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Knowledge, perceptions and attitudes of radiologists and nuclear medicine physicians towards medical teleimaging in French-speaking sub-Saharan Africa

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Abstract

Background The successful development of teleimaging platforms depends on imaging physicians' knowledge, perceptions and support, but few studies have focused on this specific subject in Africa. The objective of this study is to assess the knowledge, perceptions and attitudes of radiologists and nuclear medicine physicians towards medical teleimaging in French-speaking sub-Saharan Africa.

Materials and methods This cross-sectional study was conducted from 5 May to 5 August 2022 and included radiologists and nuclear medicine physicians practising in French-speaking sub-Saharan African countries. Data were collected electronically via Google Forms.

Results Of the 141 imagers surveyed, 7.1% were nuclear medicine physicians, 65.96% had already received training in teleimaging, and 9.93% had already carried out formal teleimaging activities. Of the respondents, 44.68% were familiar with both primary teleimaging procedures (telediagnoses and tele-expertise), 51.06% had some knowledge of Picture Archiving and Communication Systems (PACS) and Digital Imaging and Communications in Medicine (DICOM), and 84.4% knew that patient consent was required before telediagnosis. Approximately one quarter were unaware that the presence of a nuclear medicine physician was mandatory for remote diagnosis in nuclear medicine, and 51.1% had no idea of the technical specifics of a computer dedicated to teleimaging. The majority (92.90%) perceived teleimaging as having more advantages than disadvantages, and 98.6% used virtual channels such as WhatsApp to transfer images. In 56.02% of the cases, they did not take any security precautions when performing teleimaging procedures.

Conclusion The level of knowledge of teleimaging among imaging physicians in French-speaking sub-Saharan Africa was relatively unsatisfactory, although the perception was encouraging, and the right attitudes were not always adopted.

Keywords Teleimaging, Radiologists, Nuclear medicine physicians, Telemedicine, French-speaking sub-Saharan Africa

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Background

Medical teleimaging involves the remote practice of medical imaging, enabled by advancements in information and communication technologies [1]. It is a form of telemedicine that involves performing a medical imaging procedure (radiology or nuclear medicine) and making the data from the examination available to a remote imaging physician who access it via a telecommunications system [1, 2].

Medical teleimaging was born at the end of the 1960s, when Dr. Kenneth Bird used a radio wave television transmission system between Massachusetts General Hospital (USA) and Logan Airport in Boston (USA), approximately 5 km apart [3]. In 1972, Andrus introduced 'teleradiology,' facilitating image transmission and interpretation over 50 km via radio waves [3]. Since then, teleimaging has benefited enormously from advances in information technology and telecommunications and is now the most mature, most advanced and undoubtedly most widely practised form of telemedicine. Its main objective is the exchange and sharing of medical information between healthcare professionals at a distance, in real or delayed time. The advent of the COVID-19 pandemic encouraged the use of telemedical imaging, which has emerged as an ideal solution for compliance with barrier procedures.

Unlike Europe, where several countries have formalised teleimaging services, the majority of remote medical imaging initiatives in Africa are limited to pilot projects [4, 5]. Despite the potential of teleimaging in improving healthcare access, few studies have explored its application in French-speaking sub-Saharan Africa. In Togo, for example, the first telemedical imaging initiatives began after 2010, notably with the low-cost teleimaging platform piloted between the CHU Campus de Lomé, the CHU de Tours in France and the CHR de Tsévié [6].

Analysis of these projects reveals that a number of conditions are essential for the sustainable introduction of teleimaging in sub-Saharan Africa [4, 5]. The development of a teleimaging platform depends on the support of imaging physicians (radiologists and nuclear medicine physicians). This support, in turn, depends on their knowledge and perceptions of teleimaging. However, few studies have focused on this specific subject in French-speaking sub-Saharan Africa. Therefore, we undertook this study, the general aim of which was to assess the knowledge, perceptions and attitudes of radiologists and nuclear medicine physicians towards teleimaging in French-speaking sub-Saharan Africa.

Materials and methods

This descriptive cross-sectional study was conducted from 05 May to 05 August 2022. The study included French-speaking radiologists and nuclear medicine physicians practising in sub-Saharan Africa, excluding trainees and those working outside the region. Informed consent was obtained from all individual participants included in the study.

The parameters studied were the general characteristics of radiologists and nuclear medicine physicians and their knowledge, perceptions and attitudes towards teleimaging in French-speaking sub-Saharan Africa in 2022. A pretested, bilingual questionnaire with both open- and closed-ended questions was distributed electronically. The questionnaire was developed for this study and the English language version is appended to the manuscript as a supplementary file. This questionnaire designed and saved on Google Forms at the address uniform resource locator https://docs.google.com/forms/d/e/1FAIpQLSeUrbrbOH23zXIvl4NunrBFt3nk17aSTjODWBaRJD-L_iDZg/viewform was sent by e-mail to the consenting radiologist and nuclear medicine physicians included in the data collection. The form was set up in such a way as to prevent multiple responses. All participants were informed about the purpose of the study and were requested to participate in the study if they consented. All the information regarding the study was mentioned in the body text of the Google form and mail invitation. They were also informed about their right to refuse participation or drop out at any moment of the study collection process. The data were recorded in Google Sheet and then transferred and analysed in the Microsoft Excel 2019 spreadsheet, where we produced dynamic cross-tabulations with graphs. Chi-square tests were used for categorical variables, and Fisher's exact test was applied for smaller sample sizes. Differences were considered statistically significant when the p value was less than 0.05.

Results

General characteristics of radiologists and nuclear medicine physicians (imaging physicians)

Our sample consisted of 141 imaging physicians, 131 of whom were radiologists (92.90%) and 10 of whom were nuclear medicine physicians (7.10%). Eighty-nine imaging physicians were male (63.12%), and 52 were female (36.88%), for a sex ratio of 1.71.

Burkina Faso and Togo were the most represented countries of origin and practice; the countries of training in general medicine and medical imaging of the respondents were dominated by Burkina Faso and Togo (Table 1).

Professional experience was between 0 and 5 years for 55 respondents (39%), between 6 and 10 years for 70

Table 1 Distribution of respondents by country of origin and training

	Country of origin		Country of practice		Country of training in general medicine		Country of specialisation	
	n	%	*n*	%	*n*	%	*n*	%
Benin	22	15.60	13	9.22	22	15.60	20	14.18
Burkina Faso	26	18.44	23	16.31	26	18.44	25	17.73
Cameroon	6	4.26	11	7.80	6	4.26	3	2.13
Central African Republic	1	0.71	2	1.42	1	0.71	0	0
Ivory Coast	18	12.76	15	10.64	10	7.09	18	12.76
Guinea Conakry	0	0	0	0	10	7.09	2	1.42
Mali	6	4.26	10	7.09	7	4.96	2	1.42
Morocco	0	0	0	0	1	0.71	1	0.71
Niger	15	10.64	16	11.35	15	10.64	0	0
DRC*	6	4.26	4	2.84	2	1.42	0	0
Senegal	14	9.93	14	9.93	14	9.93	16	11.35
Togo	27	19.15	33	23.40	27	19.15	54	38.30
Total	141	100	141	100	141	100	141	100

*DRC: Democratic Republic of the Congo

respondents (49, 64%), between 15 years for 10 respondents (7.09%) and more than 15 years for 6 respondents (4.25%).

Among the respondents, 51 (36.2%) had already performed a postdoctoral internship in Europe, 45 (88.23%) of whom had done their postdoctoral internships in France.

Forty-four respondents (31.2%) worked in both the public and private sectors. Forty-one imaging physicians (29.1%) worked solely in the public sector, whereas the remainder ($n=56$; 39.7%) worked in the private sector. Of the respondents, 93 (65.96%) reported prior training in teleimaging, 49 (52.69%) of whom had taken it in their medical school. A total of 94 imaging physicians (66.7%) stated that they did not know of any formal structure for medical teleimaging in their country, and 90 (63.8%) did not know whether their country had legislation on telemedicine. Internet connections were available at the place of practice of 130 imaging physicians (92.2%), with the quality of the internet connections judged to be poor in 92 cases (71.31%). There were 14 imaging physicians (9.93%) who had already practised a formal medical teleimaging activity, 10 of whom (71.43%) had practised teleradiology, 3 (21.43%) had practised tele-echography, and 1 (7.14%) had practised tele-MRI.

Radiologists' and nuclear physicians' knowledge of medical teleimaging in French-speaking sub-Saharan Africa

There were 119 (84.4%) and 111 (78.72%) imaging physicians aware that it is important to have the patient's consent before a telediagnosis or tele-expertise procedure. The importance of patient consent prior to a tele-expertise procedure was better known, with a statistically significant difference ($p<0.05$) between imaging physicians aged over 35 years and those who had already received continuing training in medical teleimaging (Table 2).

Sixty-three respondents (44.68%) were familiar with the two main telemedical imaging procedures (telediagnosis and tele-expertise), and 72 respondents (51.06%) were familiar with PACS and DICOM. Awareness of PACS and DICOM was significantly higher among imaging physicians with European training ($p<0.05$), those starting their professional experience ($p<0.05$) and those working in the public sector ($p<0.05$) (Table 3).

One hundred and fifteen respondents (81.56%), knew that justification should be given for carrying out a medical teleimaging procedure, 69 (49.9%) claimed to have some knowledge of the technical specifications of a computer or console dedicated to medical teleimaging, and 29 (20.56%) claimed to have some knowledge of the security of teletransmission. Knowledge of the need to justify a teleimaging procedure, on the one hand, and knowledge of the technical specifications of a computer dedicated to teleimaging, on the other hand, were significantly ($p<0.05$) more common among imaging physicians aged over 35 years (Table 4).

Forty-five of them (31.91%) knew that the presence of a radiologist was important at the patient site when carrying out teleradiology activities, and 33 (23.40%) knew that the presence of a nuclear medicine physician was important at the patient site when carrying out telenuclear medicine activities. Imaging physicians under 35 years of age and those who had already carried out a

Table 2 Profile of respondents aware of the importance of obtaining patient consent prior to a telediagnosis or tele-expertise procedure

	Patient consent prior to a telediagnosis procedure			Patient consent prior to a tele-expertise procedure		
	n	%	*p*	n	%	*p*
Age			**0.375**			**0.001**
Under 35 (*n* = 23)	18	78.26		12	52.17	
35 to 65 years (*n* = 118)	101	85.59		99	83.90	
Taking part in a MTI activity			**0.159**			**0.482**
Never practised (*n* = 127)	109	85.83		101	79.53	
Already practised (*n* = 14)	10	71.43		10	71.43	
Teleimaging training			**0.803**			**0.012**
No training (*n* = 48)	40	83.33		32	66.67	
Continuing training (*n* = 93)	79	84.95		79	84.95	
Current area of practice			**0.641**			**0.148**
Private (*n* = 56)	49	87.50		47	83.93	
Public (*n* = 41)	33	80.49		28	68.29	
Private and public (*n* = 44)	37	84.09		36	81.82	
Postdoctoral internship in Europe			**0.324**			**0.623**
Completed (*n* = 51)	41	80.39		39	76.47	
Not carried out (*n* = 90)	78	86.67		72	80	
Professional experience (years)			**0.44**			**0.000**
0–5 (*n* = 55)	44	80		37	67.27	
6–10 (*n* = 70)	63	90		63	90	
11–15 (*n* = 10)	9	90		9	90	
>15 (*n* = 6)	3	50		2	33.33	
Doctor's speciality			**0.612**			**0.210**
Nuclear physician (*n* = 10)	9	90		5	50	
Radiologist (*n* = 131)	110	83.97		106	80.92	
Doctor's qualifications			**0.699**			**0.690**
University hospital (*n* = 30)	26	86.67		20	66.67	
Hospital practitioner (*n* = 111)	93	83.78		91	81.98	

MTI: medical teleimaging

formalised medical teleimaging activity were the most aware of the need for a nuclear medicine physician to be present at the patient site during a telenuclear medicine activity, with a statistically significant difference ($p < 0.05$) (Table 5).

Perceptions and attitudes of radiologists and nuclear medicine physicians towards medical teleimaging in French-speaking sub-Saharan Africa

One hundred thirty-nine respondents (98.58%) felt that teleimaging had advantages, and 132 (93.61%) felt that it had disadvantages. One hundred thirty-one respondents (92.90%) felt that telemedical imaging had more advantages than disadvantages, with a statistically significant difference ($p < 0.05$) among hospital practitioners over 35 years of age (Table 6).

One hundred thirty-seven respondents (97.16%) felt that they would like to practice teleimaging in their country of practice, and 136 (96.45%) felt that radiologists and nuclear medicine physicians needed training before practising medical teleimaging. These perceptions were not statistically significantly related to any of the general characteristics of the respondents (Table 7).

One hundred and thirteen imaging physicians, or 80.14%, with a statistically significant difference ($p < 0.05$) between radiologists and those who had already received continuing education in teleimaging, felt that medical imaging was the specialty most concerned with telemedicine (Table 8).

One hundred and twenty-one imaging physicians (85.81%) felt that their interest in medical teleimaging had increased since the COVID-19 pandemic, and

Table 3 Profile of respondents with knowledge of the two medical teleimaging (MTI) procedures and those with knowledge of Picture Archiving and Communication Systems (PACS) and Digital Imaging and Communications in Medicine (DICOM)

	Knowledge of the two MTI procedures			Basics of PACS and DICOM		
	n	%	*p*	*n*	%	*p*
Age			**0.050**			**0.304**
Under 35 (*n* = 23)	6	26.09		14	60.87	
35 to 65 years (*n* = 118)	57	48.30		58	49.15	
Taking part in a MTI activity			**0.673**			**0.000**
Never practised (*n* = 127)	56	44.09		58	45.67	
Already practised (*n* = 14)	7	50		14	100	
Teleimaging training			**0.112**			**0.110**
No training (*n* = 48)	17	35.42		29	60.42	
MTI Continuing training (*n* = 93)	46	49.46		43	46.24	
Current area of practice			**0.052**			**0.000**
Private (*n* = 56)	30	53.57		20	35.71	
Public (*n* = 41)	12	29.27		33	80.49	
Private and public (*n* = 44)	21	47.73		19	43.18	
Postdoctoral internship in Europe			**0.940**			**0.037**
Completed (*n* = 51)	23	45.10		32	62.75	
Not carried out (*n* = 90)	40	44.44		40	44.44	
Professional experience (years)			**0.014**			**0.000**
0–5 (*n* = 55)	39	70.91		34	61.82	
6–10 (*n* = 70)	5	7.14		23	32.86	
11–15 (*n* = 10)	9	90		9	90	
>15 (*n* = 6)	0	0		6	100	
Doctor's speciality			**0.757**			**0.214**
Nuclear physician (*n* = 10)	4	40		7	70	
Radiologist (*n* = 131)	59	45.04		65	49.62	
Doctor's qualifications			**0.159**			**0.304**
University hospital (*n* = 30)	10	33.33		24	80	
Hospital practitioner (*n* = 111)	53	47.75		48	43.24	

MTI: medical teleimaging

95 imaging physicians (67.37%) wanted to pay the same medical teleimaging as for face-to-face medical imaging.

One hundred thirty-nine imaging physicians (98.6%) had already sent, received or interpreted a virtual medical imaging examination. The virtual channel most commonly used by imaging physicians for transferring medical imaging examinations was the WhatsApp application, followed by e-mail (Fig. 1).

Seventy-nine imaging physicians (56.02%) stated that they had not made any arrangements for remote medical imaging. Four respondents (2.83%) had managed authorisations, 55 (39%) had identified the patient, and 3 (2.12%) had tracked access.

Fifty-four respondents (38.29%) said that they had already read an article on medical teleimaging, and 23 respondents (16.31%) said that they had already read an article on a medical teleimaging activity carried out in Africa.

Discussion

This study highlights limited teleimaging knowledge but favourable perceptions among imaging physicians in French-speaking sub-Saharan Africa. Our study included 141 radiologists and nuclear medicine physicians from 14 of the 21 French-speaking countries in sub-Saharan Africa, including 100% of the French-speaking countries in West Africa. One of the reasons why we were unable to reach radiologists in all French-speaking sub-Saharan African countries was that it was difficult to find motivated correspondents in southern African countries, for example, to encourage imaging physicians to complete the survey form. The low proportion of nuclear medicine physicians in our sample reflects the scarcity of nuclear medicine physicians compared with radiologists in French-speaking sub-Saharan Africa. Nuclear medicine is still underdeveloped in sub-Saharan Africa, particularly in

Table 4 Profile of respondents who knew that medical teleimaging should be justified, those with knowledge of the technical specifications of a computer or console dedicated to MTI and those with knowledge of the security of teletransmission

	Justification for MTI			Technical specifications			Knowledge of teletransmission security		
	n	%	*p*	*n*	%	*p*	*n*	%	*p*
Age			**0.027**			**0.004**			**0.146**
Under 35 (*n* = 23)	15	65.22		5	21.74		6	26.09	
35 to 65 years (*n* = 118)	100	84.75		64	54.24		23	19.49	
Taking part in a MTI activity			**0.251**			**0.632**			**0.215**
Never practised (*n* = 127)	102	80.31		63	49.61		24	18.90	
Already practised (*n* = 14)	13	92.86		6	42.86		5	35.71	
Teleimaging training			**0.005**			**0.110**			**0.234**
No training (*n* = 48)	33	68.75		19	39.58		8	16.67	
MTI Continuing training (*n* = 93)	82	88.17		50	53.76		21	22.58	
Current area of practice			**0.377**			**0.170**			**0.508**
Private (*n* = 56)	48	85.71		30	53.57		10	17.86	
Public (*n* = 41)	34	82.93		15	36.59		11	26.83	
Private and public (*n* = 44)	33	75		24	54.55		8	18.18	
Postdoctoral internship in Europe			**0.124**			**0.493**			**0.807**
Completed (*n* = 51)	45	88.24		23	45.10		17	33.33	
Not carried out (*n* = 90)	70	77.78		46	51.11		12	13.33	
Professional experience (years)			**0.168**			**0.003**			**0.057**
0–5 (*n* = 55)	42	76.36		17	30.91		11	20	
6–10 (*n* = 70)	62	88.57		44	62.86		12	17.14	
11–15 (*n* = 10)	7	70		6	60		2	20	
>15 (*n* = 6)	4	66.67		2	33.33		4	66.67	
Doctor's speciality			**0.475**			**0.214**			**0.429**
Nuclear physician (*n* = 10)	9	90		3	30		3	30	
Radiologist (*n* = 131)	106	80.92		66	50.38		26	19.85	
Doctor's qualifications			**0.778**			**0.006**			**0.000**
University hospital (*n* = 30)	25	83.33		8	26.67		19	63.33	
Hospital practitioner (*n* = 111)	90	81.08		61	54.95		10	9.01	

MTI: medical teleimaging

French-speaking Africa, where very few countries have functional nuclear medicine services [7].

Most imaging physicians surveyed were unaware of any formal medical teleimaging structures within their countries (66.7%) and did not know whether their country had legislation on telemedicine (63.8%), and only 9.93% of the imaging physicians had already carried out formal medical teleimaging. This result shows that teleimaging is still not widely practised or organised in French-speaking sub-Saharan Africa, with a legislative and regulatory framework that is still nonexistent in most countries. This situation has also been reported in English-speaking African countries such as Nigeria, where teleimaging is still very underdeveloped [5, 8]. Similar to findings in Nigeria, our results indicate underutilisation of teleimaging due to inadequate infrastructure and training. In addition to the organisational and regulatory aspects, the accessibility of internet connections for satisfactory quality teletransmission is one of the crucial problems in the development of teleimaging in developing countries [9, 10]; therefore, it is not surprising that the quality of internet connections was judged to be poor in 71.31% of the cases by the respondents in our study.

Medical teleimaging comprises two main procedures (acts), namely telediagnosis and tele-expertise [2, 11]. Thus, telediagnosis is defined as the remote medical imaging management of a patient in the absence of an imaging physician on site, either on a one-off emergency basis or on a regular non-emergency basis [2]. As for tele-expertise, it allows an imaging physician or other medical professional to request remote interpretation of a complex or rare examination by an imaging physician on the basis of his or her expertise [2]. Unfortunately, 55.32% of the physicians in our series were unaware of

Table 5 Profile of respondents who were not aware of the need for a nuclear medicine physician to be present at the patient's site during a telenuclear medicine activity or a radiologist to be present at the patient's site during a teleradiology activity

	Presence of a nuclear medicine physician			Presence of a radiologist		
	n	%	*p*	*n*	%	*p*
Age			**0.01**			**0.00**
Under 35 (*n* = 23)	13	56.52		7	30.43	
35 to 65 years (*n* = 118)	95	80.51		89	75.42	
Taking part in a MTI activity			**0.00**			**0.00**
Never practised (*n* = 127)	103	81.10		92	72.44	
Already practised (*n* = 14)	5	35.71		4	28.57	
Teleimaging training			**0.74**			**0.16**
No training (*n* = 48)	36	75		29	60.42	
MTI Continuing training (*n* = 93)	72	77.42		67	72.04	
Current area of practice			**0.11**			**0.00**
Private (*n* = 56)	47	83.93		46	82.14	
Public (*n* = 41)	27	65.85		18	43.90	
Private and public (*n* = 44)	34	77.27		32	72.73	
Postdoctoral internship in Europe			**0.39**			**0.30**
Completed (*n* = 51)	37	72.55		32	62.75	
Not carried out (*n* = 90)	71	78.89		64	71.11	
Professional experience (years)			**0.268**			**0.624**
0–5 (*n* = 55)	46	83.64		40	72.73	
6–10 (*n* = 70)	51	72.86		46	65.71	
11–15 (*n* = 10)	6	60		7	70	
>15 (*n* = 6)	5	83.33		3	50	
Doctor's speciality			**0.79**			**0.56**
Nuclear physician (*n* = 10)	8	80		6	60	
Radiologist (*n* = 131)	100	76.34		90	68.70	
Doctor's qualifications			**0.33**			**0.05**
University hospital (*n* = 30)	21	70		14	46.67	
Hospital practitioner (*n* = 111)	87	78.38		82	73.87	

MTI: medical teleimaging

these two telemedical imaging procedures. Telemedicine in general and medical teleimaging in particular are first and foremost acts of medicine and must therefore be governed by the ethical requirements of medical practice, in which patient consent figures prominently [11, 12]. It is therefore gratifying that 84.4% and 78.72% of the imaging physicians in our study knew that obtaining the patient's consent before a telediagnosis or tele-expertise procedure is important. Similarly, this study revealed that 81.56% of imaging physicians knew that teleimaging should be justified. Indeed, we don't do medical teleimaging for the pleasure of doing it. It is necessary when there is an emergency or a shortage of imaging physicians available to carry out the procedure in person. Whenever possible, in-person imaging should be preferred to teleimaging. Justification in medical teleimaging concerns not only the appropriateness of the teleimaging procedure but also the relevance of the imaging examination to be carried out, particularly irradiating examinations, in accordance with the first principle of radiation protection, which stipulates that an irradiating examination is justified if the expected benefit outweighs the potential risks [13]. This principle therefore remains valid for both in-person and remote imaging procedures.

Medical teleimaging platforms often use digital solutions governed by norms or standards, the most widely used of which are Digital Imaging and Communications in Medicine (DICOM) and Picture Archiving and Communication Systems (PACS), which, in our study, were known to approximately half the respondents, particularly those who had already carried out formal teleimaging activities ($p < 0.05$). The DICOM standard was created with the aim of standardising the data transmitted between different radiology equipment. This standard defines not only a file format but also a data transmission protocol [14]. The PACS, on the other hand, is a

Table 6 Profile of respondents according to their perceptions of the advantages and disadvantages of medical technology

	Advantages			Disadvantages			More advantages than disadvantages		
	n	%	*p*	*n*	%	*p*	*n*	%	*p*
Age			**0.529**			**0.620**			**0.03**
Under 35 (*n* = 23)	23	100		21	91.30		18	78.26	
35 to 65 years (*n* = 118)	116	98.31		111	94.07		113	95.76	
Taking part in a MTI activity			**0.636**			**0.202**			**2.76**
Never practised (*n* = 127)	125	98.43		110	86.61		117	92.13	
Already practised (*n* = 14)	14	100		12	85.71		14	100	
Teleimaging training			**0.631**			**0.033**			**0.072**
No training (*n* = 48)	47	97.92		42	87.5		42	87.5	
MTI Continuing training (*n* = 93)	92	98.92		90	96.77		89	95.70	
Current area of practice			**0.512**			**0.014**			**0.262**
Private (*n* = 56)	56	100		56	100		54	96.43	
Public (*n* = 41)	40	97.56		35	85.37		36	87.80	
Private and public (*n* = 44)	43	97.73		41	93.18		41	93.18	
Postdoctoral internship in Europe			**0.284**			**0.593**			**0.074**
Completed (*n* = 51)	51	100		47	92.16		50	98.04	
Not carried out (*n* = 90)	88	97.78		85	94.44		81	90	
Professional experience (years)			**0.12**			**0.233**			**0.302**
0–5 (*n* = 55)	55	100		53	96.36		49	89.09	
6–10 (*n* = 70)	69	98.57		65	92.86		67	95.71	
11–15 (*n* = 10)	10	100		8	80		10	100	
>15 (*n* = 6)	5	83.33		6	100		5	83.33	
Doctor's speciality			**0.694**			**0.068**			**0.710**
Nuclear physician (*n* = 10)	10	100		8	80		9	90	
Radiologist (*n* = 131)	129	98.47		124	94.66		122	93.13	
Doctor's qualifications			**0.317**			**0.079**			**0.021**
University hospital (*n* = 30)	29	96.67		26	86.67		25	83.33	
Hospital practitioner (*n* = 111)	110	99.10		106	95.49		106	95.49	

MTI: medical teleimaging

set of networked IT devices for acquiring, archiving, printing, consulting and interpreting medical imaging examinations on screen and is generally linked to a hospital information system for patient identification and the presentation of relevant clinical information [15]. PACS is used in almost all public hospitals in Europe today, which partly explains the fact that, in our study, awareness of PACS and DICOM was higher, with a statistically significant difference ($p < 0.05$), among imaging physicians starting their professional careers, those working in the public sector and especially those who had already completed a postdoctoral internship in Europe.

Teleimaging procedures must comply with technical requirements to guarantee the quality of the procedure (image, remote transmission, display and interpretation console). Computers or consoles dedicated to remote medical imaging must comply with well-defined technical specifications, of which 51.1% of the imaging physicians surveyed were unaware. The basic concepts of teletransmission security, known only to 20.56% of our respondents, are fundamental to efficient and secure remote medical imaging. These notions of teletransmission security are based on three main parameters, namely authentication, which must be strong, and the confidentiality and integrity of the data transmitted. The limited awareness of technical standards and security protocols underscores the need for targeted training programmes.

While the presence of a radiologist is not mandatory in teleradiology, this is not the case in telenuclear medicine, where a nuclear physician must always be present at the patient site because of the use of unsealed radiopharmaceuticals [2]. It is therefore regrettable that only 23.40% of the imaging physicians in our study (with no statistically significant difference ($p > 0.05$) between nuclear medicine physicians and radiologists) were aware that the presence of a nuclear medicine

Table 7 Profile of respondents who consider training of imaging physicians to be necessary before practising medical teleimaging and those wishing to practise medical teleimaging in their country

	Need for training of imaging physicians			Desire to practice MTI		
	n	%	*p*	*n*	%	*p*
Age			**0.144**			**0.064**
Under 35 (*n* = 23)	21	91.30		21	91.30	
35 to 65 years (*n* = 118)	115	97.46		116	98.31	
Taking part in a MTI activity			**0.022**			**0.501**
Never practised (*n* = 127)	124	97.64		123	96.85	
Already practised (*n* = 14)	12	85.71		14	100	
Teleimaging training			**0.212**			**0.494**
No training (*n* = 48)	45	93.75		46	95.83	
MTI Continuing training (*n* = 93)	91	97.85		91	97.85	
Current area of practice			**0.654**			**0.412**
Private (*n* = 56)	55	98.21		54	96.43	
Public (*n* = 41)	39	95.12		41	100	
Private and public (*n* = 44)	42	95.45		42	95.45	
Postdoctoral internship in Europe			**0.856**			**0.127**
Completed (*n* = 51)	49	96.08		51	100	
Not carried out (*n* = 90)	87	96.67		86	95.56	
Professional experience (years)			**0.674**			**0.505**
0–5 (*n* = 55)	53	96.36		52	94.55	
6–10 (*n* = 70)	69	98.57		69	98.57	
11–15 (*n* = 10)	10	100		10	100	
>15 (*n* = 6)	4	66.67		6	100	
Doctor's speciality			**0.529**			**0.575**
Nuclear physician (*n* = 10)	10	100		10	100	
Radiologist (*n* = 131)	126	96.18		127	96.95	
Doctor's qualifications			**0.298**			**0.154**
University hospital (*n* = 30)	28	93.33		28	93.33	
Hospital practitioner (*n* = 111)	108	97.30		109	98.20	

MTI: medical teleimaging

physician is important at the patient site when performing telenuclear medicine activity. The advantages of teleimaging are undeniable these days, as 98.5% of the imaging physicians in our study felt, but there are also disadvantages, such as the lack of physical contact and cybercrime (personal data can be hacked into in the absence of a secure network). In any case, we agree with 92.90% of the imaging physicians in our study that teleimaging has more advantages than disadvantages. This favourable perception of teleimaging by imaging physicians augurs better acceptance or adoption of remote imaging platforms in French-speaking sub-Saharan Africa, particularly by those over 35 years of age ($p < 0.05$). In general, medical teleimaging improves the quality of medical care by providing accurate diagnoses and wider access to care and by facilitating training and collaboration between imaging physicians and other healthcare professionals [16, 17]. The multiple benefits of several medical teleimaging projects, both for patients and for doctors, even in African countries, have been reported by authors such as Andronikou [18] and Hunter et al. [19]. The COVID-19 pandemic highlighted the multiple advantages of telemedicine in general and medical teleimaging in particular [20, 21], so it is not surprising that 85.81% of respondents felt that their interest in medical teleimaging had increased since this pandemic. Approximately 4/5 of the imaging doctors (80.14%) saw medical imaging as the main area that should benefit from the development of telemedicine. In France, on the other hand, Messon reported that 74.8% of doctors preferred dermatology [22]. Nevertheless, medical imaging and dermatology remain the medical fields where telemedicine is easiest to implement. Indeed, these specialities present numerous cases where inspection and therefore visual information is sufficient for diagnosis. The equipment required

Table 8 Profile of respondents who consider medical imaging to be the specialty most concerned with telemedicine, those whose interest has increased since the COVID-19 pandemic, and those who would like to see remuneration for teleimaging activity equal to that for face-to-face medical imaging activity

	Medical imaging more concerned by telemedicine			Interest in MTI increased since Covid-19			Fair remuneration		
	n	%	*p*	*n*	%	*p*	*n*	%	*p*
Age			**0.086**			**0.074**			**0.055**
Under 35 (*n* = 23)	9	39.13		17	73.91		20	86.96	
35 to 65 years (*n* = 118)	104	88.14		104 104	88.14		75	63.56	
Taking part in a MTI activity			**0.061**			**0.991**			**0.031**
Never practised (*n* = 127)	99	77.95		109	85.83		84	66.14	
Already practised (*n* = 14)	14	100		12	85.71		11	78.57	
Teleimaging training			**0.004**			**0.033**			**0.028**
No training (*n* = 48)	32	66.67		37	77.08		35	72.92	
MTI Continuing training (*n* = 93)	81	87.10		84	90.32		60	64.52	
Current area of practice			**0.908**			**0.467**			**0.003**
Private (*n* = 56)	45	80.36		50	89.29		40	71.43	
Public (*n* = 41)	32	78.05		33	80.49		26	63.41	
Private and public (*n* = 44)	36	81.82		38	86.36		29	65.91	
Postdoctoral internship in Europe			**0.070**			**0.535**			**0.099**
Completed (*n* = 51)	45	88.23		45	88.24		35	68.63	
Not carried out (*n* = 90)	68	75.56		76	84.44		60	66.67	
Professional experience (years)			**0.008**			**0.028**			**0.010**
0–5 (*n* = 55)	40	72.73		45	81.82		40	72.73	
6–10 (*n* = 70)	63	90		65	92.86		48	68.57	
11–15 (*n* = 10)	5	50		6	60		4	10	
>15 (*n* = 6)	5	83.33		5	83.33		3	50	
Doctor's speciality			**0.001**			**0.182**			**0.288**
Nuclear physician (*n* = 10)	4	40		10	100		7	70	
Radiologist (*n* = 131)	109	83.21		111	84.73		88	67.18	
Doctor's qualifications			**0.079**			**0.105**			**0.059**
University hospital (*n* = 30)	15	50		23	76.67		24 24	80	
Hospital practitioner (*n* = 111)	98	88.29		98	88.29		71	63.96	

MTI: medical teleimaging

for the effective use of telemedicine is therefore limited to a high-definition camera and sufficient internet connectivity for data transfer.

Our study revealed that 98.6% of the imaging physicians had already sent, received or interpreted an imaging examination by virtual means. The virtual channel most commonly used by imaging physicians for imaging examinations was the WhatsApp application, followed by email. The use of social networks such as WhatsApp has been reported by other authors in Africa [23] and elsewhere in the world [24]. The majority of imaging physicians (56%) had not taken any security precautions when carrying out a teleimaging procedure. This attitude can be explained by the fact that most imaging data are sent between imaging colleagues via social networks, particularly WhatsApp, which were not originally designed for this type of activity. These results are similar to those of Gaggioli et al. in their 2005 survey of telemedicine among doctors in Milan, Italy, in which telephone and e-mail were the most suitable means of communication for doctor–patient interactions [25]. Given that these networks have no security guarantees, we can rightly question the security and efficiency of these practices. The use of the WhatsApp application to transfer personal data is subject to various risks, including piracy and theft of the phone and the information it contains.

Overall, there was no statistically significant difference between the knowledge of radiologists and nuclear medicine physicians ($p > 0.05$), and almost all their perceptions and attitudes towards teleimaging assessed in our

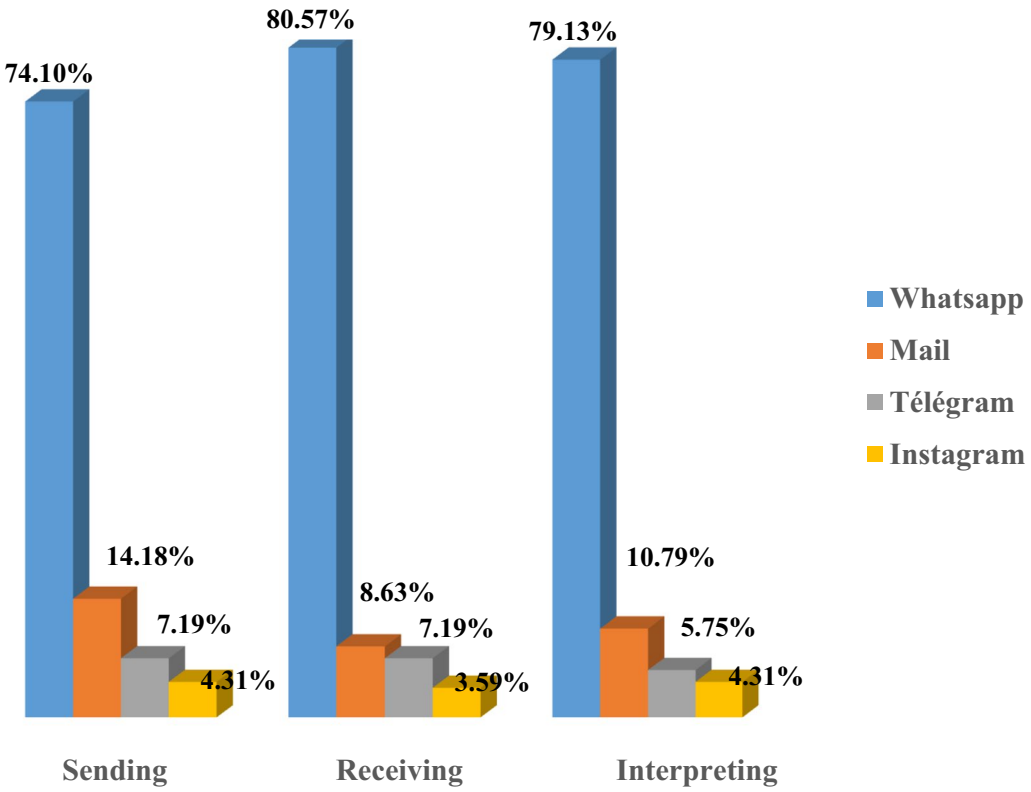

Fig. 1 Distribution of virtual channels used for imaging examinations

study. This result therefore shows that the level of knowledge about teleimaging in French-speaking sub-Saharan Africa is not influenced by training or practice in either of the two medical imaging specialities, namely, radiology or nuclear medicine. In our study, good knowledge and good practice were more common among imaging physicians who had received further training in teleimaging. Continuing training is therefore essential for both radiologists and nuclear medicine physicians to improve knowledge and promote good attitudes towards teleimaging in French-speaking African countries. In addition to continuing training and awareness raising on good practices in medical teleimaging, health authorities in African countries must make efforts to provide health structures with adequate technical infrastructure and substantial technological readiness so that teleimaging becomes a daily reality in French-speaking sub-Saharan Africa in the years to come.

The reliance on self-reported data and sample size constraints constitute a certain limitation to our study.

Conclusion

Teleimaging knowledge in this region remains limited despite positive perceptions, and adoption attitudes were mixed. Efforts should focus on developing comprehensive training programmes and improving infrastructure to facilitate secure teleimaging practices.

Declarations of interest

None.

Clinical trial number

Not applicable.

Abbreviations

CHU	Centre Hospitalo-Universitaire
CHR	Centre Hospitalier Regional
MRI	Magnetic resonance imaging
DICOM	Digital Imaging and Communications in Medicine
PACS	Picture Archiving and Communication Systems
IT	Information technology
COVID-19	Coronavirus disease 2019
ORQs	Short-answer questions
MCQs	Multiple-choice questions
MTI	Medical teleimaging

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Authors' contributions

K.A. put the idea and the design of the study. R.S.D., K.A and S.D performed data collection and have contributed to the conception and design of the manuscript. A.B.K., R.S.D, G.D.H, P.A.O., M.D., P.G. and K.A had contributed to the conception and design of the manuscript. All authors have been involved in drafting and revising the manuscript. All authors read and approved the final manuscript.

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Declarations

Ethics approval and consent to participate
An approval from the Faculty of Health Sciences, University of Lomé, had been obtained. The study did not involve the use of animals. The manuscript has not been submitted to any other journal/site in part or in whole for consideration. It is solely submitted to this journal. The physicians included in this study gave verbal informed consent to participate in this research.

Consent for publication
The physicians included in this study gave verbal informed consent to publish this research.

Availability of data and material
The data used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests
The authors declare that they have no competing interests.

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