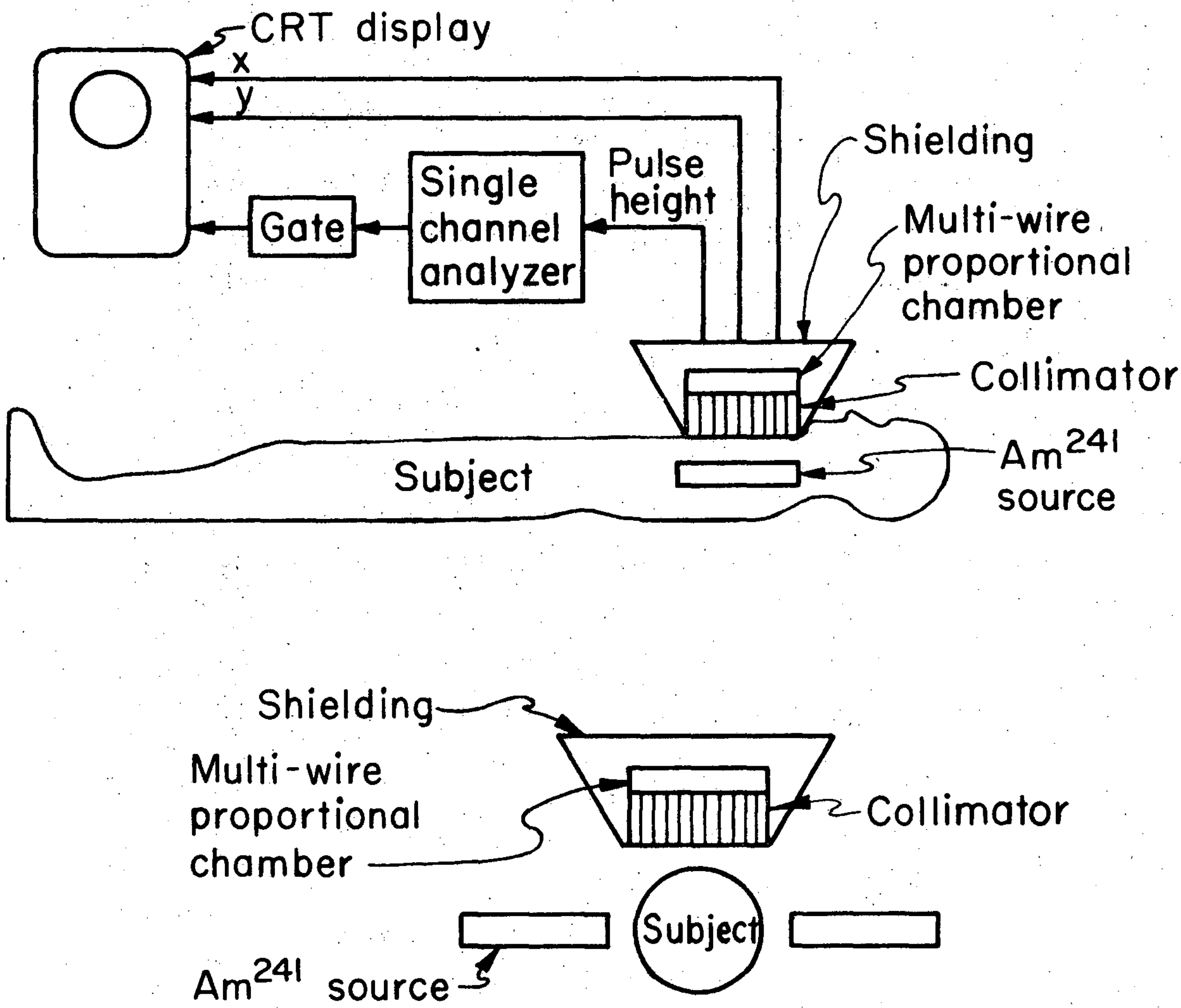

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Fig. 1. Schematics of the Laminographic Excitation Camera.

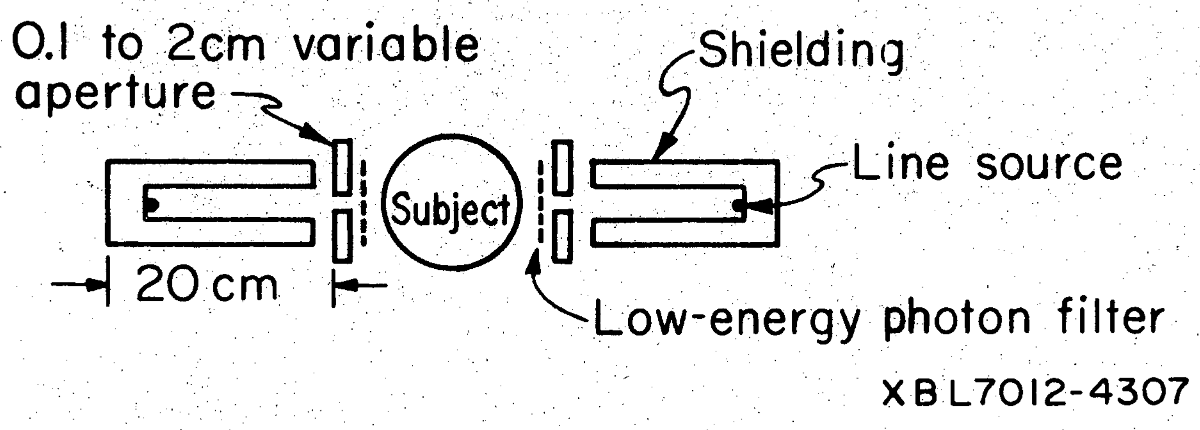

Fig. 2. Excitation Source Housing

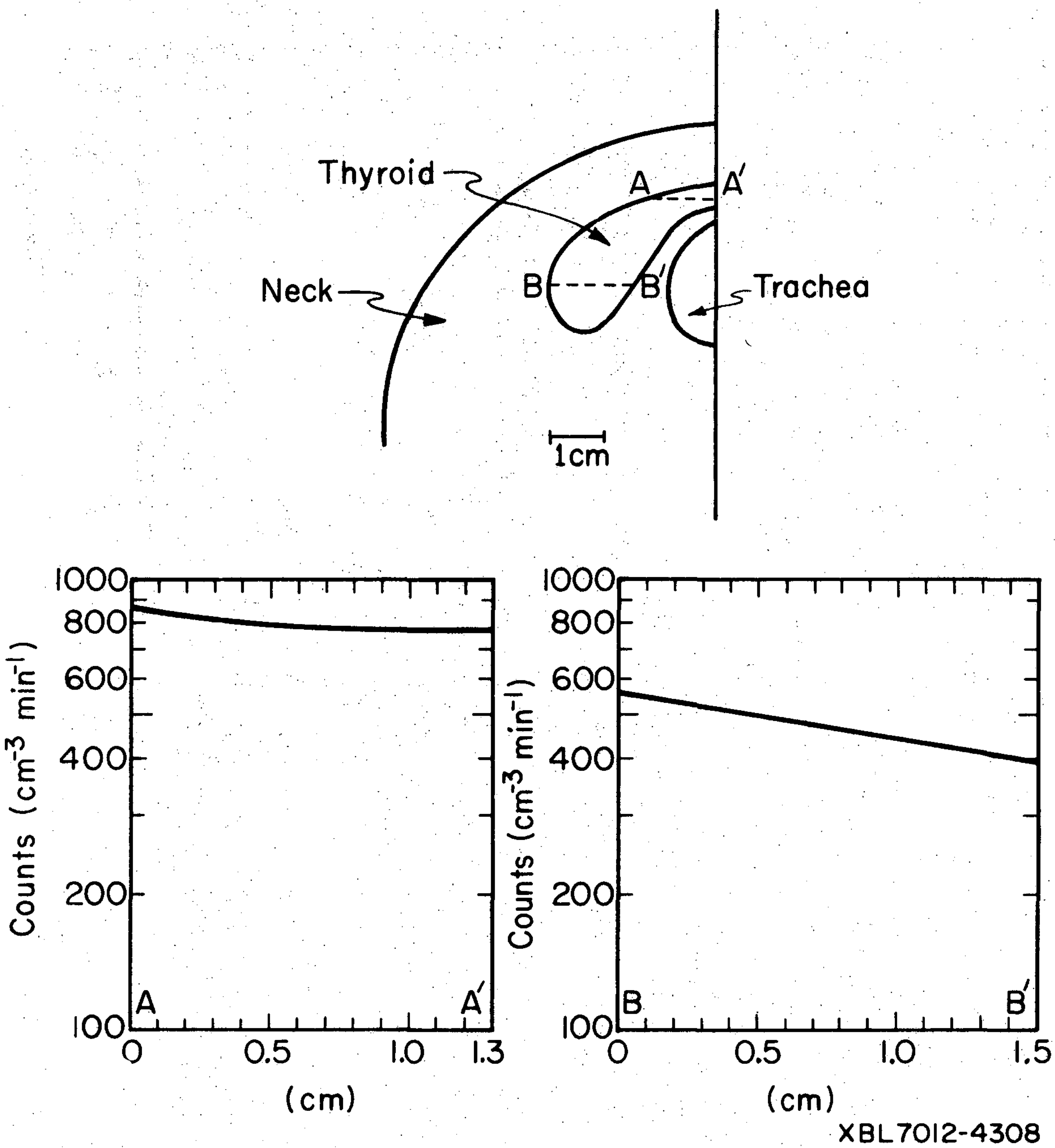

Fig. 3. Counting rate along two cuts, AA' and BB' of a thyroid with an iodine content of 5×10^{-4} g/cm^3, using two symmetrically located planar sources with an effective strength of 2.5 Ci of ^{241}Am each.

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