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RESEARCH ARTICLE

Comparison of 99mTc Injected Activity with Prescribed Activity in Four Types of Nuclear Medicine Exams

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Abstract: ***Background:*** 99mTc is a radioactive isotope that is obtained by eluting a 99Mo/99mTc generator. (PINSTECH, Islamabad) and used for radionuclide scanning.

Objectives: The objective of this work is to study the uncertainties in 99mTc activity that exist due to time delay between injection preparation and administration to patients, during the process of gamma camera scanning.

Methods: Lead canisters were used for storing elution vials and dose calibrator for measuring 99mTc activity in mCi. The activity of preparing 99mTc injection and its administration to patients were compared with the prescribed values of activity recommended in the Society of Nuclear Medicine procedure guidelines.

Results: This study showed that uncertainty in the activity existed in one thyroid patient, 38 bone patients, 5 renal patients and 45 cardiac patients.

Conclusion: This uncertainty in activity exists due to time delay between injection preparation and administration to patients, as well as due to residual radionuclide that is not injected into patients and remains in the syringe.

Keywords: 99Mo/99mTcgenerator, radiopharmaceutical, 99mTc, dose calibrator, lead canisters, thyroid patient, cardiac patients, bone scintigraphy, MDP.

1. INTRODUCTION

In nuclear medicine, radioactive isotopes are useful for providing functional information related to specific tissues, and for treating diseases [1, 2]. Two components are used for preparing radiopharmaceuticals; one of them is a radionuclide for radioactivity and second is a chemical compound for tracing the pathology [3]. An isotope that is used in the field of medicine is 99mTc, which is used for numerous specialized medical studies due to its emitting rays energy of about 140 keV, its convenience for detection and its suitable half-life (6h) that leads to very fast clearing from the body after scanning [4]. For the purposes of anatomical specificity, image formation of the radioisotope is combined with a biologically active chemical agent [5] such as 99mTc and sodium pertechnetate used for thyroid scanning, 99mTc sestamibi (MIBI) is used for cardiac imaging, 99mTc diethylene triamine penta acetic acid (DTPA) for renal scanning and 99mTc Methylene diphosphonate (MDP) for bone scanning. Emitted gamma radiation from the decay of the radioisotope, is detected outside the body by a gamma camera [6, 7]. 99mTc plays an important role in nuclear medicine field due to emanation of gamma rays of 140 keV energy. For medical imaging, short lived radioactive daughter nuclei with good characteristics are separated chemically from the long lived parent nuclei by using radionuclide generators [8]. This method is mostly applied for the separation of 99mTc, with a half-life of six hours from the long lived 99Mo, with a half-life of 2.7 days. In 1937 Emilio Segre discovered technetium, in Italy. In 1940, it was identified as a decay product of 99Mo [9, 10].

Due to the extensive use of radioactive elements and possible threats of these elements, measurement of radioactivity of the administered dose is necessary for assessing thebenefits and risks of any nuclear medicine technique [11]. Several problems are created due to improper storage of radioactive materials like contamination of the environment and dose to workers/patients [12]. In 1996, first radiopharmaceutical kidney scan was performed [13]. In 1990, almost 3 million cardiology scans were performed in the United States. With the passage of time the number of these scans tripled to almost 9.9 million since 2002 [14]. From 2002 to 2003, Cardiac Computed Tomographic (CT) volume doubled to

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485,000 cases and continued to grow afterward [15]. 99mTc methylene diphosphonate MDP was introduced by Subramanian *et al*, in 1973 and 99mTc hydroxymethyline diphosphonate HMDP was introduced by Bevan *et al* in 1980 [16, 17]. These two radiopharmaceuticals are widely used for bone scanning. In this paper, we investigate four radiopharmaceuticals tailored for different organs, which play an important role in the diagnosis of disease.

2. METHODS AND MATERIALS

A 99Mo/99mTc generator was used for obtaining radioactive 99mTc after elution as shown in Fig. (**1**). The eluted 99mTc was used for kit preparation combined with a suitable pharmaceutical. Radiopharmaceutical kits were prepared according to the physician's instructions. The radiopharmaceutical kit was brought to room temperature and then opened. The required activity of 99mTc was inserted into a pharmaceutical vial [18]. The kit was shaken for a few seconds. Kit quality control was performed using the thin layer chromatography [19]. As the radioactive material decays with the passage of time uncertainity in 99mTc activity was observed due to time delay. For this purpose, we recorded the injection preparation time, $t_{o,}$ 99mTc activity for injection A_o and the administration time to patients t_1 . After injecting the patients, we measured the remaining activity for injection A_2, and then we calculated the difference between the injection preparation time and administration time as $t = t_1 - t_o$. By using the decay constant L per second of 99mTc 0.001925 s^{-1} the formula of time delay activity was determined:

A_1=Ao exp(-Lt)

By subtracting the remaining activity from time delay activity **A=A1-A2,** we calculated the uncertainty and the final value "A" that was injected to the patient. To findout that how much uncertainty exists in the activity decay, we comparedthe activity that is injected to the patient with the standard value of dose recommended by nuclear medicine centers [20].

3. RESULTS AND DISCUSSION

3.1. Comparison of Injection Prepared Activity, and Administration Activity with the Standard Value Limit

In (Figs. **2**-**5**), the blue line shows the maximum standard value of the activity of 99mTc and the Dark cyan line shows the minimum standard value of the activity that is acceptable for scanning. The black line represents the activity at the time of injection preparation and the red line shows the activity that is finally injected into the patient after some time delay and after subtracting the remaining activity, which is within the syringe.

3.2. Bone Scintigraphy

The study was performed on 50 patients with bone diseases including 31 females and 19 males ranging from 28 to 90 years. Uncertainty in the activity was calculated in all patients but only 24% of patients fell within the range of the standard value while 76% did not as shown in Fig. (**2**). The standard value range is 20-30 mCi of 99mTc with Methylene diphosphonate MDP [21].

3.3. Renal Scintigraphy

For Renal Scintigraphy, 50 renal patients including 23 females and 27 males with age ranging from 17 to 67 years, were scanned. Only 10% patients showed99mTc activity outside the standard limit whereas 90% of patient's activity was within the range of standard value as shown in Fig. (**3**).

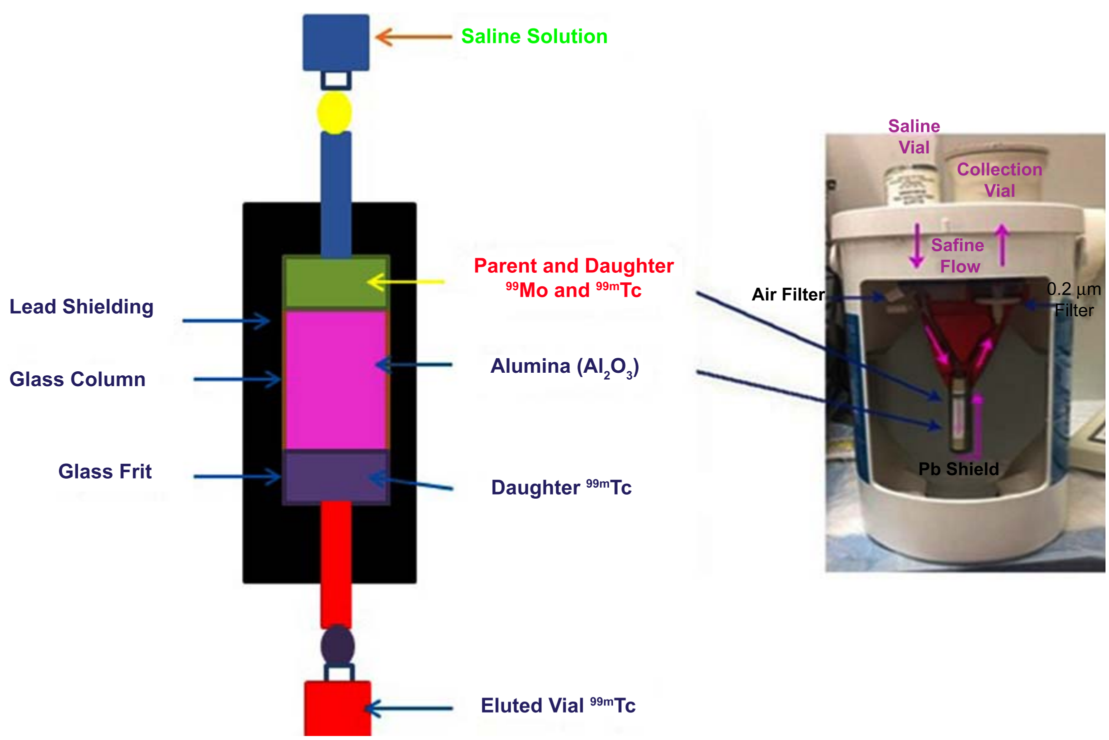

Fig. (1). 99Mo/99mTc generator.

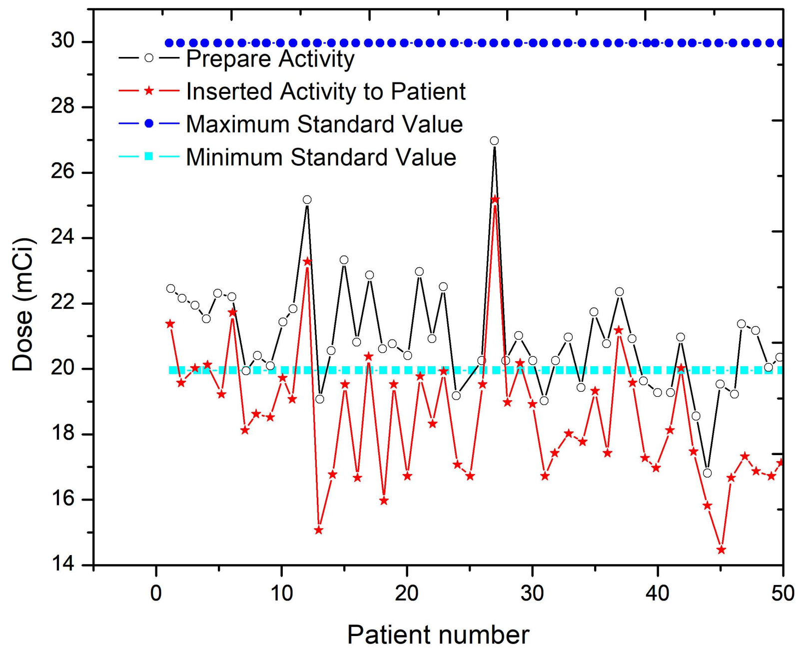

Fig. (2). Bone Scintigraphy: showing uncertainty in 99mTc activity of 50 patients with bone diseases.

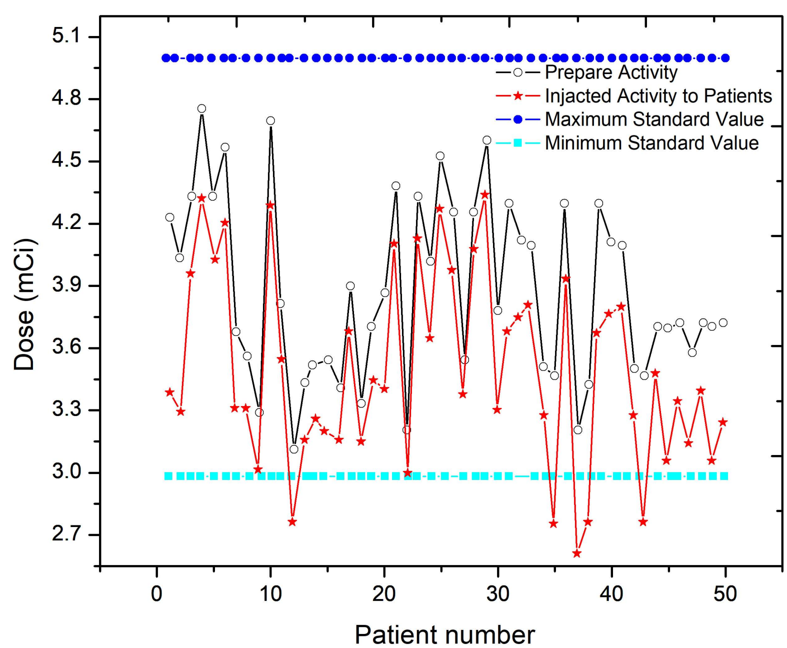

Fig. (3). Renal Scintigraphy: showing uncertainty in 99mTc activity of 50 renal patients.

The standard value range is 3-5 mCi of 99mTc with DTPA in normal weight (70 kg) patients.

3.4. Thyroid Scintigraphy

In case of 50 thyroid patients including 45 females and 5 males with age ranging from 15 to 72 years, it was observed that the activity uncertainty fell outside the tolerance values in only 2% patients, whereasin 98% patients, the activity fell within the range as shown in Fig. (**4**). The range of acceptable values is 2-10mCi of 99mTc with sodium pertechnetate [22].

3.5. Cardiac Scintigraphy

We observed 50 cardiac patients including 30 females and 20 males with age ranging from 24 to 68 years, and only 10% patients were injected with the activity within the standard value limits whereas in 90% patients, uncertainty was found. (Fig. **5**) shows standard value limit in the range of 20-30 mCi of 99mTc with MIBI [23].

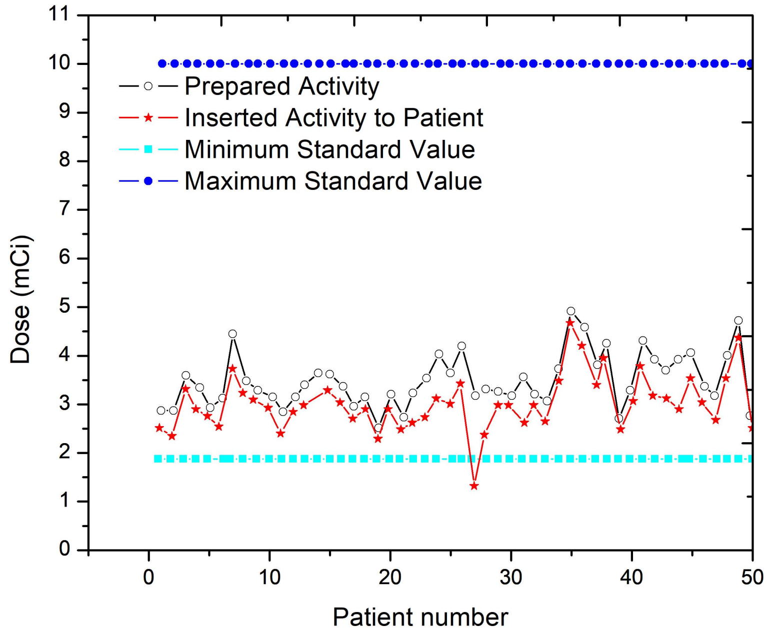

Fig. (4). Thyroid Scintigraphy: showing uncertainty in 99mTc activity of 50 thyroid patients.

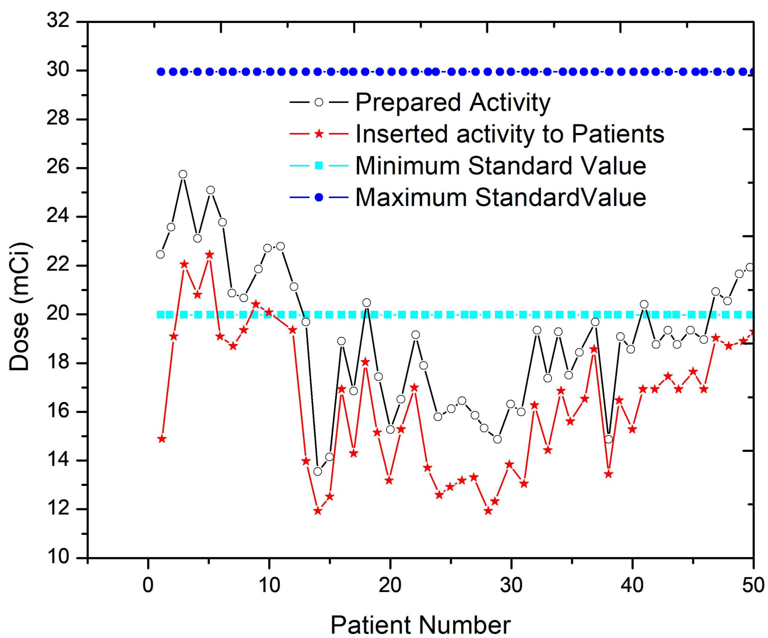

Fig. (5). Cardiac Scintigraphy: showing uncertainty in 99mTc activity of 50 cardiac patients.

Uncertainty exists in the injected dose due to different reasons, such as time delay between injection preparation and administration, absorption and retention of activity within the syringe and vials. Adsorption of 99mTc activity within the injection vials increases with the increasing storage timeThe increase in storage time also causes uncertainty, due to the time delay in 99mTc decay. Terumo syringes were used during all data collection, which help in absorbing very minute amounts of 99mTc [24].

The average of the residual activity for 50 injection syringes was 1.045 mCi, 0.31 mCi, 0.282 mCi and 1.686 mCi in the case of bone Scintigraphy, renal Scintigraphy, thyroid Scintigraphy and cardiac Scintigraphy, respectively. In the case of bone Scintigraphy maximum uncertainty occurred due to the time delay *t* and in the case of cardiac Scintigraphy, uncertainty in dose activity was observed due to lack of prepared activity for the administration as compared to the standard value limit range. In the other two cases including thyroid and renal scintigraphy, uncertainty is minimum as per the recommendations shown in graphs.

Uncertainty leading to poor quality image affects usering diagnostic ability may also affect the treatment. Similarly, for high image quality, this uncertainty in dose may require more time for scanning with gamma camera, which is a waste of time and an inappropriate use of the gamma camera. This effect can have more benefits, such as collateral dose calculation or more accurate quantification of the nuclear medicine scan for appropriate thresholding when making a decision or contouring.

CONCLUSION

Uncertainty beyond the tolerance levels was found in 2% of thyroid patients, 10% of renal patients and in case of bone and cardiac Scintigraphy, 76% and 90% of patients were found, respectively. It was concluded that uncertainty exists due to time delay between injection preparation and administration time. This uncertainty can be minimized by preparing the injection as soon as the patient enters the injection room (minimize the time between drawing up activity and injecting the patient) and by using syringe that does not absorb radioactive dose or adding a little more activity (at the upper end of the allowed range) to make sure that enough activity is present when it comes to injecting the patient.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The experimental protocol was approved by the Medical Society of University of Gujrat, (07.08.2019/Isa/Physics/UOG/012) Gujrat, Pakistan.

HUMAN AND ANIMAL RIGHTS

No animals were used in this research. All human procedures were followed in accordance with the ethical standards of the committee responsible for human experimentation (institutional and national), and with the Helsinki Declaration of 1975, as revised in 2013 (http://ethics.iit.edu/ecodes/node/3931).

CONSENT FOR PUBLICATION

It is declared that written consent was obtained from the patient prior to the study.

AVAILABILITY OF DATA AND MATERIALS

The data supporting the findings of the article are available in the Influenza Research Database at “https://www.fludb.org/brc/uploadedFileDetail.spg?method=SharedFileDetail&uploadedFileId=23300&decorator=influenza”.

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CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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