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RESEARCH ARTICLE

Knowledge and perception of pharmacists and patients on the use of radiopharmaceuticals in disease management

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Abstract

Introduction: Nuclear medicine services, though still an emerging area in the field of medicine in Nigeria, have not been optimally utilised, possibly due to a lack of awareness by health workers. This study evaluated the knowledge and awareness of pharmacists and patients regarding radiopharmaceutical use in disease management. **Methods**: In this cross-sectional survey in southwest Nigeria, online self-administered and interviewer-administered structured questionnaires were used to collect data on the knowledge and perception of radiopharmaceuticals from 343 pharmacists and 67 ambulatory patients. The influence of the participant's socio-demographic characteristics on the knowledge of radiopharmaceuticals scores was assessed with Man-Whitney U and Kruskal Wallis tests at $p < 0.05$. **Results**: The study found that 191 (55.7%) pharmacists and 75 (98.7%) patients had good knowledge of radiopharmaceuticals, while 70 (21.3%) pharmacists knew radiopharmaceuticals are regulated as radioactive substances and drugs. Most patients, 47 (61.8%), knew how to prevent radiation exposure to others, and 68 (89.5%) believed radiopharmaceuticals would help disease management. **Conclusion**: Pharmacists and patients have good knowledge of the use of radiopharmaceuticals. Pharmacists' knowledge was influenced by the state of practice and prior knowledge of radiopharmaceuticals, while the number of clinics attended influenced patients' knowledge.

Introduction

Radiopharmaceuticals play a crucial role in medicine and are essential to nuclear medicine practice (Debnath & Babu, 2015). They are unique medicinal formulations containing radioisotopes for diagnostic and therapeutic purposes (Parasuraman *et al*., 2014b). The number of radiopharmaceuticals in clinical use is increasing, thus allowing the medical community better access to detailed information on the features of different types of tumours (IAEA, 2017). Also, using diagnostic radiopharmaceuticals in multi-modality imaging is beginning to gain widespread application. It offers a more accurate diagnosis and helps bring about personalised therapy and a better understanding of the underlying pathological processes (Sterjova *et al*., 2018). Recently, there has been a remarkable increase in therapeutic radiopharmaceutical applications, playing a more critical role in the fight against cancer and several other medical conditions (IAEA, 2018). Anxiety about radiation exposure is shared among the general public, but nuclear medicine procedures are considered safe (Adedapo *et al*., 2013). Health risks from medical radiation have generated debates (Busey *et al*., 2013). Radiopharmaceutical low-level radiation exposure hazards are unknown, but it is generally agreed that all human radiation exposures should be kept as low as reasonably achievable, or "ALARA" (Bevelacqua, 2010).

Radiopharmaceuticals comprise two components: the radionuclide, which produces the radiation required for its activity, and a chemical compound whose structure or chemical properties determine the radiopharmaceuticals' physiological or in vivo

distribution (Madulid *et al*., 2020). Most radiopharmaceuticals are used for diagnostic imaging and are usually injected, swallowed, or inhaled. Bone, thyroid, and renal scans are the usual nuclear medicine diagnostic procedures in developing countries (Adedapo *et al*., 2013). Another clinical application of nuclear medicine is in oncology, which has become Nigeria's significant public health concern (Adedapo *et al*., 2013; Madulid *et al*., 2020).

Radiopharmacy operation is one of the advancements in the pharmacy profession, and pharmacy professionals must keep abreast of new developments (Riyasha *et al*., 2013). Pharmacists also need to maintain an active role in disseminating information related to the use of radiopharmaceuticals, including medication-related problems that occur with the clinical use of radiopharmaceuticals. While nuclear pharmacy practice is established and recognised in developed countries, in developing nations in Asia and Africa (for example in Nigeria), there is a lack of awareness of pharmacists' roles and responsibilities in nuclear medicine practice (Adedapo *et al*., 2013; Parasuraman *et al*., 2014b). Brazil's hospitals believed pharmacists' services were not required at the nuclear medicine unit (Patidar *et al*., 2010). Whereas, in the Philippines, there is increasing use of radiopharmaceuticals. However, only a few hospitals have encouraged the inclusion of pharmacists in the nuclear pharmacy unit (Bautista & San Luis Jr, 2016). Beach et al. (2012) advocated the inclusion of radiopharmacists in the nuclear medicine team to provide appropriate and adequate pharmaceutical care. The International Atomic Energy Agency had reported an acute shortage of radiopharmacists resulting from the absence of pharmacists with adequate radiopharmacy training or certification (Agency, 2010). All these underpinned the fact that there is a shortage of radiopharmacists among nuclear medicine teams. This could have stemmed from pharmacists' lack of training or interest in nuclear medicine practice.

Research in radiopharmacy and the use of radiopharmaceuticals is scanty, but previous publications have emphasised patients' lack of knowledge regarding radiation (Alomi *et al*., 2021a; Busey *et al*., 2013). This has been attributed to the fact that many healthcare providers have little knowledge about radiation and, thus, are poorly equipped educators (Busey *et al*., 2013). Nuclear medicine services, though still an emerging area in the field of medicine in Nigeria, have not been optimally utilised in the country. This can be attributed, among other factors, to the knowledge of healthcare professionals on the role of radiopharmaceuticals in disease management and how nuclear medicine services are perceived. A significant factor that may influence pharmacists' participation and patients' acceptance of nuclear medicine technology is their knowledge and perception of the role of radiopharmaceuticals in disease management. In Nigeria, there is a dearth of data on the awareness of the use of radiopharmaceuticals among pharmacists and patients. Hence, this study evaluated the knowledge and awareness of pharmacists and patients on the use of radiopharmaceuticals in diagnosing and managing diseases. The study also assessed the socio-demographic characteristics of pharmacists and patients associated with the knowledge of radiopharmaceuticals.

Methods

Study period, site and population

This cross-sectional study was conducted between September 2020 and August 2021 among ambulatory patients at the Nuclear Medicine Centre, Radiopharmacy Unit, University College Hospital, Ibadan, and among hospital and community pharmacists in three selected states in southwest Nigeria. Two states, Lagos and Oyo, were chosen because of their peculiarities. Lagos state has one of the country's largest populations and is the commercial nerve centre of the nation. Different ethnic groups and professionals live and work in the state. Oyo state is the 2nd biggest state in the country and houses one of the nuclear medicine centres in the nation. This serves as a referral centre for most hospitals in the nation. The third state is a neighbouring southwest state which also houses the oldest tertiary health centre in the country, though without a Nuclear Medicine Centre.

Sample size determination

According to the Pharmacy Council of Nigeria (PCN) register of 2019, 4,199, 550, and 269 community and hospital pharmacists were in Lagos, Oyo, and Osun states, respectively. From these sample frames, the sample size for each condition was calculated using the Taro Yamane formula with a 5% sampling error, 95% confidence interval and 10% allowance for non-response. The estimated sample size for the community and hospital pharmacists in Lagos, Oyo, and Osun states were 365, 231, and 161, respectively.

On average, 25 patients per month attend the Nuclear Medicine Centre, radiopharmacy unit, with an estimated 5 repeat patients. The study among the patients was conducted over four months, and the estimated number of patients who attended the

Nuclear Medicine Clinic was 100. The number of possible repeat patients for this period was 20. Thus, the sample frame from which the sample size was calculated using the same formula above was 80. The eventual sample size of the patients with consideration for 10% non-response was 67.

Selection criteria

Community and hospital pharmacists in different cadres of practice, interns and pharmacists on the National Youth Service Corp programme for recent graduates working in hospitals or community pharmacies from each selected state participated in the study. Student pharmacists on externship posting to community and hospital pharmacies were excluded. Ambulatory patients who were 18 years and above were included. Patients or caregivers who could not communicate with the data collector in Yoruba or English (the languages the questionnaire was written) were excluded. Patients or pharmacists who declined consent were also excluded from the study.

Data collection instrument

The questionnaire was developed after a detailed review of the literature (Alomi *et al*., 2021a; Brasil *et al*., 2012; Busey *et al*., 2013; Debnath & Babu, 2015; Laven & Martin, 1989; Mayur *et al*., 2016; Parasuraman *et al*., 2014b; Ramil, 2022). The structured self-administered online questionnaire for pharmacists consisted of three sections: a section on socio-demographic characteristics of the participants, a section containing 17-item Likert scale with 7-graded responses (1 – Strongly disagreed to 7 – Strongly agree) which assessed the knowledge of pharmacists on radiopharmaceuticals, the third section contained 11-item Likert scale with 7-graded responses (1 – Untrue of what I believe to 7 - True of what I believe) on perception of the pharmacists on the health benefits and risks of radiopharmaceuticals in disease management and nuclear pharmacy practice. The patient's structured interviewer-administered questionnaire was written in English for those who could read and write in the language but translated to Yoruba and back-translated to English for patients who do not understand the English language. The questionnaire for patients was similarly structured like the pharmacists to collect socio-demographic data, assess patients' knowledge of radiopharmaceuticals with 13-item Likert scale questions with 5-graded responses (1 – Strongly disagree to 5 – Strongly agree), and perceived benefits and risks of radiopharmaceuticals in the management of diseases with 6-item questions using a Likert scale with similar graded responses.

The study protocol and sampling technique

Three experts validated the questionnaires; two were lecturers in Clinical Pharmacy Department, and the third was a radiopharmacist in the Nuclear Medicine Department of University College Hospital. The three experts ascertained whether the questions effectively captured the study's objectives. A pre-test of the questionnaire for pharmacists was carried out among fifteen hospital and community pharmacists in Oyo state who did not participate in the main study, while the questionnaire for patients was pre-tested among five patients who were subsequently excluded from the main study. Some of the questions in the questionnaire were either rephrased or deleted based on the expert reviewers' advice and the pre-test outcome.

An online questionnaire-guided survey was conducted among hospital and community pharmacists in the three selected states, Lagos, Oyo and Osun, in the southwestern part of Nigeria using a convenient sampling method. The link to the questionnaire was shared on the Association platforms of community and hospital pharmacists in each state and the Pharmaceutical Society of Nigeria WhatsApp platform of each state with the instruction that only community and hospital pharmacists should fill out the online questionnaire. Pharmacists were encouraged to share among colleagues practising in the same area. At the beginning of the online questionnaire, pharmacist participants had to indicate if they consented to participate in the study by checking a box. Those who declined consent could not proceed further with the questionnaire filling.

The questionnaire for patients was interviewer-administered, and patients were conveniently sampled as they visited the Nuclear medicine clinic. Those who gave consent to participate after a detailed explanation of the purpose of the study were administered the questionnaire. The caregivers assisted patients who did not understand English. Translation and back translation of responses were done to ensure comprehension and consistency. Repeat patients were those returning to the clinic for a scan or treatment but had filled out the questionnaire before. This group of participants was not allowed to fill out the questionnaire again.

Data analysis

Data obtained were sorted, coded, and analysed using Statistical Package for Social Sciences version 27 (IBM Corp, New York, USA). Descriptive statistics such as frequency and percentage were used to summarise the data. The responses to pharmacists' knowledge were categorised into Disagree (strongly disagree, disagree, and somewhat disagree responses), Neither agree nor disagree, and Agree (somewhat agree, agree, and

strongly agree). Those patients were categorised into three Agree (agree and strongly agree), Neither agree nor disagree, and Disagree (disagree and strongly disagree). The reliability of the scales was determined with the Cronbach alpha reliability coefficient. Correct responses to the knowledge questions, whether agree or disagree, were assigned 1 point, and incorrect answers were given 0 points. Total knowledge and percentage knowledge scores were calculated. Minimum and maximum knowledge of radiopharmaceutical obtainable by a pharmacist or patient is (Min. = 0, Max. = 17); and (Min. = 0, Max. = 11), respectively. For the pharmacists, good knowledge was assigned a value of ≥ 50% and below average knowledge, a value of < 50%, while for patients, good knowledge was rated as ≥ 40% and below average knowledge as < 40%.

The responses on the pharmacists' perception were further categorised into Very untrue of what I believe (very untrue of what I believe, untrue of what I believe, and somewhat untrue of what I believe), Neutral, and Very true of what I believe (somewhat true of what I believe, true of what I believe, and very true of what I believe). Kruskal Wallis and Mann Whitney U tests were employed to investigate the association between socio-demographic variables of the pharmacists and patients with the knowledge of radiopharmaceuticals score at $p < 0.05$ level of statistical significance.

Results

Pharmacists' knowledge and perception of radiopharmaceuticals

The response rate for pharmacists could not be ascertained as the questionnaire was distributed online. The Cronbach alpha reliability coefficient of the scales used ranged between 0.591 to 0.711. Table I shows that more male pharmacists (177 (51.6%) than females (166 (48.4%) participated in the study. The average year since graduation and the number of years spent in the current practice setting were 14.50 ± 10.58 years and 8.58 ± 7.99 years, respectively. One hundred and fifty-seven pharmacists (45.8%) had additional postgraduate degrees.

Table I: Demographic characteristics of pharmacists

Variable	Frequency (%)	Mean ± SD
Age, years		38.93 ± 10.94
≤ 28	38 (11.1)	
29 - 39	159 (46.4)	
40 - 50	90 (26.20	
51+	56 (16.3)	
Sex		
Male	177 (51.6)	
Female	166 (48.4)	
Additional qualification		
None	147 (42.9)	
Doctor of Pharmacy	39 (11.4)	
Postgraduate degree	157 (45.8)	
Practice setting		
Community pharmacy	187 (54.5)	
Hospital pharmacy	156 (45.5)	
Stage of practice		
Lagos	129 (37.6)	
Oyo	142 (41.4)	
Osun	72 (21.0)	
Year of graduation		14.50 ± 10.58
≤ 8	119 (34.7)	
9 - 16	119 (34.7)	
17+	105 (30.6)	
Years spent at current practice setting		8.58 ± 7.99
≤ 3	111 (32.4)	
4 - 6	69 (20.1)	
7 - 11	79 (23.0)	
12+	84 (24.5)	

The mean pharmacists' knowledge score was 8.72 ± 2.59. Overall, 191 pharmacists (55.7%) had good knowledge of radiopharmaceuticals while 150 (44.3%) had below-average knowledge. More than half of the community pharmacists, 101 (54.0%) and the hospital pharmacists had good knowledge of radiopharmaceuticals 90 (57.7%). Of some of the pharmacists, 107 (31.2%) knew that radiopharmaceuticals could not be used to treat the majority of diseases, and because radiopharmaceuticals are made from radioisotopes, 251 (73.2%) of the pharmacists correctly affirmed that the rays emitted can damage healthy cells. Seventy-three pharmacists (21.3%) were aware that radiopharmaceuticals are not only controlled by regulatory authorities as radioactive substances but also as drugs, and 167 (48.7%) affirmed that radiopharmaceuticals are organ or tissue specific. In Table II, 213 (62.1%) pharmacists disagreed with the statement that: "*drug interactions are not possible with radiopharmaceuticals",* while 253 (73.8%) of the pharmacists also disagreed with the statement that "*pharmaceutical care is impracticable with radiopharmaceuticals*".

Table II: Pharmacists knowledge of radiopharmaceuticals

Questions on knowledge of radiopharmaceuticals	Disagree N* (%)	Neither agree nor disagree N* (%)	Agree N* (%)
Radiopharmaceuticals are mainly used for diagnosis	142 (41.4)	31 (9.0)	170 (49.6)†
Radiopharmaceuticals can be used in the treatment of majority of diseases	107 (31.2)†	37 (10.8)	199 (58.0)
Because radiopharmaceuticals are made from radioisotopes, the rays emitted by these isotopes can cause severe damage to healthy cells in the body	61 (17.8)	31 (9.0)	251 (73.2)†
Radiopharmaceuticals are metabolised before elimination from the body	84 (24.5)	111 (32.4)	148 (43.1)†
The half-life of a radiopharmaceutical does not have effect on its usefulness	243 (70.8)†	60 (17.5)	40 (11.7)
A radiopharmaceutical has two components: a radionuclide and a pharmaceutical substance.	43 (12.5)	73 (21.3)	227 (66.2)†
The ideal pH of a radiopharmaceutical should be 4.7	44 (12.8)†	215 (62.7)	84 (24.5)
Radiopharmaceuticals are controlled ONLY as radioactive substances by regulatory authority.	73 (21.3)†	109 (31.8)	161 (46.9)
Radiopharmaceuticals are not organ or tissue selective	167 (48.7)†	71 (20.7)	105 (30.6)
The type of radiation emitted by the radiopharmaceutical is selected depending on the purpose of its use	27 (7.9)	57 (16.6)	259 (75.5)†
Drug interactions are not possible with radiopharmaceuticals	213 (62.1)†	64 (18.7)	66 (19.2)
Some radiopharmaceuticals may be applied as a topical application	87 (25.4)	87 (25.4)	169 (49.3)†
Technetium, Tc 99m, is a radiopharmaceutical most widely used for diagnosis	20 (5.8)	153 (44.6)	170 (49.6)†
Radiation exposures from administration of radiopharmaceuticals are harmless	237 (69.1)†	49 (14.3)	57 (16.6)
Nuclear medicine imaging does not offer the potential to identify disease in its earliest stages	231 (67.3)†	71 (20.7)	41 (12.0)
Knowledge categories	**Community pharmacists N (%)**		**Hospital pharmacists N (%)**
Below average knowledge (< 50%)	86 (46.0)		66 (42.3)
Good knowledge (≥ 50%)	101 (54.0)		90 (57.7)

†Correct answer, *Number of participants in each category

Most pharmacists, 212 (61.8%), believed that radiopharmaceuticals are administered as a drug. However, a few pharmacists, 71 (20.7%), would not like to practice radiopharmacy if the remuneration was higher than other pharmacy practice settings (Table III). Almost half of the pharmacists, 146 (42.6%), are deterred from practicing radio-pharmacy because of the perceived belief that radioactive exposure can lead to cancer, and the practice requires highly specialised skills 141 (41.1%). Two hundred and forty-five (71.4%) would like to offer their service as radiopharmacists if adequately trained, and 308 (89.8%) thought that patient education on radiopharmaceuticals is vital to ensure safety and avoid contamination (Table III).

Table III: Perception of pharmacists on radiopharmaceuticals

Questions on perception of radiopharmacy practice	Untrue of what I believe	Neutral	True of what I believe
Radiopharmaceuticals are administered as drugs	84 (24.5)	47 (13.7)	212 (61.8)
Radiopharmaceuticals should not be handled by pharmacists because the risks outweigh the benefits	272 (79.3)	37 (10.8)	34 (9.9)
I would not like to practice radiopharmacy even if the remuneration is higher than other areas of pharmacy practice	194 (56.6)	78 (22.7)	71 (20.7)
The possibility of having cancer as a result of radioactive exposure may deter me from engaging in radiopharmacy practice	125 (36.4)	72 (21.0)	146 (42.6)
The practice of radiopharmacy requires highly specialised training which I do not have time for	154 (44.9)	48 (14.0)	141 (41.1)
Radiopharmacy practice is not possible in community pharmacy setting	122 (35.6)	68 (19.8)	153 (44.6)
I consider radiopharmacy practice interesting because it allows complex interaction of disciplines including physics, chemistry, pharmacology, etc.	31 (9.0)	53 (15.5)	259 (75.5)
I would like to offer my services as a radiopharmacist if properly trained because I see radiopharmacy as an emerging area of practice	42 (12.2)	56 (16.3)	245 (71.4)
I would prefer that radiopharmacy is taught as a Postgraduate course	71 (20.7)	67 (19.5)	205 (59.8)
The use of radiopharmaceuticals is more cost effective compared with surgery for the same disease condition.	73 (21.3)	114 (33.2)	156 (45.5)
Patient education about radiopharmaceuticals is necessary to ensure safety and avoid contamination	17 (5.0)	18 (5.2)	308 (89.8)
Resources as well as enabling environment for optimal radiopharmacy practice are not readily available in Nigeria. I would rather embrace other field of pharmacy practice	86 (25.1)	73 (21.3)	184 (53.6)

The distribution of knowledge of radiopharmaceuticals score was the same across the different categories of the pharmacists' sex, age, additional qualifications, practice settings, year of graduation from pharmacy school and years spent in the current practice setting ($p > 0.05$), Table IV. Kruskal Wallis test revealed that the pharmacists' knowledge of radiopharmaceuticals score differs based on the state of practice (Lagos state Mean rank (MR) = 150.63, Oyo state MR = 191.69, Osun state 171.45; KW = 11.769, $p = 0.003$). Also, Mann Whitney U test showed that pharmacists who had attended lectures or seminars on radiopharmaceuticals (MR, = 215.59) had better knowledge of radiopharmaceuticals than those who did not participate in any lecture or seminar on radiopharmaceuticals (MR = 166.41), U = 4228.000, $p < 0.003$.

Table IV: Association of demographic variable of pharmacists with the knowledge score of radiopharmaceuticals

Variable	Categories	Number of participants in each category (N)	Radiopharmaceutical knowledge score Mean rank	*p*-value
Sex	Male	177	175.16	0.539[a]
	Female	166	168.63	
Age, years	≤ 28	38	182.34	0.554[b]
	29 - 39	159	170.51	
	40 - 50	90	179.09	
	51+	56	157.80	
Additional qualification	None	147	167.92	0.480[b]
	Doctor of Pharmacy	39	160.76	
	Postgraduate degree	157	178.61	
Practice setting	Community pharmacy	187	165.86	0.206[a]
	Hospital pharmacy	156	179.36	
State of practice	Lagos	129	150.63	0.003[b†]
	Oyo	142	191.69	

Variable	Categories	Number of participants in each category (N)	Radiopharmaceutical knowledge score Mean rank	*p*-value
	Osun	72	171.45	
Year of graduation	≤ 8	119	174.07	0.944[b]
	9 - 16	119	169.75	
	17+	105	172.21	
Years spent at current practice setting	≤ 3	111	173.36	0.870[b]
	4 - 6	69	168.93	
	7 - 11	79	168.09	
	12+	84	178.27	
Attended seminar or lecture of radiopharmaceuticals	Yes	39	215.59	0.003[a]†
	No	304	166.41	

[a]Mann Whitney U test, [b]Kruskal Wallis test, †$p < 0.05$.

Patients' knowledge and perception of radiopharmaceuticals

Eighty questionnaires were distributed among patients who gave consent to participate, but 76 of the questionnaires were useable and therefore analysed. The response rate for the patient was 95.0%. The mean age of the patients was 38.93 ± 10.94 years, with more being females 43 (56.6%), as shown in Table V. Most of the patients were of Yoruba ethnic origin, 50 (65.8%), had first degree, 43 (56.6%), worked in the private sector, 46 (60.5%), had cancer-related diagnosis, 45 (59.2%) and had had the disease for less than a year, 63 (82.9%).

As shown in Table VI, almost all the patients, 75 (98.7%), had good knowledge of radiopharmaceuticals. Most patients agreed that radiopharmaceuticals could be used to treat some cancer, 55 (72.4%), that taking fluid will help in the excretion of radiopharmaceuticals, 74 (97.4%), patients on radiopharmaceutical treatment must use separate cutleries to prevent radiation exposure to others, 47 (61.8%) and that radio pharmacists can help improve patient care by ensuring safe and quality preparation of radiopharmaceuticals, 67 (88.2%).

Patients, 68 (89.5%), believed that using radiopharmaceuticals for diagnosis and treatment would help in disease management and that education on radiopharmaceuticals is necessary, 75 (98.7%). Some patients, 44 (57.9%), believed that radiopharmaceuticals are not expensive and the procedure for administering radiopharmaceuticals is not time-consuming, 37 (48.7%). Few patients, 15 (19.7%), prefer other forms of treatment to the use of radiopharmaceuticals, and most, 60 (78.9%), are more concerned about getting better from their sickness than the effect of radiopharmaceutical radiation since the radiation is relatively low and safe.

Table V: Demographics of patients

Variable	Frequency (%)
Age, years	
≤ 40	14 (18.4)
41 -52	24 (31.6)
53 - 64	24 (31.6)
65+	14 (18.4)
Sex	
Male	33 (43.4)
Female	43 (56.6)
Highest level of education	
Primary/ Secondary	11 (114.5)
First degree	43 (56.6)
Postgraduate	22 (28.9)
Occupation	
Unemployed	14 (18.4)
Private sector	46 (60.5)
Public section	16 (21.1)
Patient diagnosis	
Renal Hydronephrosis (6), Renal cysts (5), Enlarged kidney on the right side (1), Kidney stone (3), Urine retention (3).	18 (23.7)
Cancer Thyroid cancer (5), Prostate cancer (21), Breast cancer (18), Lung cancer (1).	45 (59.2)
Others Pelvic uretic junction obstruction (2), Hyperthyroidism (9), 'Graves' disease (2).	13 (17.1)
Duration of illness, years	
< 1	63 (82.9)
1 – 10	4 (5.3)
>10	9 (11.8)
Purpose of clinic visit	
Diagnostic scan	65 (85.5)
Radioactive scan	11 (14.5)
Number of clinic visits	
≤ 3	62 (81.6)
4+	14 (18.4)

Patients' age, sex, level of education, occupation, diagnosis, duration of illness and the purpose of clinic visit were not associated with the knowledge of radiopharmaceuticals (p > 0.05). Patients who had more than four clinic visits (MR = 49.96) had more knowledge of radiopharmaceuticals than those who visited the clinics three times or less (MR = 35.91), U = 273.500, p = 0.029, Table VII.

Table VI: Patients knowledge of radiopharmaceuticals

Questions on knowledge of radiopharmaceuticals	Disagree N* (%)	Neither agree nor disagree N* (%)	Agree N* (%)
Radiopharmaceuticals are given as injections only	24 (31.6)†	28 (36.8)	24 (31.6)
Radiopharmaceuticals can be used to treat cancer	4 (5.3)	17 (22.4)	55 (72.4)†
Radiopharmaceuticals are used for diagnosis and treatment of diseases	1 (1.3)	10 (13.2)	65 (85.5)†
It is necessary that the patient tells the doctor about the drugs or herbs that he/she is taking before the scan or treatment	6 (7.9)	2 (2.6)	68 (89.5†
Drinking plenty water is good because it will help to remove the radiopharmaceuticals out of the body	1 (1.3)	1 (1.3)	74 (97.4†
Patients on radiopharmaceuticals for therapy have to use separate spoons and plates to prevent radiation exposure	14 (18.4)	15 (19.7)	47 (61.8†
The use of radiopharmaceuticals exposes one to radiation	7 (9.2)	9 (11.8)	60 (78.9†
Radiation exposure from radiopharmaceuticals are relatively low and safe	17 (22.4)	15 (19.7)	44 (57.9†
Patients on radiopharmaceuticals should keep away from family members and other people to reduce their radiation exposure	10 (13.2)	10 (13.2)	56 (73.7†
Radiopharmaceuticals can pass out of the body through urine or feces	2 (2.6)	11 (14.5)	63 (82.9†
Radiopharmacists help in patient care by preparing safe and good quality radiopharmaceuticals	2 (2.6)	7 (9.2)	67 (88.2†
Patient knowledge category			
Below average knowledge (< 40%)	1 (1.3%)		
Good knowledge (≥ 40%)	75 (98.7%)		

†Correct answer, *Number of participants in each category

Table VII: Association of demographic variable of patients with the knowledge score of radiopharmaceuticals

Variable	Frequency (%)	Mean rank	p-value
Age, years			
≤ 40	14	39.11	
41 -52	24	34.29	0.181[b]
53 - 64	24	35.92	
65+	14	49.54	
Sex			
Male	33	36.82	0.554[a]
Female	43	39.79	
Highest level of education			
Primary/secondary	11	43.27	
First degree	43	39.22	0.535[b]
Postgraduate	22	34.70	
Occupation			
Unemployed	14	35.04	
Private sector	46	38.27	0.662[b]
Public section	16	42.19	
Patient diagnosis			
Renal	18	31.08	

Variable	Frequency (%)	Mean rank	*p*-value
Hydronephrosis (6), Renal cysts (5), Enlarged kidney on the right side (1), Kidney stone (3), Urine retention (3).			
Cancer Thyroid cancer (5), Prostate cancer (21), Breast cancer (18), Lung cancer (1).	45	38.39	0.073[b]
Others Pelvic uretic junction obstruction (2), Hyperthyroidism (9), 'Graves' disease (2).	13	49.15	
Duration of illness, years			
< 1	63	39.59	
1 – 10	4	24.13	0.379[b]
>10	9	37.28	
Purpose of clinic visit			
Diagnostic scan	65	36.75	0.088[a]
Radioactive scan	11	48.82	
Number of clinic visits			
≤ 3	62	35.91	0.029[a]†
4+	14	49.96	

[a]Mann Whitney U test, [b]Kruskal Wallis test, †$p < 0.05$

Discussion

Pharmacists are one of the most respected professionals in the world (Blank, 2020). Aside from the core pharmacy practice and providing various forms of intervention to improve patient outcomes (Parasuraman *et al*., 2014b), pharmacists need to expand their horizons to include nuclear medicine. This evolving field also requires the pharmacist's expertise (Parasuraman *et al*., 2014b). Radiopharmacists operate a radio-pharmacy according to international guidelines and ensure pharmaceutical services to patients (Parasuraman *et al*., 2014b). To do this, adequate knowledge of radiopharmaceuticals is required, and to this end, this study was conducted among pharmacists and patients.

More than half of the pharmacists have good knowledge of radiopharmaceuticals; one-third knew that not all diseases could be treated with radiopharmaceuticals, and almost three-quarters agreed that rays from radiopharmaceuticals could damage healthy cells. These findings are slightly different from the report of other studies. According to the survey by Alomi et al. (2021a), Saudi Arabia pharmacists had poor knowledge of nuclear pharmacy practice. In a study conducted in Malaysia, India, Pakistan, Sri Lanka, Bangladesh, UAE and Nepal by Parasuraman et al. (2014a), about 30% of health professionals were aware of the use of radiopharmaceuticals in the health sector. However, their knowledge of the role of pharmacists in nuclear medicine was poor. The differences in these studies could be due to the instruments' construct. This study examined basic knowledge of radiopharmaceuticals, while the survey in Saudi Arabia evaluated the implementation of nuclear pharmacy practice. The background training of the pharmacists and their cadre might have also contributed to the differences noted. In Saudi Arabia, many of the healthcare organisations have nuclear medicine headed by the consultant physician working in collaboration with nurses, pharmacists, and technicians (Barnett & Kavula, 1992; Paez *et al*., 2016; Alomi *et al*., 2021a; Alomi *et al*., 2021b). Hospital pharmacists might have been slow in adding nuclear pharmacists to their staff and might have transferred such professional obligation to non-pharmacist personnel in the nuclear medicine domain. Thus incapacitating the provision of quality and safe radiopharmaceuticals and patient-oriented care peculiar to patients receiving radiopharmaceuticals for diagnosis or treatment (Laven & Martin, 1989).

Pharmacists' knowledge of radiopharmaceuticals is reflected in the excellent knowledge of the patients in this study. Almost all the patients knew the basics about radiopharmaceuticals, such as their use to treat some forms of cancers, how to excrete the radiopharmaceuticals from the body and how to prevent radiation exposure to others. It is possible that the healthcare professionals, including pharmacists who were in charge of patients requiring the use of radiopharmaceuticals must have consistently counselled and educated the patients on the need and use of radiopharmaceuticals as attested to by the level of knowledge of patients who had attended more clinics. However, this was not investigated in this study. Appropriate education and counselling help patients

understand the disease and its management and the possible therapeutic outcomes and untoward effects to expect. One of the most significant challenges of nuclear pharmacists is educating various stakeholders, including health professionals, manufacturers, government agencies or professional bodies, on its ability to reduce the cost of patient care (Laven & Martin, 1989). One of the duties of pharmacists is to understand the patient's attitudes and behaviour towards medication use. This will assist the pharmacists in knowing whether the patient is willing and will use the medication. The patients in this study were of the opinion that radiopharmaceuticals are not expensive, and their administration is simple. Most prefer treatment with radiopharmaceuticals and are more concerned with recovery than side effects.

Few pharmacists, 21%, knew that radiopharmaceuticals are regulated as drugs and radioisotopes. Tubis & Wolf (1986) identified three areas where radio-pharmacists are needed, including in-house preparation and quality control of radiopharmaceuticals, formulation of radiopharmaceuticals that are not commercially available and fulfilling regulatory requirements in the Nuclear Medicine Unit/Radiology Department. Pharmacists are critical to these drugs' formulation and quality control (Daya, 2022).

One-fifth of the pharmacists would not like to practice radio-pharmacy even if the remuneration is high, and more than half of the pharmacists are deterred from practising radio-pharmacy because of the consequences of exposure to radioactive rays. Contrary to these findings, in Sri Lanka, as reported by Riyasha et al. (2013) participants were willing to practice radio-pharmacy. Most pharmacists and other healthcare professionals are not aware of the job of a nuclear pharmacist (Barnett & Kavula, 1992; Ponto & Hung, 2000; Gillings *et al*., 2021) and the protective measures put in place to guard against radiation exposure and its consequences. However, radiation-induced cancer can occur when radiopharmaceuticals are given for radioactive imaging in diagnosis (Madulid *et al*., 2020). Though there is a need for radio pharmacists in the interprofessional nuclear pharmacy collaborative practice (Ramil, 2022), the seeming lack may be due to a deficiency in education at the undergraduate pharmacy training programme, which might have stimulated the interest of some undergraduate pharmacists to pursue such practice after graduation (Lutz, 2015). In the Philippines, courses in nuclear pharmacy are only offered to Master's and Ph.D. students (Ramil, 2022). Such should be extended to the undergraduate pharmacy curriculum. Nuclear medicine courses are included in the curriculum of the Pharm.D. programme in Saudi Arabia (Kastango & American Society of Health-System Pharmacists (ASHP), 2005). This was done to better pharmacists' knowledge of radio-pharmacy and increase the uptake of radio-pharmacy practice. About 71% of the pharmacists in this study would offer their services as radio-pharmacists if adequately trained.

Strengths and limitations of the study

The study's strength lies in assessing the knowledge of both the provider and receiver of radiopharmaceuticals, pharmacists and patients. Since there is a dearth of study in this area, it also added to the body of literature. One limitation of the study was that those who speak and understand other languages aside from English and Yoruba in Nigeria, though few, were excluded from the study. This might have affected the number of patients included in the survey. Nevertheless, the sample size calculated for the study was met. Also, in-patients were excluded from the study because access was denied for health and protective reasons. As with the online questionnaire among the pharmacists, only interested participants filled out the form and low response rates are associated limitations of online surveys. Thus, the results presented may represent the view of only those interested in this kind of study. It should also be noted that the knowledge evaluation was not a comprehensive assessment of the knowledge of radiopharmaceuticals but a general awareness of the basics. Pertaining to the generalisability of the results, this may be limited by the study's cross-sectional nature and the number of states involved. Inherent biases in self-report should also be considered when interpreting the results.

Conclusion

Pharmacists and patients in three states in Nigeria (Lagos, Oyo, and Osun) have good knowledge of the use of radiopharmaceuticals. Pharmacists' knowledge was influenced by the state of practice and prior knowledge of radiopharmaceuticals through lectures or seminars. On the other hand, the number of clinics attended influenced patients' knowledge. Pharmacists are unwilling to practice radio-pharmacy even with better remuneration unless adequate training is provided. Extending this to the undergraduate pharmacy curriculum would equip pharmacy graduates with the necessary skills in radio-pharmacy and stimulate interest.

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Conflict of interest

The authors declare no conflict of interest.

Ethical approval and informed consent

Ethical approval was obtained from University of Ibadan/University College Hospital Ethics Committee at the Institute for Advanced Medical Research and Training, College of Medicine, University of Ibadan. The committee's approval number of the protocol was UI/EC/20/0360. Written informed consent was obtained from each patient while an online indication of consent to participate was obtained from the pharmacists.

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