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Thyroid Scan with minimal dose of Technitium-99m: An effort to mitigate hazardous effects of ionizing radiation

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Abstract

To overcome the health hazards related to the over dosage of radiopharmaceuticals, a study was conducted on 120 patients of different genders and age groups (from 10 – 50 years), who visited Punjab Institute of Nuclear Medicine (PINUM) at Faisalabad in Pakistan for thyroid scan. Patients were treated with different doses of Technitium-99m ranging from 1 to 5 mCi. Infinia Hawkeye-4 SPECT/CT was used to investigate Technitium-99m uptake measurements by thyroid. The results revealed that instead of presently used Technitium-99m dose of 3-10 mCi to get a thyroid scan in 1–4 min, the same scan can be acquired with a dose of 2-3 mCi in 4-8 min. The study helped to perform thyroid scan with a reduced dose of lowest activity to save patients, attendants and general public from hazardous effects of over dose of radioactive materials.

Keywords: Thyroid scan; Minimal dose; Technitium-99m; Infinia Hawkeye-4 SPECT/CT.

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1. Introduction

Advancement in radiologic procedures to diagnose human diseases have had a significant impact on medical practice over the past few decades [1-3]. At present about 2.3 million diagnostic radiation workers are engaged in using ionizing radiation for different nuclear imaging procedures in more than 10,000 hospitals worldwide [1-6]. These ionizing radiations also have environmental and hazardous effects, which include genetic mutations, hematopoietic system dysfunction, oxidative stress and immune dysfunction [7-11]. During radiotherapy, ionizing radiation generates free radicals in living tissues which can damage cell membranes, macromolecules including DNA and enzymes [12-14]. Physicians usually miscalculate the amount of radiation doses and their allied hazardous effects, such as cancer, the probability of which increases with dose [15-23]. Although, medical imaging procedures are carried out in the dose range of 5–15 mSv, yet there is epidemiologic proof of cancer risk associated with a dose of > 10 mSv which is further increased when a person undergoes numerous procedures [24-26]. Studies by Eisenberg et al. (2011) in the United States, involving one million adults (age 18 – 65 years), revealed increased cancer risk attributed to multiple procedures with cumulative dose > 50 mSv [24-29]. Although, only a few of the cancers diagnosed have been linked with direct exposure to radiation during medical imaging, however, a 2.5% risk of cancer occurrence for each 1000 mSv dose amongst persons aged 40 to 60 years has been reported. Adding up of one new cancer in every two thousand patients receiving a 20 mSv dose has been attributed to radiation exposure for the duration of medical procedures which sounds the alarm of latent risk to radiation workers and inhabitants [30-34]. Besides, in oxford survey of childhood cancers (oscc), pediatric cancer mortality in off-springs was associated with diagnostic procedures involving exposure to radiations [35-43]. Due to adverse socioeconomic conditions in developing countries, majority of the people live in small houses in a joint family system and the persons undergoing radiological treatment may not find isolation and there is a risk of exposure to other family members also, especially children. Besides, increasing cost and difficulties in purchase and transport of radio-isotopes from international market, it is has become need of the day to save the activity also. Therefore, an effort was made to perform thyroid scan with a reduced dose of lowest activity to save patients, attendants and general public from hazardous effects of over dose of radioactive materials.

The most frequently used radioisotope in diagnosis is technetium-99m, with which some 30 million nuclear medicine procedures are carried out worldwide per year. Technitium-99m is considered most suitable for thyroid scan due to near physiological analogue of iodine and has a short half-life of only 6.02 hr and low energy gamma emission (140 keV) that can be efficiently collimated to study various aspects of thyroid [44]. Moreover, studies can be performed rapidly and accurately by administering milli curie quantities of activity without delivering a high radiation dose to the patient. Especially, thyroid uptake and scintigraphy with ^{99m}Tc-pertechnetate is more useful than with ^{131}I-iodide, for better image quality. The recent insight to mitigate hazard to patients is by taking up 'as low as reasonably achievable (ALARA) approach', realization of which is possible through technological innovations, by developing proper images with minimum radiation contact [34].

Here we report a study conducted on 120 patients of different age groups to achieve the thyroid scan with minimal dose of tecnitium-99m ranging from 1 to 5 mCi for different duration of exposure to radiation.

2. Materials and Methods

A sterile solution of Tc-99m as sodium pertechnetate produced with technetium generator was eluted using a 0.9% sterile and end toxin free solution of sodium chloride from an alumina (Al_2O_3) chromatography column ready for the combination with an agent to form the radiopharmaceutical [45]. 'Hot Lab' was used to prepare radiopharmaceuticals for administration to the patients. Lead shield was used to reduce the radiation exposure. Radioactivity in vials and syringes was measured in dose calibrator (CRC-15) before administration to the patient [46,47]. One hundred and twenty (120) patients of different age groups (from 10 – 50 years) were administered different doses of Technitium-99m ranging from 1 to 5 mCi for different duration of exposure to radiation (Table 1). Gamma camera Infinia Hawkeye-4 SPECT/CT was used for thyroid scanning. Standard pinhole collimator was used for high resolution thyroid imaging [48].

3. Results and Discussion

To support health care providers, in September 2006, society of nuclear medicine (SNM) agreed on the guiding principle for the cost-effective use and excellence in nuclear medicine procedures [50-51]. By comparing different radiopharmaceuticals for thyroid scintigraphy, Tc-99m pertechnitate was given preference due to less expensive, more readily available and ease of rapid examination by administering milli Currie quantities of activity. Besides, technitium-99m isotope exhibits a very low energy level (~140 keV) for gamma emission, making it safer for use due to substantially-reduced ionization compared with other gamma emitters such as I-123 (159 keV), I-124 (511/602 KeV) and I-131 (364/606KeV) [50-53]. The range for administering the Tc-99m activity was suggested to be from 2 – 10 mCi. However, in the present study, thyroid scan was acquired with a reduced Tc-99m dose of 2 - 3 mCi in an acquisition time of 4 to 8 min.

3.1. Relationship between injected activity of Tc-99m and acquisition count rate

Figure-1 clearly illustrate that by increasing the activity dose from 1 to 5 mCi, average count rate (cts/s) increases gradually from 530 to 990 cts/s which may affect the technicians, general public and family members of patient mainly children. Previously the hazardous effects of exposure to ionizing radiation have been mentioned by Boice et al., [38], Eisenberg et al., [28], Fazel et al., [29], and also reported in Ann ICRP 2007 and UNSCEAR 2000. Einstein et al., [7,25,26,31], Kim et al., [32] and Brenner et al., [33] also appraised the hazardous effects of ionizing radiation and cancer risk attributed to excessive radiation exposure.

3.2. Relationship between Technitium-99m activity and acquisition time

The graph between doses of Technetium-99m versus acquisition time clearly shows that time of acquisition varied with respect to injected doses of Technitium-99m (Figure 2). By decreasing the dose from 5 to 1 mCi, the time of acquisition increased from 3 to 8 min approximately. The best dose for the patients of 10-15 year age group was found to be 1.89 mCi for the age group 15-20 years it was 2.52 mCi and for 20-25 years patients, suitable dose was found to be 3.07 mCi. For age group 25-30 years, thyroid scan was acquired with minimum injected activity of 3.07 mCi in maximum 4 min whereas for 30 - 50 years patients the minimal dose of injected activity was found to be 4.2 mCi. The results revealed that instead of presently used Tc-99m dose of 3 -10 mCi to get a thyroid scan in 1 to 4 min, the same scan can be acquired with a dose of 2 - 3 mCi in an acquisition time of 4 to 8 min [42]. The present study, suggests that by increasing time of acquisition for thyroid scan, saving of 50 to 60% activity dose is possible for scanning of more patients along with alleviation of the hazardous effects attributed to high dose exposure.

4. Conclusions

Medical imaging procedures are an imperative source of exposure to ionizing radiations. By using ongoing technological advances to lower the doses required to achieve the same effect, 120 patients of different age groups (from 10 – 50 years) were scanned with different doses of Technitium-99m ranging from 1 to 5 mCi for different duration of exposure to radiation. Gamma camera Infinia Hawkeye-4 SPECT/CT was used to investigate Technitium-99m uptake measurements by thyroid. The results revealed that instead of presently used Technitium-99m dose of 3 - 10 mCi to get a thyroid scan in 1–4 min, the same scan can be acquired with a dose of 2 - 3 mCi in an acquisition time of 4 - 8 min. thereby saving approximately 55% activity. In the growing use of medical procedures these findings have important implications in performing thyroid scan with a reduced dose of lowest activity to save patients, attendants and general public from hazardous effects of over dose of radioactive materials.

Table 1: Number of Patients treated Technitium-99m for thyroid scan

	Technitium-99m Dose			
Age Group (years)	1-2 (mCi)	2-3 (mCi)	3-4 (mCi)	4-5 (mCi)
10-15	2	2	1	1
15-20	2	1	1	1
20-25	5	4	6	3
25-30	6	8	6	5
30-35	7	7	5	6
35-40	6	4	5	5
40-45	1	2	5	5
45-50	1	2	1	4

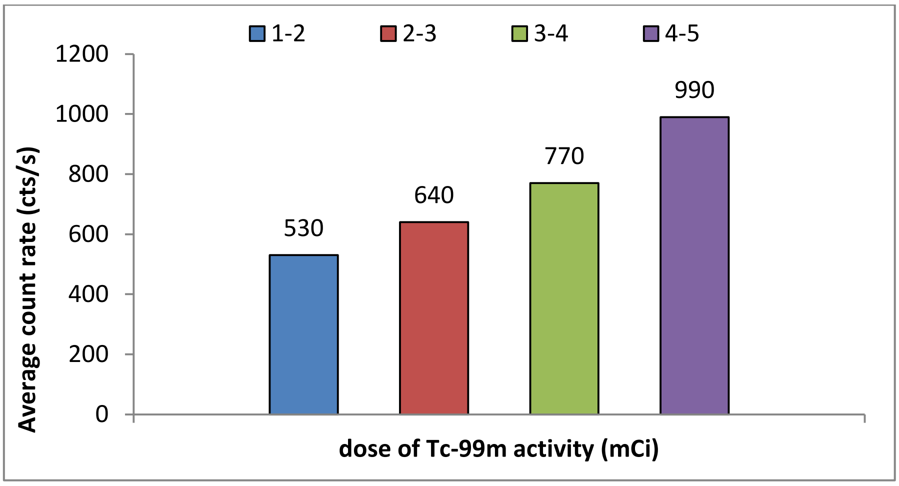

Fig. 1. Dose of Technetium-99m versus acquisition count rate

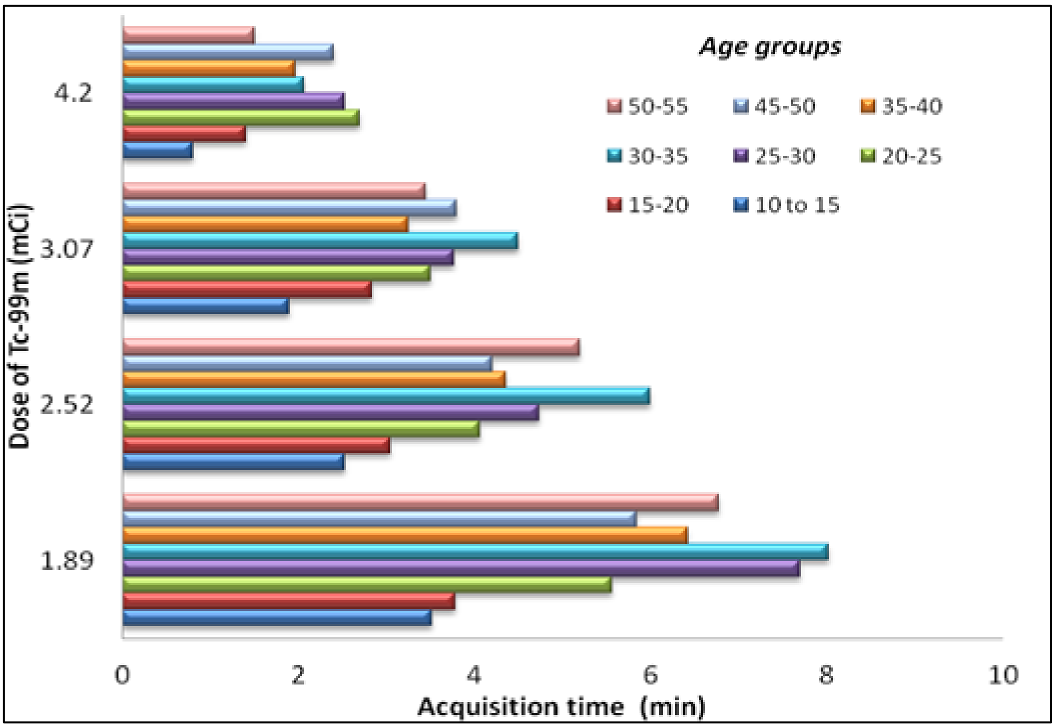

Fig. 2. Dose of Technetium-99m versus Acquisition time

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Conflict of Interest "The authors declare no conflict of interest".

References

[1] A. J. Einstein. Effects of Radiation Exposure From Cardiac Imaging: How Good Are the Data? (2012). Journal of American College of Cardiology. 59: 553–565.

[2] A. J. Einstein, K. W. Moser, R. C. Thompson, M. D. Cerqueira, M. J. Henzlova. (2007). Radiation dose to patients from cardiac diagnostic imaging. Circulation. 116: 1290–1305.

[3] S. Yoshinaga, K. Mabuchi, A.J. Sigurdson, M. M. Doody, E. Ron. (2004). Cancer risks among radiologists and radiologic technologists: Review of epidemiologic studies. Radiology. 233: 313-321.

[4] M. S. Linet, D. M. Freedman, A. K. Mohan, M.M. Doody, E. Ron, K. Mabuchi, B. H. Alexander, A. Sigurdson, M. Hauptmann. (2005). Incidence of hematopoietic malignancies in US radiologic technologists. Occupational and Environmental Medicine. 62: 861–867.

[5] W. J. Lee, E. S. Cha, M. Ha, Y. M. Jin, S. S. Hwang, K. A. Kong, S.W. Lee, H. K. Lee, K. Y. Lee, H.J. Kim. (2009). Occupational radiation doses among diagnostic radiation workers in South Korea, 1996–2006. Radiation Protection Dosimetry. 136: 50–55.

[6] UNSCEAR. (2008). Report Vol. 1. Sources and effects of ionizing radiation. Available online: www.unscear.org/unscear/en/publications/2008_1.html (accessed on 30 Jan 2013).

[7] A. J. Einstein. (2008). Radiation risk from coronary artery disease imaging: how do different diagnostic tests compare? Heart. 94: 1519–21.

[8] A. R. Verma, M. Vijayakumar, C. V. Rao, C. S. Mathela. (2010). In vitro and in vivo antioxidant properties and DNA damage protective activity of green fruit of Ficusglomerata. Food and Chemical Toxicology. 48: 704–709.

[9] Y. R. Li, W. Cao, J. Guo, S. Miao, G. R. Ding, K. C. Li, J. Wang, G. Z. Guo. (2011). Comparative investigations on the protective effects of rhodioside, ciwujianos ide-B and astragaloside IV on radiation injuries of the hematopoietic system in mice. Phytotherapy Research. 25:644–653.

[10] T.Sangsliwan T, Haghdoost S. (2008). The nucleotide pool, a target for low-dose gamma-ray-induced oxidative stress. Radiation Research. 170: 776–783.

[11] R. Y. Yang, X. R. Pei, J. B.Wang, Z. F. Zhang, H. F. Zhao, Q. Li. (2010). Zhao M, Li Y. Protective effect of a marine oligopeptide preparation from Chum Salmon (Oncorhynchus keta) on radiation-induced immune suppression in mice. Journal of the Science of Food and Agriculture. 90: 2241–2248.

[12] S. P. Hussain, I. J. Hofseth, C. C. Harris. 2003. Radical Causes of Cancer. Nature Reviews. 3: 276-285.

[13] R. D. Bont, N. V. Larebeke. (2004). Endogenous DNA damage in humans: a review of quantitative data. Mutagenesis. 19: 169-185. Downloaded from http://mutage.oxfordjournals.org/ on January 30, 2013.

[14] J. H. Seyed. (2010). Flavonoids and genomic instability induced by ionizing radiation. Drug Discovery Today. 15: 907–918.

[15] S. Shiralkar, A. Rennie, M. Snow, et al. (2003). Doctors' knowledge of radiation exposure: questionnaire study. British Medical Journal. 327: 371-2.

[16] L. Krille, G. P. Hammer, H. Merzenich, et al. (2010). Systematic review on physician's knowledge about radiation doses and radiation risks of computed tomography. European Journal of Radiology. 76:36-41.

[17] M. J. Correia, A. Hellies, M. G. Andreassi. (2005). Lack of radiological awareness among physicians working in a tertiary-care cardio-logical centre. International Journal of Cardiology. 103:307-11.

[18] M. M. Rehani. (2007). Training of interventional cardiologists in radiation protection — the IAEA's initiatives. International Journal of Cardiology. 114: 256- 60.

[19] M. J. Eisenberg, J. Afilalo, P. R. Lawler, et al. (2011). Cancer risk related to low-dose ionizing radiation from cardiac imaging in patients following acute myocardial infarction. *Canadian Medical Association Journal.* 183: 430-6.

[20] E. C. Lin. (2010). Radiation risk from medical imaging. Mayo Clinic Proceedings. 85: 1142-6.

[21] D. J. Brenner, R. Doll, and D. T. Goodhead, et al. (2003). Cancer risks attributable to low doses of ionizing radiation: assessing what we really know. Proceedings of the National Academy of Science USA. 100: 13761-6.

[22] V. Beri. (1990). Committee on Biological Effects of ionizing radiation. The effects on population of exposure to low levels of ionizing radiation. National Academy of Sciences, Washington (DC).

[23] ICRP. (2003). Publication 90, Biological effects after prenatal irradiation (embryo and fetus). Pp.167– 170.

[24] D. J. Brenner, R. Doll, D. T. Goodhead, et al. (2003). Cancer risks attributable to low doses of ionizing radiation: assessing what we really know. Proceedings of the National Academy of Sciences USA. 100: 13761-66.

[25] A. J. Einstein, S. Balter. (2011). Cancer risk from multiple imaging tests-reply. JAMA. 305:887–8.

[26] A. J. Einstein, S. D. Weiner, A. Bernheim, et al. (2010). Multiple testing, cumulative radiation dose, and clinical indications in patients undergoing myocardial perfusion imaging. Journal of the American Medical Association. 304: 2137–44.

[27] M. Mercuri, T. Sheth, M. K. Natarajan. (2011). Radiation exposure from medical imaging: A silent harm? *Canadian Medical Association Journal. 183:413-414.* doi: 10.1503/cmaj.101885

[28] M. J. Eisenberg, J. Afilalo, P. R. Lawler, et al. (2011). Cancer risk related to low-dose ionizing radiation from cardiac imaging in patients following acute myocardial infarction. *Canadian Medical Association Journal.* 183:430-6.

[29] R. Fazel, H. M. Krumholz, Y. Wang. et al. (2009). Exposure to low-dose ionizing radiation from medical imaging procedures. New England Journal of Medicine. 361:849-57.

[30] K. Vijayalakshmi, D. Kelly, C. L. Chapple, et al. (2007). Cardiac catheterization: radiation doses and life time risk of malignancy. Heart.93: 370-371.

[31] A. J. Einstein, M. J. Henzlova, S. Rajagopalan. (2007). Estimating risk of cancer associated with radiation exposure from 64-slice computed tomography coronary angiography. Journal of the American Medical Association. 298:317–23.

[32] K. P. Kim, A.J. Einstein, A. Berrington de Gonzalez. (2009). Coronary artery calcification screening: estimated radiation dose and cancer risk. Archives of Internal Medicine. 169:1188–94.

[33] D.J. Brenner, I. Shuryak, A. J. Einstein. (2011). Impact of reduced patient life expectancy on potential cancer risks from radiologic imaging. Radiology. 261: 193– 8.

[34] Recommendations of the International Commission on Radiological Protection. Ann ICRP, 1991; 21: 1-201.

[35] A. M. Stewart, J. Webb, D. Giles. (1956). Malignant diseases in childhood irradiation in utero. Lancet. 271(6940): 447.

[36] I. R. Dol, R. Wakeford. (1997). Risk of childhood cancer from fetal irradiation. British Journal of Radiology. 70:130–139.

[37] V. F. Stepanenko, P. G. Voilleque, Y. I. Gavrilin, V. T. Khrouc, S. M. Shinkarev, M. Y. Orlov. (2004). Estimating individual thyroid doses for a case control study of childhood thyroid cancer in Bryansk Oblast. Russian Radiation Protection Dosimetry. 108: 143-60.

[38] J. D. Boice, R. W. Miller. (1999). Childhood and adult cancer after intrauterine exposure to ionizing radiation. Teratology. 59:227–233.

[39] N-Radiation protection in medicine: ICRP publication 105. Ann ICRP 2007; 37:1-63.

[40] R. E. Shore. (1992). Issues and epidemiological evidence regarding radiation induced thyroid cancer. Radiation Research. 131: 98-111.

[41] E. Ron. (2003). Cancer risk from medical radiation. Health Physics. 85: 47-59.

[42] United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). Sources and effects of ionizing radiation. Vol 2. Effects. New York (NY): United Nation, 2000.

[43] E. Cardis, A. Kesminiene, V. Ivanov. (2005). Risk of thyroid cancer after exposure to ^{131}I in childhood. Journal of the National Cancer Institute. 97: 724–732.

[44] C. D. Ramos, W. D. E. Zantut, E. C. Etchebehere, M. A. Tambascia, C. A. Silva, E. E. Camargo. (2002). Thyroid uptake and scintigraphy using 99mTc pertechnetate: standardization in normal individual. Sao Paulo Medical. Journal. 120: 45-48.

[45] P. W. Moore. (1984). Technitium-99m in generator systems. Journal of Nuclear Medicine. 25: 499-502.

[46] Ch. McCollough. (2008). CT dose: how to measure, how to reduce. Health Physics. 95: 508-17.

[47] M. M. Ahasan. (2004). Assessment of radiation dose in nuclear medicine hot lab. Iranian Journal Radiation Research. 2: 75-78.

[48] F. A. Mettler, W. Huda, T. T. Yoshizumi, M. Mahesh. (2008). Effective doses in radiology and diagnostic nuclear medicine: a catalog. Radiology. 248: 254-63.

[49] P. C. Shrimpton, M. C. Hillier. (2005). Doses from computed tomography (CT) examinations in the UK – 2003. Review. National Radiological Protection Board; Chilton, UK.

[50] K. A. Lathrop, H. L. Atkins, M. Berman, et al. (1976). MIRD dose estimate report number 8. Summary estimate to normal humans from Tc-99m. Journal of Nuclear Medicine. 17:74-77.

[51] H. R. Balon, E. B. Silberstein, D. A. Meier, et al. (2006). Society of nuclear medicine (SNM) guidelinesV.3. *interactive.**snm**.org/docs/Thyroid_Scintigraphy_V3.pdf*

[52] M. Berman, L. E. Braverman, J. Burke, et al. 1975. MIRD dose estimate report number 5. Radiation absorbed does from I-123, I-124, I-125, I-126, I-130, I-131, and I-132 as sodium iodide. Journal of Nuclear Medicine. 16: 857- 860.

[53] Z. Kusic, D. V. Becker, E. L. Sanger, et al. (1990). Comparison of technetium-99m and iodine-123 imaging of thyroid nodules: correlation with pathologic findings. Journal of Nuclear Medicine. 31: 393-399.