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# Development of an artificial intelligence-based dynamic release system for iodine (I-131) treated patients and close contact criteria

Uzma Ilyas<sup>1\*</sup>, Ghufraan Ahmed<sup>2</sup>, Hina Hashmi<sup>1</sup>, Mohsin Raza<sup>3</sup>, Mohsin Raza<sup>4</sup>

## ABSTRACT

**Background:** In Nuclear Medicine, managing radioiodine (I-131) treated thyroid cancer patients remains challenging due to variations in global practices, regulatory criteria, and the need for individualized care. The lack of harmonization in patient release protocols has prompted the development of innovative, adaptive approaches.

**Methods:** This research introduces a novel artificial intelligence (AI)-based “Dynamic Patient Release Management System” designed to predict patient discharge timing using machine learning models. The system integrates patient-specific parameters (e.g., administered dose, biokinetics, contact scenarios, and socio-economic factors) while adhering to international safety standards. Approximately 350 patients treated with 50, 100, 150, and 200 mCi of I-131 were retrospectively analyzed to train and validate the model.

**Result:** The system reliably predicted safe discharge timelines: 1.5, 2.0, 2.5, and 3.0 days for 50, 100, 150, and 200 mCi doses, respectively. It also generated tailored recommendations for patient-specific occupancy factors, ensuring compliance with dose limits for caregivers and the public. Importantly, it allowed minor regional adaptability while maintaining regulatory compliance, particularly relevant for resource-limited settings.

**Conclusion:** The proposed AI model offers a personalized, safe, and flexible approach to managing I-131 patient release. It minimizes human judgment errors, standardizes practices across institutions, and supports policy implementation in diverse healthcare environments. This tool represents a significant advancement in balancing regulatory compliance with contextual needs.

**Index Terms -** AI patient release, Patient Release criteria of I-131, I-131 treated patient release via AI, one-click decision of patient release.

**Keywords:** Artificial intelligence patient release, iodine radioisotopes, radiation protection, patient discharge, radiation dosage, radiation monitoring, machine learning, clinical decision support systems, patient release criteria of I-131, one-click decision of patient release.

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**Address for correspondence:** Uzma Ilyas

\*Atomic Energy Medical Centre (AEMCK), Pakistan Atomic Energy Commission (PAEC), Karachi, Pakistan.

**Email:** [uzma.paec@gmail.com](mailto:uzma.paec@gmail.com)

Full list of author information is available at the end of the article.

## Introduction

Iodine-131 is a radioactive isotope of iodine (I), and has been used in diagnostic imaging and treatment since 1945 [1]. Its half-life is about 8.093 days, and it emits both beta particles (which provide the therapeutic effect by damaging diseased tissue) and gamma rays (which are used in imaging). I-131 is used for the treatment of the thyroid gland, an endocrine gland located in the anterior region of the neck. The thyroid gland's primary function is to produce thyroid hormones that regulate the metabolic rate, oxygen consumption, respiration rate, and body temperature. If the gland produces an unbalanced (insufficient

or excessive) amount of thyroid hormones, it can lead to various thyroid disorders [1]. The abnormal generation of these hormones may cause the thyroid gland to become inflamed or swollen due to one or more nodules forming within it. Some of these nodules may develop into malignant tumors, while others may result in diffuse goitre. The Nuclear Physician determines whether the patient requires a low or high administered dose of I-131 for treatment. After the administration of a high-dose radioisotope, such patients are advised to remain in isolation to minimize radiation exposure to the public, maintaining levels within the limits recommended by regulatory authorities.

The challenge is determining the appropriate isolation time for patients treated with Radioactive I-131. Practices worldwide regarding the release of patients after therapies involving unsealed radio-nuclides, as shown in Figures 9 and 10 [2], vary significantly and lack standardization. Numerous research studies focus on predicting thyroid diseases based on hormonal trends and treatment via I-131 dose administration, like [1,3,4,5]. This research is unique in predicting release criteria for I-131-treated patients from a radiation protection perspective rather than diagnosis or treatment. A specialized dataset was created from the AEMCK hospital, containing the medical histories and socioeconomic backgrounds of patients. By analyzing the trends in isolation periods and other attributes, the study successfully predicted patient release using machine learning algorithms. The Decision Tree Classifier, a reliable data-driven approach for optimizing patient safety and resource management, performed well – achieving an accuracy of 74%, which is expected to improve as more data are accumulated.

This study holds significant potential to enhance both safety and efficiency in nuclear medicine patient care at AEMCK. By leveraging artificial intelligence (AI), it demonstrates a forward-looking approach to healthcare that can benefit both patients and healthcare providers. Additionally, it addresses ethical and regulatory considerations, which are paramount in the healthcare industry.

### *Benefits of AI in patient release criteria*

The primary aim of the study is to develop an AI-based release system to improve patient radiation protection and provide a systematic process to release patients.

**Enhance Patient Safety and Reduce Exposure Risk:** Patients treated with Iodine-131 require strict monitoring in close contact aspect and adherence to safety protocols to protect both the patient and the public from radiation exposure. By utilizing AI, this system can provide a more accurate assessment and close contact, leading to safer conditions for the public and the environment.

**Optimising resource allocation:** AI-supported effective release systems can help healthcare facilities allocate resources more efficiently by accurately determining when a patient can be safely discharged and the appropriate duration of isolation. This enables hospitals to free up much-needed space and resources for other patients, ultimately enhancing the overall quality of patient care.

**Data-driven decision-making:** The use of AI allows for a data-driven approach to patient release, which is a critical one that demands a precise evaluation of multiple factors, including socio-economic conditions, the administered activity, measured dose, retained activity, total effective dose equivalent (TEDE), patient-specific parameters, and the patient's mental, physical, and physiological condition and exposure risk. The system can provide objective, consistent, and reliable judgments, reducing

the potential for human error and subjectivity in the decision-making process.

**Retrospective data analysis:** The isolation time can also be estimated through retrospective data analysis, helping to predict the expected isolation period for iodine-treated patients. This approach is especially relevant given the increasing number of thyroid cancer cases and the resulting shortage of isolation rooms. Instead of expanding the number of isolation rooms, the isolation period could be shortened, or other strategies like reducing the occupancy factor to lower exposure could be employed to facilitate earlier patient release. This would make more rooms available for additional patients, reduce treatment costs, and address patient complaints regarding the inconvenience and anxiety caused by prolonged isolation, ultimately improving their overall experience.

### *Related work*

Numerous studies have investigated the use of artificial intelligence in diagnosing and treating thyroid diseases. AI algorithms have been developed to improve the accuracy and efficiency of thyroid nodule classification, aiding in the early detection of thyroid disorders [1,6,7]. Most previous research has focused on diagnostic tools, predictive models, and treatment recommendations using AI technologies. However, the present study is distinct in its objective to develop an AI-based system specifically designed to determine the release criteria for patients treated with Iodine-131. Some studies have relied on traditional release criteria, such as those referenced in [8] and [9]. Integrating AI into the patient-release decision-making process is a novel approach. This research goes beyond the traditional applications of AI in thyroid care by addressing a crucial aspect of patient management that has been largely overlooked in the literature. Additionally, the study's comparative analysis highlights the effectiveness and efficiency of the proposed AI-based release system in contrast to conventional methods, incorporating both regulatory frameworks and AI/ML technologies.

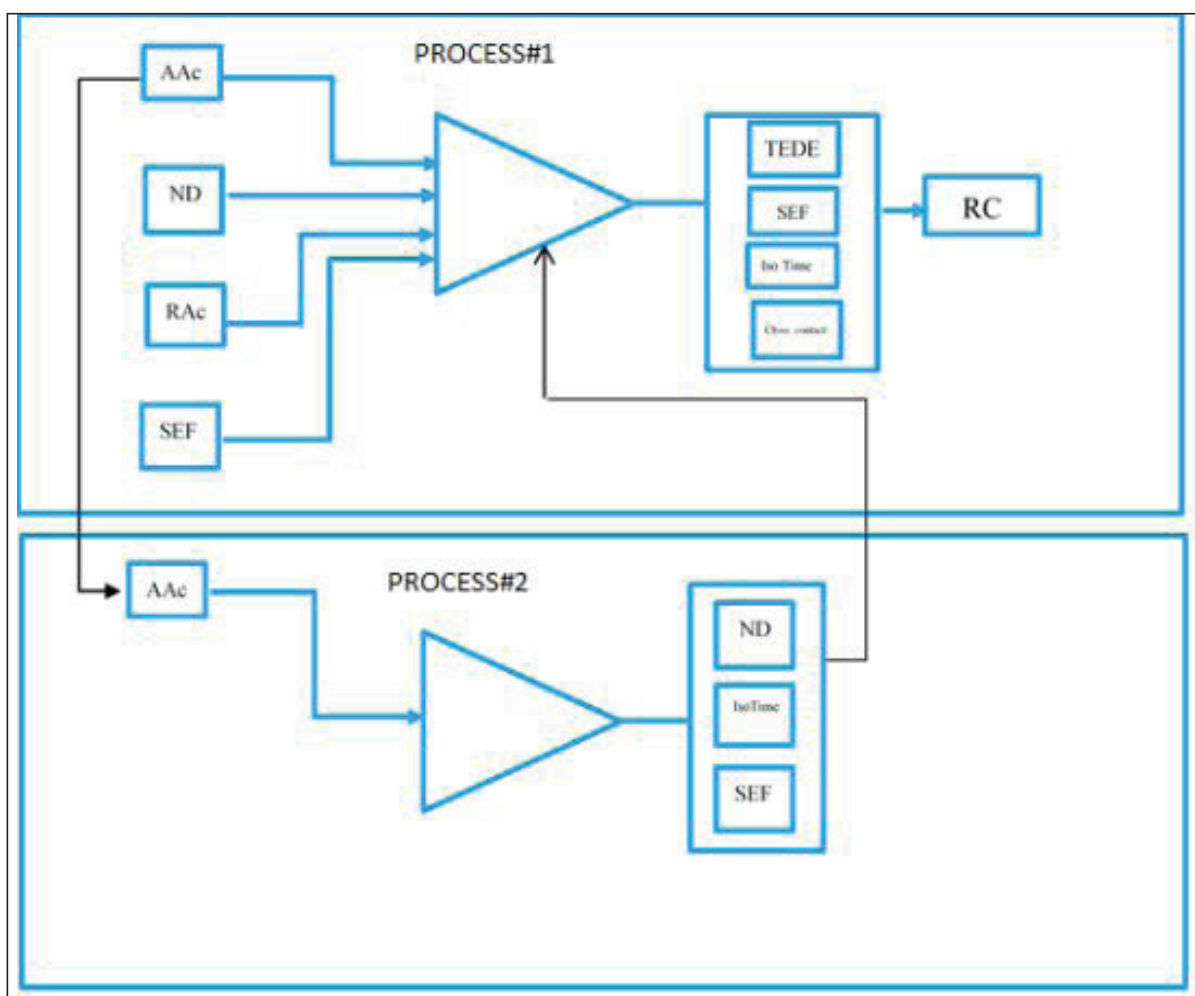
### *Traditional release criteria*

Following thyroidectomy, radioactive iodine therapy (I-131) is the standard treatment for patients with various thyroid disorders. Patients receiving high doses of I-131 (greater than 30 mCi) are required to remain in isolation for a specified period. The U.S. Nuclear Regulatory Commission (NRC) and the International Atomic Energy Agency have periodically updated the release guidelines for thyroid cancer patients undergoing high-dose radioactive iodine therapy. The primary principle is that the TEDE to family, friends, and co-workers should not exceed 5 mSv (Table 1) [10]. In the field of nuclear medicine, there exists a critical need for a more accurate, efficient, and data-driven system to determine the safe release of patients treated with Iodine-131 and to establish clear close contact criteria along with global standardisation.

**Table 1.** Regulatory release criteria.

Regulation NRC Regulation	Release limit when the patient could be let go			
Then (Before 1997)	Retained activity	DOSE-RATE @ 1 m	Exposure to individual (TEDE)	
	(mci)	(mrem/hour.)	(mrem)	
	= 33	5	Conservative	
Now (Since 1997)	* $\leq 33$	$< 7$	500	@ AEMCK AI decided as per socioeconomic Criteria
			100	ALARA Instruction given and record keeping for 3 years with release

\*Indicates retained activity threshold allowing release since 1997 NRC revisions, with TEDE calculations, AI decided as per socioeconomic Criteria and ALARA guidance; record-keeping required for 3 years in certain cases.



**Figure 1.** Decision tree predictive classifier algorithm.

Current release systems and criteria often rely on generalized judgments and can lead to both overcautious and potentially unsafe patient releases, as some regions belong to developing countries and their family system and economic conditions do not allow them to obey the regulatory limits, therefore posing risks to patients and the general public (Figures 9 and 10). In this condition, a “Dynamic Patient Release Management System” is required. This

research study proposes a single standard system (software) designed to adhere to regulatory limits, but it incorporates flexibility for adjusting the decision-making process based on factors like the patient’s economic condition. The system stays within statutory regulations but allows for the release of patients under more accommodating criteria, which could be useful in the context of developing countries like Pakistan, India, and so on.

**Table 2.** System attribute.

Attribute	Description	Type
Gender	Patient sex male or female	String
Dose	Patient administered dose	Integer
Age	Patient age at time of visit	Integer
Measured neck dose	Patient daily neck dose	Long Integer
Remaining activity	Retained activity calculated	Integer
TEDE	Total effective dose equivalent	Integer
Isotime	Isolation time via retrospective analysis	Integer
Homeyard	Lenght of home	Integer
Room	Number of room in home	Integer
Wroom	Number of washroom	Integer
Pedu	Patient education	Integer
Cedu	Care giver education	Integer
SEF	Socio economic factor	Integer
Rc	Release criteria	Boolean
Pwoman	Pragnant women	Boolean
Nchild	Number of child	Integer

Integrating AI will help them calculate the values and make decisions quickly and intelligently. This AI-based dynamic patient release system would balance between two critical factors: Regulatory Compliance, which ensures patient release meets the standard radiation safety criteria. Contextual Adaptability, which allows adjustments within permissible statutory ranges, considering the socio-economic conditions of patients. In the case of countries with limited resources, such adaptability could help optimize healthcare outcomes while still prioritizing safety. Adapting with consistent criteria and practices, healthcare facilities worldwide can adhere to the same standards, which not only improves the safety of patients and healthcare workers also reducing confusion in international medical practices. This process creates a consistent and standardized approach to assessing a patient’s condition and determining when it is safe to release them. In summary, the engineered design of an AI-based expert system can help standardize and harmonize the practices of admitting and releasing patients, including isolation duration, close contact period, and expected discharge dose, based on historical and current patient data, across the globe. This not only enhances patient safety but also streamlines healthcare operations, reduces the potential for errors, and takes into account a wider range of factors, including socio-economic conditions, to improve patient-centered care, as shown in (Figure 1).

## Methodology

### Data collection

To create a dataset of patients for a patient-centered adaptive decision-making system, with thyroid disease treated at AEMCK Cancer Hospital, data were compiled from

two sources, encompassing information on nearly 300 patients. The first data source includes personal details for each patient, such as age, date of birth, sex, profession, education, marital status, the family history. The second data source includes socio-economic details for each patient, such as residence, family composition, disability status, travel mode, and distance from home. Both sources were merged into a unified dataset comprising 321 thyroid cancer patients (267 women and 54 men; mean age 41 years), with each record containing the patient’s clinical, physical, and socio-economic information.

### Proposed feature Modal

The feature set used in this study is derived from various attributes describing patients from multiple perspectives, including personal data, economic conditions, and physical health. From the initial set of features, 20 relevant attributes related to patient information were selected. Table 2 lists these attributes, with the name in the first column, a brief description in the second column, and the type in the last column. The final row of the table shows the predicted features: Isolation Time (iso-time) and Release (RC).

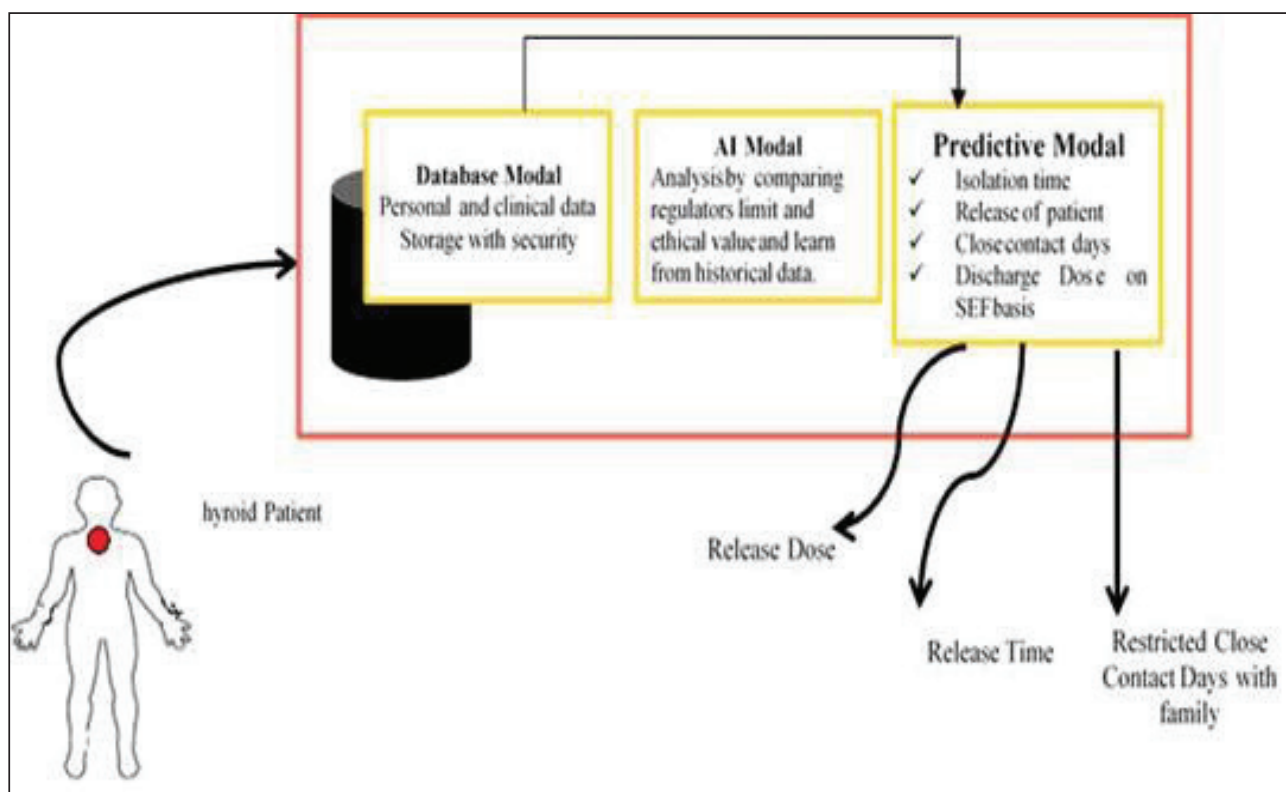
**Data Input:** For an individual patient, collect input data, including measured values (neck dose and administered activity) and socioeconomic factors (SEF), Figure 12.

**TEDE calculation:** Based on the input data, the model calculates the TEDE for the patient, from Equations in DOSE CALCULATION section VII. TEDE is a measure of the total radiation dose that an individual is exposed to, including external and internal sources, Figure 12.

**Regulator’s limit:** The model then compares the calculated TEDE, section VII, with the regulator’s limit. This

**Table 3.** Patient release dependent parameter.

Patient group	Basis for release	Release criteria	Instruction needs	Release record required
All patients who are Administered by RAI	Administered activity	33 mci	Yes	No
	Retained activity	33 mci	Yes	Yes
	Measured dose	5 mrem/hour	Yes	Yes
	Patient specific	Calculated dose	Yes	Yes
	Calculation	5 mSv (0.5rem)		



**Figure 2.** AI base release methodology.

limit is set by regulatory authorities to ensure that radiation exposure remains within safe bounds, Table 1.

**Release prediction:** Based on the TEDE comparison, the model predicts whether the patient can be released or not. If the TEDE is within the regulator’s limit, the patient may be eligible for release.

**Historical data:** The system also considers historical data, which includes information about previously treated patients. This data provides insights into isolation time, neck dose at the time of release, and potentially other factors.

**Isolation time matching:** The historical data are used to determine the appropriate isolation time for the current patient. If the current patient’s isolation time matches that of similar cases in the historical data, it may influence the decision to release the patient.

**Decision adjustment:** Based on the combination of the patient’s current data, TEDE calculation, SEF, and

historical data, the system makes a final decision regarding patient release.

*ML Classifier*

In the context of patient release criteria, the objective is to predict whether a patient should be released based on various input features and historical data. A decision tree classifier (DTC) was selected due to its simplicity, interpretability, and ability to handle both categorical and numerical variables [11,12]. Similar approaches have been successfully applied in medical decision-making and thyroid disease prediction [13]. In DTC, each node in the tree represents a feature or attribute (such as isolation time, radiation dose, or socio-economic factors), and each branch shows the potential outcome based on a threshold. The selection of DTC is also because of its nature to handle mixed types of data as categorical and numerical data, with real-time decisions. DTC also encounters missing or incomplete data. The DTC can still function effectively,

**Table 4.** TEDE with occupancy factor = 0.25 (Stay 6 hours).

Measured dose		*TEDE maximum possible radiation dose	Administered activity	TEDE maximum possible radiation dose
		Measured dose based	Q	Activity based
		$D(\infty) = 1.44 \times T_{1/2} \times O \times R$		$D(\infty) = 34.6 \times T_{1/2} \times Q_0 / r_2$
(Usv/hour)	(mrem/hour)	(rem)	(mci)	(rem)
120	12	0.8	20	0.3
94	9.4	0.7	25	0.4
70	7	0.5	33	0.5
60	6	0.4	50	0.8
50	5	0.4	100	1.5
40	4	0.3	150	2.3

Record ID	Radiosotope	Batch#	Sample#	Arrival Date	Administered Activity	Elution Time	Certified	P-STATUS	Elution Date
17215	I-131	39/23	1268	09-Oct-23		08:30 AM	YES	-	09/10/2023
17211	I-131	39/23	1268	09-Oct-23		10 08:30 AM	YES	-	09/10/2023
17210	I-131	39/23	1059	09-Oct-23		100 08:30 AM	YES	F/U in Thyroid OPD with post ablative scan	09/10/2023
17209	I-131	39/23	1268	09-Oct-23		8 08:30 AM	YES	-	09/10/2023
17208	I-131	39/23	1268	09-Oct-23		8 08:30 AM	YES	-	09/10/2023
17207	I-131	39/23	1059	09-Oct-23		100 08:30 AM	YES	F/U in Thyroid OPD with post ablative scan	09/10/2023

**Figure 3.** All Iodine -131 treated patient.

making it a reliable choice in such scenarios. In short, by selecting this algorithm, it can offer a reliable, data-driven approach to optimizing patient safety and resource management. The class labels are defined as follows: "0" indicates "Not Released," and "1" indicates "Released".

**Release criteria**

The expert system is based on Regulatory Guide [14-16], NRC-10CFR [17]. It is a patient-centered adaptive decision-making system that introduces a tiered approach to patient release based on individual risk factors. This

would go beyond merely following the regulatory limit and include a detailed assessment of the patient’s circumstances. The system would provide two sets of recommendations.

Regulatory-compliant release: if the patient meets regulatory criteria for release, Table 3, the system will indicate they are eligible to leave. Extended Stay Suggestion: If the system identifies that the patient could still pose a risk (e.g., to family members, crowded living conditions, and so on), it could recommend an extended stay in a

Report TO		AEMCK									
Select Source Type		Select Year		Select Status							
I-131		2023		OPEN							
Record ID	Radiosotc	Batch#	Sample#	ArrivalDate	Administer	Elutiontime	Certified	P-STATUS	ElutionDate		
17212	I-131	39/23	1268	09-Oct-23		08:30 AM	YES	-	09/10/2023		
17211	I-131	39/23	1268	09-Oct-23	10	08:30 AM	YES	-	09/10/2023		
17210	I-131	39/23	1059	09-Oct-23	100	08:30 AM	YES	F/U in Thyroid OPD with post ablative scan	09/10/2023		
17209	I-131	39/23	1268	09-Oct-23	8	08:30 AM	YES	-	09/10/2023		

Figure 4. Single patient medical.

controlled environment. It could flag that even though the patient is eligible to leave by law; however, if they stayed longer in a controlled environment, the safety of the patient and the public would improve.

The AI system uses the mentioned conditions for releasing patients. The architecture of the AI model is illustrated in (Figure 2). It enables efficient storage of patient data, performs deep analytical processing, and generates clinically relevant results. The database structure of this expert system is as follows.

### A. Database structure

All patient data, including socio-economic information, treatment details, neck dose, retention activity, and effective dose equivalent, are stored in a Database developed in Microsoft Access by a Nuclear Physicist/Tech during patient interview (Figure 11).

### B. Data calculation

The system calculates the total effective dose equivalent (TEDE) to the public, Table 4, and retention activity based on the entered data (Figure 12).

### C. Comparison logic

The system compares the calculated values with the measured values. If three out of four analogy meet safety standards, the system deems it safe to release the patient after getting the release parameters from previous data analysis of the same scenario.

### D. User interface

A user-friendly interface displays the patient’s data, comparison results, and safety duration recommendations (Figure 4).

### E. Reporting

The system generates a release report /certificate summarizing patient data and safety recommendations for patients (Figure 12).

### F. Data entry forms

Design user-friendly data entry forms to input patient information. These forms should include fields for socio-economic data, treatment details, and radiation exposure data (Figure 11).

### Dose calculation

Patients receiving radioactive substances can be released once safety limits are satisfied as per the regulator, when the TEDE to any other individual is unlikely to exceed 0.5 [18] based on activity

$$D(t) = (34.6 * \text{GammaConst}Q0 * O * T) / r^2$$

based on neck dose, [19]

$$D(t) = R(t)dt$$

Where;

$$\text{Factor "34.6"} = 1.44 (\text{decayconst}) * 24 (\text{days in hour})$$

1.44 is decay constant (Ln2)

$$D(t) = \text{Accumulate dose to time } t (\text{rems})$$

T = Physical half-life in (days)

O= Occupancy factor

r= point source Exposure rate constant (R/hrpermCixhr) at 1 cm

Q(0) = Initial activity at the start of time interval in (mci)

t = Exposure time in (days)

**Table 5.** TEDE with occupancy factor = 0.125 (Stay 3 hours/24 hours).

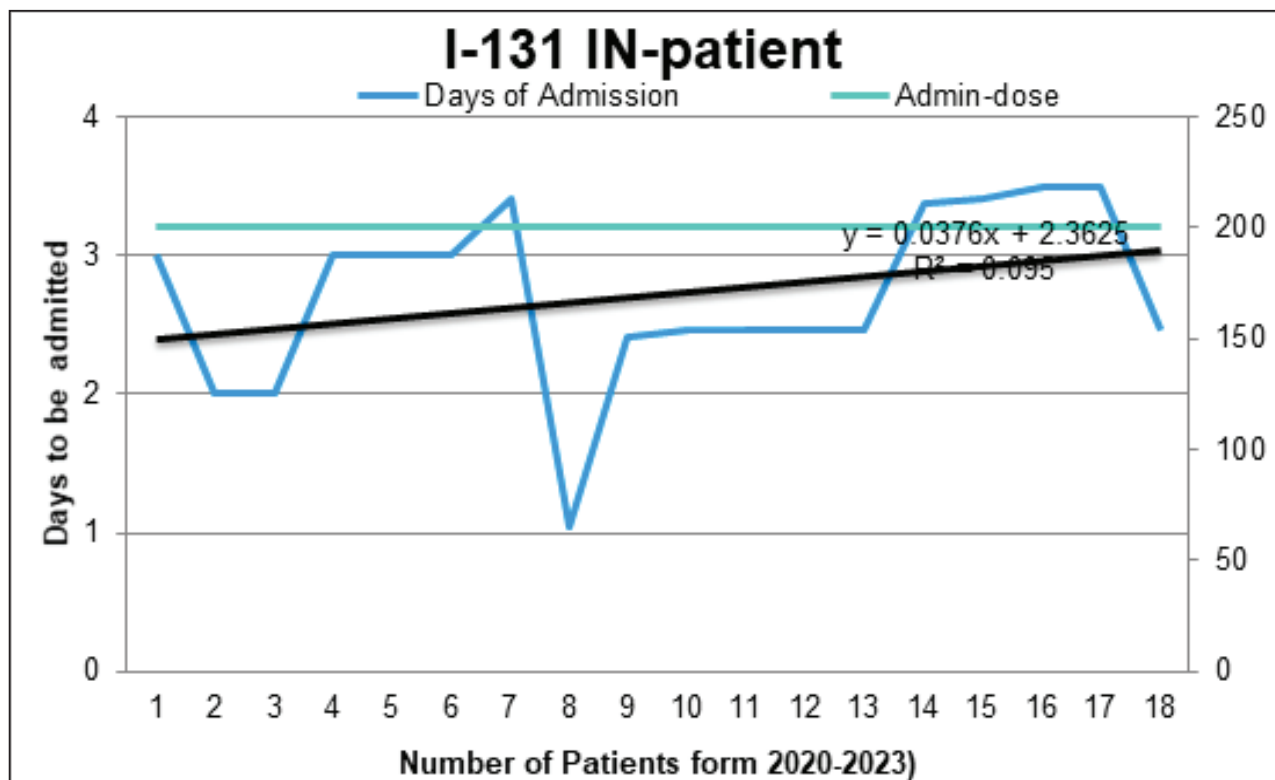
Measured dose		*TEDE Maximum possible radiation dose	Administered activity Q	TEDE maximum possible radiation dose
		Measured dose based		Activity based
(Usv/hour)	(mrem/hour)	$D(\infty) = 1.44 \times T1/2 \times O \times R$	(mci)	$D(\infty) = 34.6 \times T1/2 \times Q0/r^2$
		(rem)		(rem)
120	12	04	20	0.2
94	9.4	0.3	25	0.2
70	7	0.2	33	0.3
60	6	0.2	50	0.4
50	5	0.2	100	0.8
40	4	0.1	150	1.1

**Table 6.** Close contact with cancer patient.

Administer doses (mCi)	Thyroid cancer (days)
>=200	21
>=150	18
>=100	13
>=50	6
>=30	3

**Table 7.** Close contact with thyroid be-nign patient.

Administer doses (mCi)	Thyroid benign (days)
>=10	15
>=15	18
>=20	20
>20	23
>=30	30



**Figure 5.** Iodien -131 treated patient with 200mci.

r = Distance in centimeters, 100 cm (1 m).

**Assumptions**

Patient is an unshielded point source.

Elimination is only by physical decay. An exposed individual stands one meter away from the patient for 6 hours per day, 7 days per week for 1 year (O = 0.25) exposure constant for 131I is 2.2 R / hour per mCi at 1 cm, over the 1 year.

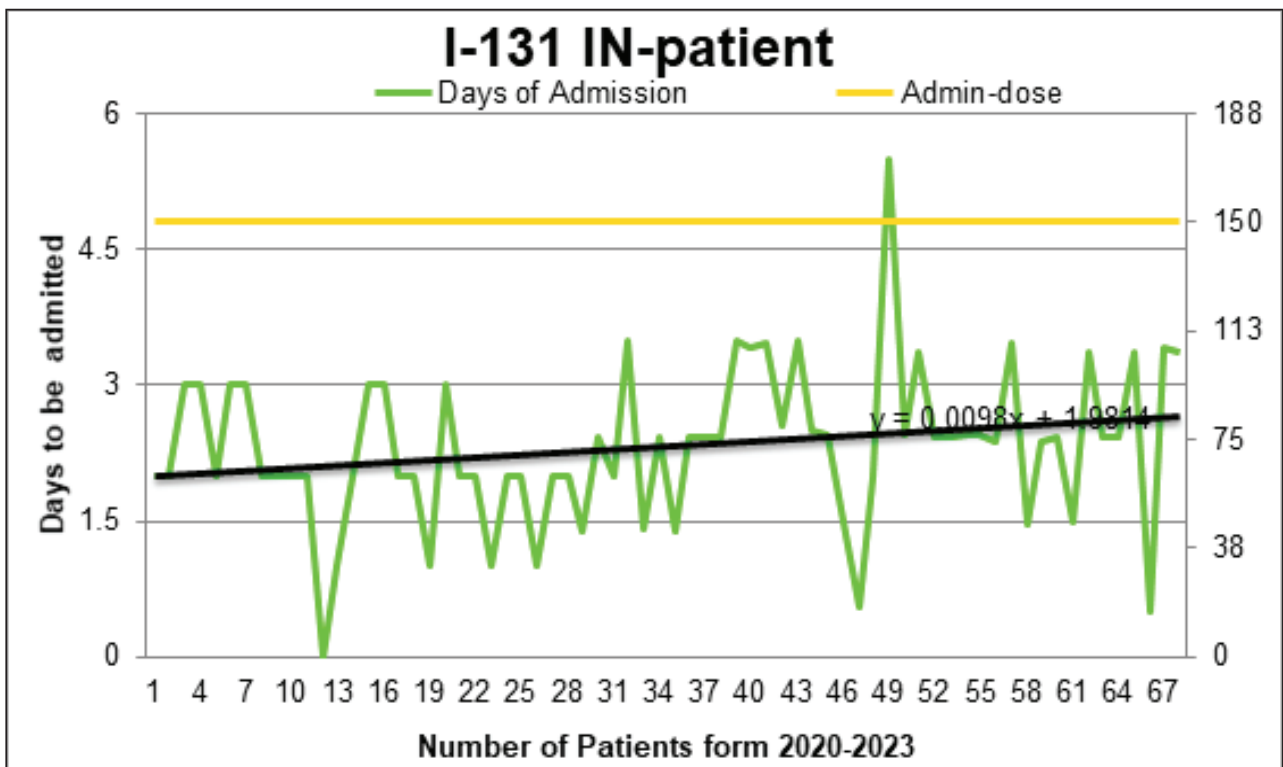


Figure 6. Iodien -131 treated patient administered with 150 mci.

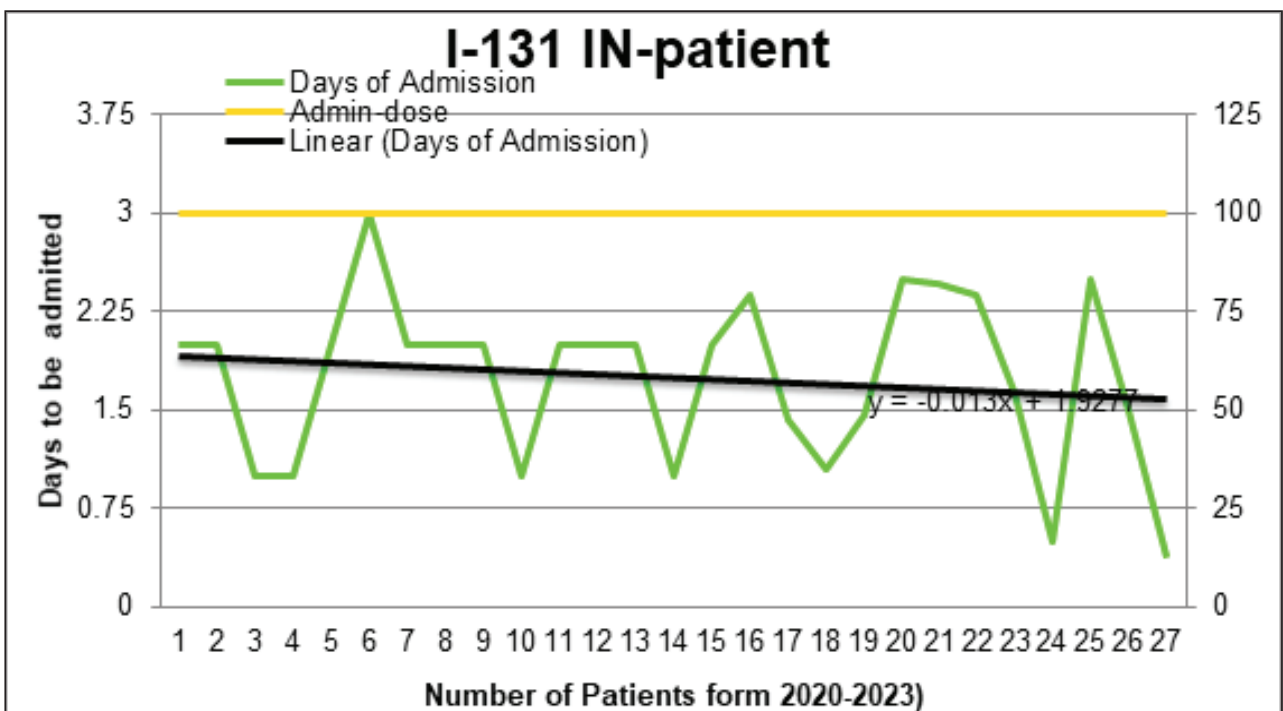


Figure 7. Iodien -131 treated patientred with 100 mci.

The above Table 4 and Table 5 show TEDE with different occupancy factors, can make a well-informed decision to release the patient from isolation. The instruction to the patient should be robust as per safety protocols.

*Close contact criteria*

Patients need to know how long should he/she limit interaction with public, family, friends, and co-workers The higher the computed “general public” TEDE dose, the longer the time certain activities should be avoided by the

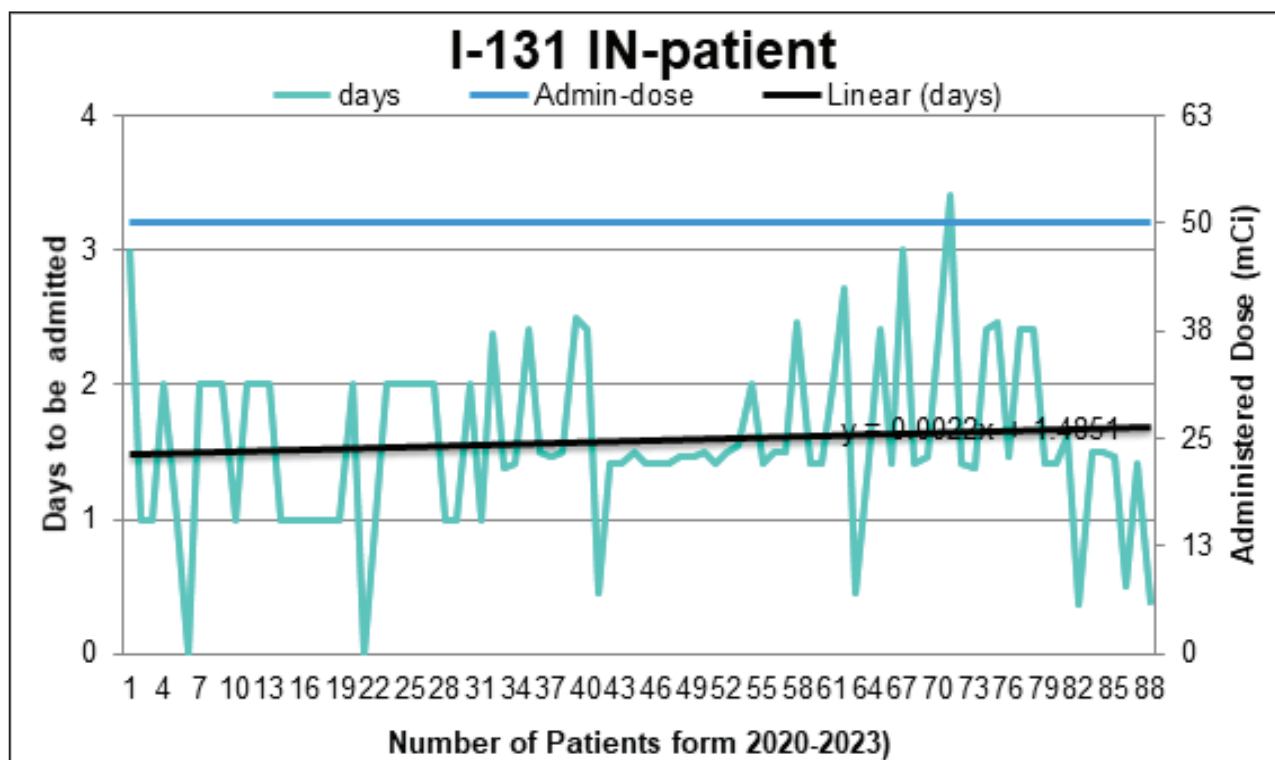


Figure 8. Iodien -131 treated patient administered with 50 mci.

Table 8. Expected isolation period.

Administered activity		Isolation period
(mci)	(GBq)	(Days)
50	1.85	1-1.5
100	3.7	1.5-2
150	5.55	2-2.5
200	7.4	2.5-3

patient. Times to avoid certain activities can be calculated based on the estimated “public dose.” AI provides instruction to patients about how much and how long should patient can closely contact with his/her family members and public by avoiding close contact for dose exposure to public, especially with children and Pregnant women as per their administer doses.

As per International Commission on Radiological Protection (an independent international organization providing recommendations on radiation protection), Close contact with iodine patients, especially with children and pregnant women is also restricted as per patient-administered doses; therefore, this type of isolation may be stressful, tactful, and emotionally challenging for patients.

During isolation, patients will need to limit interactions with others, remain several feet away from family members, avoid physical contact with others, Tables 6 and 7, thoroughly wash eating utensils, clothing, and linens, sleep alone, and clean all surfaces carefully, among other precautions. The rules are generally stricter for the first few days after treatment, when patients may still be in the

hospital, but get less strict towards the end of the week. Patients who live with small children or pregnant women should be even more cautious.

### Isolation period

The AI expert system can enhance healthcare efficiency by minimising unnecessary isolation periods and ensuring timely patient discharge. The present study also includes a retrospective analysis of the hospitalisation duration of patients, Figure 3, treated with I-131 therapeutic doses at the Atomic Energy Medical Centre, Karachi, Pakistan, from 2020 to 2023. A total of 321 patients (aged 20–65 years) were included in the study, comprising 25 male and 175 female patients. Among them, 18 patients (8.5%) received 7.4 GBq (200 mCi), 68 patients (32%) received 5.55 GBq (150 mCi), 26 patients received 3.7 GBq (100 mCi), and 88 patients (44%) received 1.85 GBq (50 mCi) of I-131 over the 3-year period. The radiation exposure of each patient was measured using a portable survey meter by a Medical Physicist or Nuclear Medicine Technologist. The proposed system will use state-of-the-art AI to releasing

Responses Gathered From Each Country				
Country	Requirements	Standard Practice	Typical Activity Administered	Date of Latest Revision of Requirements
Australia	Patient dose rate must be <25 $\mu\text{Sv/h}$ (2500 $\mu\text{rem/h}$ ) at 1 m for release.		15 mCi (555 MBq) or 25 $\mu\text{Sv/h}$ (2500 $\mu\text{rem/h}$ ) for toxic thyroid, 50-200 mCi (1850-7400 MBq) (100 mCi (3700 MBq) average) for Ca thyroid.	Published in 2002. Currently under review.
Bangladesh (Unofficial Response)	Patient must have activity <1100 MBq (29.7 mCi) for release.			Guidelines revised in 2002.
Canada	Patients administered >1100 MBq (29.7 mCi) held for a few hours to ensure capsule is properly ingested. Released if they meet criteria for safe discharge (e.g., no children in home, separate bathrooms for patient and caregiver). Instructions provided at release.	Canadian Nuclear Safety Commission (CNSC) does not recommend release to hotels.	5-29 mCi (185-1073 MBq) (average 10-15 mCi (370-555 MBq)) for hyperthyroidism, 30-250 mCi (1110-9250 MBq) (average 100 mCi (3700 MBq)) for ablation.	Act came into effect in 2000. Multiple revisions since then. Radiation Protection regulations currently being considered for amendment
China	Patient have activity <400 MBq (10.8 mCi) for release.	Patients kept in separate clinic room until activity <400 MBq (10.8 mCi).	Varies according to patient needs.	Last revised in 2002.
France	Hospitalize patients when activity is >800 MBq (21.6 mCi). Doctor must provide written instructions to limit exposure to persons in contact with patient.	Hospitalize patients when activity is >800 MBq (21.6 mCi) for at least 48 hours until dose rate is <40 $\mu\text{Sv/h}$ (4000 $\mu\text{rem/h}$ ) at 1 m. Urine stored in special tanks for >80 days and until activity is <100 Bq/L (0.01	200 MBq-1 GBq (5.41-27.0 mCi) for hyperthyroidism, 1.1 GBq (29.7 mCi), 3.7 GBq (100 mCi) or 5.5 GBq (149 mCi) for thyroid cancer.	HERCA requirement approximate to actual practice.

Figure 9. International data.

Country	Requirements	Standard Practice	Typical Activity Administered	Date of Latest Revision of Requirements
		$\mu\text{Ci/gal}$ ). Feces sent to the tank only to delay elimination towards sewage system.		
Germany	Hospitalize for at least 48 hours post treatment. Local dose rate must be <3.5 $\mu\text{Sv/h}$ (350 $\mu\text{rem/h}$ ) at 2 m or whole body activity must be <250 MBq (6.8 mCi) for release.	Hospitalize for at least 48 hours following thyroid carcinoma treatment. Ward equipped with separate waste water treatment installation.		Last revision in 2002.
Japan		Licenses are not allowed to isolate patients in hotels or other non-medical facilities. To reduce a patient's radiation to an acceptable level for release ( <i>patients may be released when body residual radiation dose drops below 500 MBq (13.5 mCi) at 1m</i> ), they are isolated in a room designed for radiation therapy or a room where patients are administered radioactive medicines while in the hospital.	Medical doctors overseeing the patient must decide upon the activity to be provided. The guideline for thyroid cancer released by the Japanese Society of Nuclear Medicine and the Japanese Society of Nuclear Medicine in Oncology and Immunology notes the standard activities given to thyroid cancer patients is 3,700 -7,400 MBq.	The guideline was established on June 30, 1998, and revised on November 8, 2010. (2010's revised guideline, allowed thyroid cancer patients who were administered 1,110 MBq of I-131 for ablation therapy, after complete removal of their thyroid due to differentiated cancer and without distant metastasis, to go home directly.)
Lithuania	Patient must have activity <400 MBq (10.8 mCi) for release.	Hospitalize for 3 days.	200-300 MBq (5.4-8.1 mCi) for hyperthyroidism, 1.6-3.2 GBq (43-86 mCi) for thyroid cancer.	Reviewed in 2013.

Figure 10. Internation release criteria.

patient on appropriate time with appropriate exposure dose (these are different for different patients) because of biological release of iodine as well as socio-economic condition. All these process imitating human judgments.

Just like store, sort and manipulate the data and human made rules and mimic the human intelligence.

### Out come

Due to the patient's different Socioeconomic conditions (Good or Bad) and external dose rate criterion and in

Patient Name	Mohammad Kaleem	Patient Name	Mohammad K
Patient Dose	50	Patient PRN#	006539/22
Visit Date	01/11/2023	Patient A.Dose	50

Patient CT Name	Mohammad azeem
Age Of CT	47
Literacy Level CT	12 10' is for Matric
Literacy Level Pt	112
Patient Home Area	180 Yards
Number of Room	8 Can patient arrange a room for sleep alone <input checked="" type="checkbox"/>
NO. of Childrens 2 to 10 yea	5 Can any arrangement to stay other place <input type="checkbox"/>
Number of WRoom	5 Could patient use exclusively <input checked="" type="checkbox"/>
No.Of Persons	18
Is any Pregnant Women there	<input checked="" type="checkbox"/> Can any arrangement to stay other place <input checked="" type="checkbox"/>
Do patient has any physical problem require extensive care	<input type="checkbox"/>
Is patient working	<input checked="" type="checkbox"/>
Is travelling Distance is >220Km	
How long taking to reach home	30
<input checked="" type="radio"/> Travel by Bus <input type="radio"/> Travel by Car	
Other Information	Patient is unmarried and can live in isolation for upto the mentioned days.

Figure 11. Patient interview.

### IODINE NECK DOSE FOR PATIENT

Filled by (Name, Designation ,Sign) Saleem Ansari,Stech Signature of NM Tech *Saleem Ansari,Stech*

<b>Patient Details</b>	<b>Neck Dose</b>	<b>Paitient Qusionnaire</b>	<b>Consent Form</b>
Patient Name	asia danis	Patient Dose	100
Visit Date	09/10/2023	Patient PRN#	018866/18
Patient Age	24	! I-131 Instruction	
Patient Mobile	0323286009	mCi	
Patient Address	korangi		

Figure 12. All Iodien -131 treated patie.

keeping view of the TEDE criterion (less than 5 mSv)/500 mRem, patients administered with 30 mci could have been released on average after 1.0 days. the patients administered with 50 mci could have been released on average

after 1.5 days. The patients administered with 100 mci could have been released on average after 2.0 days patients administered with 150 mci could have been released on average after 2.5 days, and patients administered with 200

mci could have been released on average after 3.0 days. On the basis of these calculations, it alters the releasing decisions and intelligently provides the final decision for the amalgamation of current and past data. An appropriate isolation period was estimated for iodine-treated patients administered 50, 100, 150, and 200 mci. 50 mci patients could have been released within 1.5 days. Moreover, 2.0 d, 2.5 d, and 3.0 days, respectively, Table 8, of radiation treatment, Figures 5–8.

### Modal evaluation

After developing and executing the model, its performance must be assessed. To evaluate the effectiveness of any machine learning approach, it is essential to conduct a thorough assessment of the model's performance when applied to real data. Therefore, to verify our model's reliability and execution quality, performance metrics such as accuracy and precision were evaluated, along with re-substitution validation on the testing dataset. In order to verify our modal performance how well the model is executed, along with accuracy/ precision, and re-substituting validation during testing dataset.

### Resubstituting validating technique

In this model validation method, the entire dataset is used for training the model. Then we calculate the error rate using the actual and predicted values from the same training dataset. This error is known as the re-substituting error, and this technique is known as the re-substituting validation technique. In our case, the resubstitution error is approx +0.01.

### Accuracy validating technique

The metrics we used to validate the model are accuracy, precision, recall, and F-score. In detail, accuracy indicates the accuracy of the model, i.e., the fraction of the test dataset on which the model provides a correct prediction. By defining true positives (TP) and true negatives (TN) as the instances that are correctly classified, and the false positives (FP) and false negatives (FN) as the instances that are misclassified, accuracy is defined as follows:

$$\text{Accuracy} = \frac{TP + TN}{TP + FP + TN + FN} \quad (1)$$

Precision and recall, on the other hand, want to quantify the rate of TP and TN, respectively. More specifically, precision is the ability of a classifier not to label a positive instance that is actually negative and is defined as follows:

$$\text{Precision} = \frac{TP}{TP + FP} \quad (2)$$

Instead, recall measures the sensitivity of the model. It is the ratio between the correct predictions for a class on the total of cases in which it actually occurs and is defined as follows:

$$\text{Recall} = \frac{TP}{TP + FN}$$

## Discussion

In this study, we want to adopt appropriate release criteria for iodine patients commensurate with earlier release

with regulators' safe limit, to treat more iodine patients with less exposure to family and the public. For this an iodine patient is registered and interviewed for his/her socio-background condition and education level and administered. An artificial intelligence system processes the patient data compares it with the regulator limit and views the previous data. Based on the data, the system immediately determines whether the patient is recommended for discharge, imitating human judgment through TEDE calculation and comparison with the measured dose and retained activity release criteria. The machine learns the isolation time and discharge dose from real patient data, and these values are used to determine the final decision regarding patient release. The contact criteria and special instructions to members of the public or family members are guided in one click.

## Conclusion

This research project marks a significant advancement in nuclear medicine and patient care. It tackles the crucial need for a standardized, objective, and data-driven approach to determining the safe release of I-131-treated patients while establishing clear criteria for close contact restrictions.

Through the development of an AI-based expert system, this research project aims to revolutionize the decision-making process and introduce a tiered approach to patient release based on individual risk factors. This would go beyond merely following the regulatory limit and include a detailed assessment of the patient's circumstance. This system would provide two sets of recommendations.

Regulatory-Compliant Release in which a patient meets regulatory criteria for release, the system will indicate they are eligible to leave, and other is Extended Stay Suggestion in which the system identifies that the patient could still pose a risk (e.g., to family members, crowded living conditions, and so on), so the system recommends an extended stay in a controlled environment. It could flag that even though the patient is eligible to leave by law, the safety of the patient and public would improve if they stayed longer in a controlled environment. The project has the potential to harmonize patient admission and release practices worldwide by altering the decision based on the patient's economic condition. In the end, improving patient safety, resource allocation, and the overall quality of healthcare.

Use machine learning algorithms to continuously learn from past patient outcomes, adjusting recommendations based on how effective extended stays have been in similar situations.

Overall, this project's findings are that the AI system developed holds the future of patient care in nuclear medicine, offering standardized, data-driven, and ethically sensitive solutions that prioritize patient safety and quality of care [20].

## List of Abbreviations

AI	Artificial intelligence
AEMCK	Atomic Energy Medical Centre Karachi
ALARA	As low as reasonably achievable
DTC	Decision tree classifier
I-131	Iodine-131 (Radioiodine)
IAEA	International atomic energy agency
ICRP	International commission on radiological protection
ML	Machine learning
NRC	U.S. nuclear regulatory commission
PAEC	Pakistan atomic energy commission
RAI	Radioactive iodine
RC	Release Criteria
SEF	Socio-economic factor
TEDE	Total effective dose equivalent

## Conflict of interest

The authors declare that they have no conflict of interest (financial or non-financial).

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## Consent to participate

Not applicable (retrospective study using anonymized historical patient data; no direct participant involvement).

## Ethical approval

The study was conducted in accordance with institutional ethical guidelines at Atomic Energy Medical Centre (AEMCK), Pakistan Atomic Energy Commission (PAEC). As a retrospective analysis of existing patient records, formal ethical approval was waived per institutional policy for non-interventional studies; patient data were anonymized.

## Author details

Uzma Ilyas<sup>1</sup>, Ghufuran Ahmed<sup>2</sup>, Hina Hashmi<sup>3</sup>, Mohsin Raza<sup>3</sup>, Mohsin Raza<sup>4</sup>

1. Atomic Energy Medical Centre (AEMCK), Pakistan Atomic Energy Commission (PAEC), Karachi, Pakistan
2. Department of Computer Science (FAST-NUANCES), National University of Computer and Emerging Sciences Karachi Campus, Karachi, Pakistan
3. Department of Computer Science (Norwich, UK), University of East Anglia, Norwich, UK
4. Department of Computer Science (Norwich, UK), University of East Anglia, Norwich, UK

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