Small-surface Charge-coupled Device for Radiosotope Probing

Naprava male površine velikog naboja za otkrivanje radioizotopa

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Abstract

Objective: *Radionuclide imaging is used to determine the distribution of radioactively labelled radiopharmaceuticals following application to establish the anatomy affected by a variety of neoplastic, metabolic and inflammatory conditions. This is accomplished through recording radioactive emissions using a gamma camera of a SPECT system, neither of which provides high resolution. The purpose of this investigation was to determine whether a charge-coupled device designed for intraoral radiography could be modified to detect high energy emissions made by radiopharmaceutical agents.*

Methods: *A RadioVisioGraphy (RVG) 32000 (Trophy Radiologie, Vincennes, France) with an unsealed sensor was employed so that the scintillator could be varied. The system was further modified to be activated by a CCX timer (Trophy Radiologie, Vincennes, France) disassociated from an x-ray generator. Radionuclides tested included* ^{125}I, ^{133}Xe, ^{99m}Tc, ^{131}I *and* ^{60}Co. *Images were attempted of metallic test objects of known outline. Images were stored in a PC-compatible computer using the proprietary software provided by Trophy Radiologie for digital dental radiography.*

Results: *Discernible images were found with Tc-99m calibrated at 900-925 mCi. No deterioration of the sensor occured despite the high energy of the source, hence the tungsten glass fiberoptic prism of the RVG 32000 was effective in protecting the change-coupled device (CCD) from radiation damage.*

Conclusions: *While further studies are needed, this preliminary study shows that there is a potential for using small surface CCDs for the detection of radiopharmaceuticals and, hence, to better localize the distribution of deposition within small cavities such as the mouth.*

Key words: *charge-coupled device, nuclear medicine, radiopharmaceuticals*

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Introduction

Radionuclide imaging is one of the most important applications of radioactivity in medicine. Radionuclide imaging departments are found in most hospitals; hundreds or even thousands of nuclear medicine procedures are performed each month in large institutions. The purpose of radionuclide imaging is to determine the distribution of a radioactively labelled agent within the body following administration, usually intravenously. External radiation detectors, placed at locations outside the patient, are generally used to accomplish this task.

The first attempts at radionuclide imaging were made in the late 1940's. An array of radiation detectors was positioned at various measuring points around the head. Such devices were tedious to use and provided only very crude mappings of the distribution of the administrated radioisotope deposits in the head, providing such details as left versus right side asymmetries (1).

A significant advance occurred in the 1950's with Cassen's introduction of the rectilinear scanner (1). This instrument used a detector which scanned the area of interest mechanically in a rasterlike pattern. The resulting image was a pattern of dots imprinted mechanically on a sheet of paper. During the scanning motion of the detector dots were printed when gamma rays were detected. The principal disadvantage of the rectilinear scnner was its long imaging time, typically of many minutes, needed to sequentially scan the many individual points within the imaged region. The rectilinear scanner reached its zenith in sophistication around 1970 and was subsequently replaced by the gamma camera.

The first gamma camera capable of recording all points in the image at one time was described by Anger in 1953 (2). Unfortunately, the film component in this detection system was so inefficient that hour-long exposures and therapeutic levels of administered radioactivity were needed to obtain satisfactory images. In the late 1950's, Anger replaced the film/screen combination with a single, large-area, NaI(Tl) crystal and a photomultiplier tube assembly which greatly increased the detection efficiency of the gamma camera. Since that time, the Anger scintillation camera has been substantially refined and although many other ideas for gamma ray imaging instruments have come along since, none has matched the Anger camera in terms of image quality balance, detection efficiency and ease of use in a hospital environment. Thus, the Anger camera has become the standard nuclear imaging instrument for clinical applications and seems likely to remain so for the forseeable future. Problems existing with this system are that it is difficult to precisely locate the source of emitted gamma rays and that spatial resolution is comparatively low. Hence, it was decided to modify a digital intraoral x-ray detector in an attempt to better locate radioisotope deposition in small body cavities such as the mouth.

Radioisotope scanning has value in the early detection of a variety of lesions and differentiation of benign and malignant rumors (3). Radionuclide bone scanning using technetium-99m (^{99m}Tc-MDP) is widely accepted as a means of assessing tumor spread because osseous changes are detected in advance of a lesion being depicted by plain films. However, it must be remembered that abnormal bone uptake can occur in many disease processes including inflammation, neoplasia and infarction.

While the methods in higly sensitive, its specificity is low. For the maxillofacial region, radioisotope scanning has been used to locate the growth site in condylar hyperplasia (4), for the post-operative evaluation of bone grafts (5-9) and in periodontal disease progression monitoring (10). Bright et al. (5) found gamma scans provided sensitive and reliable information concerning the rate of distal ulnar bone grafts in dogs. Similar studies have been made for canine mandibular bone grafts (7-9). Radioisotope imaging has also been performed in a human following mandibular bone grafting (3).

Recently, there has been increasing interest in the use of radioisotopes for evaluation of the activity and distribution of intraoral conditions (11,12). Tsuchimochi et al. reported on local alveolar bone healing as monitored using ^{99m}Tc-MDP and imaging with a gold-collimated cadmium telluride probe (13). This was only able to detect lesions of 5 mm or greater in diameter (13). Other researchers have mentioned the possible utilization of bone scans in the assessment of periodontal disease activity, but stress the need for collaboration with a hospital nuclear medicine department (10,14).

The preferred emissions for this application are gamma rays in the energy range of approximately 80-500 keV or annihilation photons (511 keV).

Gamma rays of these energies are sufficiently penetrating to be detected when emitted from deep-lying tissues, but can still be shielded using reasonable thicknesses of lead. The gamma emissions for nuclear medicine imaging are high in energy when compared to diagnostic dental radiography using 70-90 kVp. Dental radiography involves use of a polychromatic beam of x-rays averaging 40 keV in energy.

The objective of the pilot study in this preliminary communication was to investigate the feasibility of modifying charge-coupled device (CCD) digital intraoral radiographic sensor for use as a high resolution gamma camera probe that could be inserted into small body cavities such as the mouth. The criteria for success were detection of high energy gamma rays without causing radiation damage to the sensor.

Material and Methods

The system selected for this study was the RadioVisioGraphy (RVG) 32000 (Trophy Radiologie, Vincennes, France) with a unsealed sensor to permit interchange of various scintillator materials.

The following radioisotopes were used in testing the sensor's capabilities as a gamma probe: ^{125}I(27.5 keV), ^{133}Xe (81KeV), ^{99m}Tc (140 keV), ^{131}I(364 keV) and ^{60}Co(1330 keV).

Results

Numerous attempts were made to image an aluminium step wedge at various source - to -sensor distances and with the various scintillation materials and radioisotopes; however, all attempts to differentiate the steps failed as aluminum did not attenuate the emitted high energy rays. With ^{99m}Tc-MDP an image was formed across the whole sensor face showing that gamma radiations of 140 keV were detectable when using gadolinium oxysulphide as the scintillator. Some reaction was also seen using calcium tungstate screen material and from positioning a large sodium iodide crystal over the fiberoptic tungsten glass prism protecting the CCD. No other radionuclides produced detectable alterations in the sensor.

To be certain that the source of change in the sensor was indeed the radionuclide gamma emissions, a brass household key placed over the sensor to attenuate the emitted beam in a recognisable pattern. The key physically taped to the detector probe and the evacuated glass multi-dose vial containing the radioactive isotope was placed in a position analagous to the source-to-sensor distance that would occur in a radiopharmaceutical scan on a patient. The study with all isotopes and scintillators was then repeated. The following radioisotopes were each tested. ^{125}I(27.5 keV), ^{133}Xe (81 keV), ^{131}I (364 keV), ^{60}Co (1330 keV) and ^{99m}Tc (140 keV). Again, all the radionuclides except ^{99m}Tc-MDP failed to produce detectable emissions using the modified RVG 32000 probe. The ^{99m}Tc-MDP exposures resulted in an image of the key that was readily seen (Figure 1 and 2). The ^{99m}Tc-MDP dose was calibrated at 900 mCi.

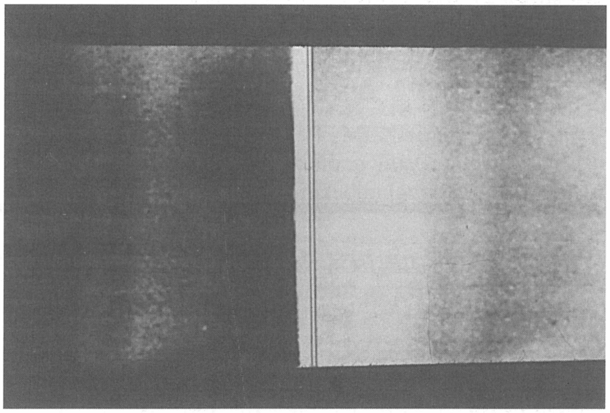

Figure 1. *Stem of a brass key demonstrated using the RVG 32000 with a ^{99m}Tc radiation source. Positive and negative images are displayed*

Slika 1. *Prikaz nazubljenog dijela mesingastog ključa s pomoću RVG 32000 s ^{99m}Tc izvorom zračenja. Prikazane su pozitivne i negativne snimke*

Discussion

With the lack of precision of typical nuclear medicine imaging and the relatively high costs of a conventional gamma camera, it is easy to see the potential cost-benefit advantage of a small area probe for use inside such small cavities as the mouth. Such a device could be primarily used as and adjunct to conventional gamma cameras for better localization of the radionuclide. The relatively high resolution of CCD devices currently used for intraoral ra-

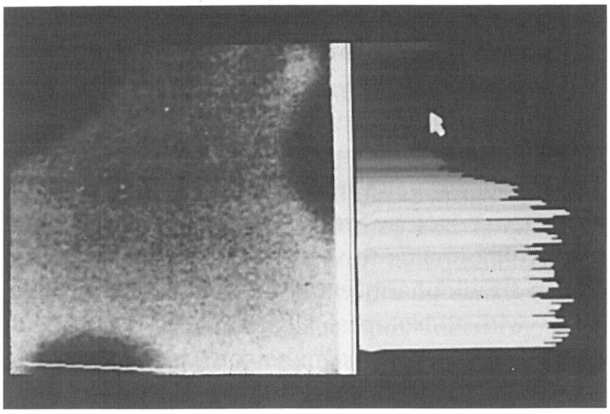

Figure 2. *Handle of a brass key using the RVG 32000 with a ^{99m}Tc radiation source. The gray levels are demonstrated as a histogram (arrow)*

Slika 2. *Prikaz drška mesingastog ključa s pomoću RVG 32000 s ^{99m}Tc izvorom zračenja. Sive razine su prikazane kao histogram (strelica)*

diography, combined with their relatively low cost makes their modificattion for this purpose a practical proposition. The fact that such probes can be site specific and used intraorally, extraorally, intravaginally and perhaps intra-aurally as well as intra-rectally adds to the potential. This study shows that the tungsten glass within the RVG 32000 was sufficient to completely protect the CCD from the untoward effects of radiation even when high energies were applied. More research is needed to select an efficient scintillator for use in the detection of such high energy emissions.

The RVG 32000 proved effective in the detection of radionuclides with only minor modification being needed despite the diagnostic range of x radiation being in the 40 keV range rather the 142 keV for ^{99m}Tc. Future modifications for use of a small surface CCD device in detection of radionuclides will undoubtedly involve better protection from scattered radiations, enhanced collimation and the determination of more appropriate scintillation materials for higher sensitivity and improved resolution.

NAPRAVA MALE POVRŠINE VELIKOG NABOJA ZA OTKRIVANJE RADIOIZOTOPA

Sažetak

Ciljevi: *Slikanje radionukleidima uporabljeno je da bi se odredila distribucija radioaktivno označenih radiofarmaceutskih preparata nakon njihove primjene, s namjerom da se utvrdi područje zahvaćeno tumorom, metaboličkim ili upalnim procesom. To je ostvareno tako da je bilježeno radioaktivno zračenje gama kamerom ili SPECT sustavom od kojih ni jedan ne osigurava visoku rezoluciju. Svrha ovog istraživanja bila je odrediti, da li naprava male površine velikog naboja za intraoralnu radiografiju može biti modificirana za otkrivanje zračenja jake snage stvorenog radiofarmaceutskim preparatima.*

Metode. *Radioviziograf (RVG) naprava tipa 32000 (Trophy Radiologie, Vincennes, Francuska) s nazaštićenim senzorom rabio se, da bi se omogućilo variranje scintilatora. Sustav se i dalje modificirao da se može aktivirati putem CCX timera (Trophy Radiologie, Vincennes, Francuska) koji nije povezan s generatorom x-zraka. Testirani su radionukleidi ^{125}I, ^{133}Xe, ^{99m}Tc, ^{131}I and ^{60}Co. Učinjene su probne slike metalnih probnih objakata poznatog obrisa. Slike su se pohranile u PC--kompatibilnom računalu koristeći program od Trophy Radiologie za digitalnu dentalnu radiografiju.*

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Rezultati: *Vidljive slike su nađene s ^{99m}Tc kalibriranim na 900-925 mCi. Nije došlo do smanjene kakvoće senzora bez obzira na visoku energiju izvora, dakle RVG 32000 tungsten staklena fiberoptička prizma bila je efikasna u šticenju naprave male površine velikog naboja od oštećenja zračenjem.*

Zaključci: *Iako je potrebno dalje istraživanje, ovo je preliminarno istraživanje pokazalo, da postoji mogućnost uporaba naprave male površine velikog naboja za otkrivanje radiofarmaceutika te zato do bolje lokalizacije i distribucije njihova odlaganja unutar malih šupljina poput usne šupljine.*

Ključne riječi: *naprava male površine velikog naboja, nuklearna medicina, radiofarmaceutici*

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