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# Effect of teleradiology on patient waiting time and service satisfaction in public hospitals, Northwest Ethiopia: a quasi-experimental study

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## Abstract

**Background** Limited access to onsite radiologists in Low- and Middle-Income Countries (LMICs) poses challenges for health facilities in delivering timely radiology services resulting in prolonged patient waiting times and dissatisfaction with the insufficient radiology services. In recent years, teleradiology has emerged as a potential solution to improve the timely diagnosis and treatment process. Therefore, this paper analysed the effect of a web-based teleradiology system that was developed and deployed to evaluate its effect on patient waiting time and service satisfaction in public hospitals of the Amhara Regional State.

**Methods** A pre-post study design was employed to evaluate the effect of a web-based teleradiology system on patient waiting time and service satisfaction. The study included a total of 836 participants, out of which 417 participated during the pre-intervention and 419 in the post-intervention periods. Data were collected from October 2021 to February 2022 and from May 2022 to January 2023 for the pre-and post-implementation periods, respectively. Supportive measures, including user guides, onsite training, and onsite/virtual assistance, were given during the teleradiology implementation period. The effects of the teleradiology on waiting time and service satisfaction were evaluated with the Mann-Whitney U-test and the Generalized Linear Model. Waiting time was measured as the duration between image consultation and report completion. Furthermore, satisfaction was assessed using a 31-item, 5-point Likert scale. The statistical analysis was done using Stata version 17 software.

**Results** After the implementation of the web-based teleradiology system, a significant decrease in the median waiting time was observed from 43.5 h (IQR: 22.88–71.63) to 4.62 h (IQR: 2.52–10.53) ($p$-value < 0.01). The effect size for this improvement was found to be 0.84. Furthermore, the median patient satisfaction score was significantly improved from 96 (IQR: 89–103) to 113 (IQR: 105–124) ($p$-value < 0.01) and an effect size of 0.65. Similarly, the percentage of the scale mean score (%SM) showed an increase in patient satisfaction levels from 52.6% (pre-implementation) [95% CI: 51.8–53.5] to 65.7% (post-implementation) [95% CI: 64.5 -66.9%]. The GLM analysis

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demonstrated a 71% decrease in patient waiting time and an 11% increase in radiography service satisfaction (*p*-value < 0.01).

**Conclusion** Implementing the web-based teleradiology system improved the patient's waiting time and service satisfaction remarkably. The notable reduction in waiting time and the significant improvement in patient satisfaction scores highlighted the benefits of teleradiology in enhancing timely diagnosis and treatment. Deploying a web-based teleradiology system in public hospitals is recommended to enhance efficiency and improve patient satisfaction in radiology consultations.

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**Keywords** Teleradiology, Pre-post design, South Gondar Zone, Public hospitals, Northwest Ethiopia

## Background

Radiology plays a vital role in enhancing healthcare by enabling early medical diagnoses, leading to prompt treatment, improved patient outcomes, and reduced healthcare expenses [1, 2]. A study revealed that availability of radiological services have a notable impact for clinicians to change their diagnosis and their treatment [3]. Unfortunately, Sub-Saharan African (SSA) countries face challenges in accessing these services due to disease spectrum, human resource, and socio-economic, socio-cultural, infrastructural, and academic disparities, especially in rural areas where over 80% of the population resides [4, 5]. The scarcity of radiologists [4, 6] further exacerbates the challenges posed by limited healthcare service availability [2], leading to morbidity and delayed diagnosis and treatment [7]. The primary causes for this delayed treatment are: (1) delayed radiology report submission resulting from incomplete patient history provided by clinicians, and (2) the radiologist's excessive reporting workload [8]. Teleradiology addresses these challenges by enabling remote interpretation of medical images using digital technology [9, 10]. It involves the electronic transmission of radiography images between locations for interpretation and consultation [11, 12].

Currently, teleradiology is increasingly recognized as a promising solution to improve patient outcomes by enhancing radiological services in various medical settings [13, 14]. It provides numerous benefits, including reduced patient transfer, shortened hospital stay, timely diagnosis and treatment, and improved diagnostic accuracy and reliability [13]. Furthermore, the proper implementation of teleradiology has been shown to improve reporting time and work patterns for medical staff [15]. However, context-specific adoption of teleradiology remains challenging for resource-constrained countries due to high implementation costs, training requirements, inadequate healthcare infrastructure, slow internet connectivity, and a shortage of skilled professionals [14, 16–19]. These challenges lead to limited access to radiological services, delayed diagnoses, and compromised healthcare delivery [20, 21].

In Ethiopia, the scarcity of skilled radiology professionals, with only 300 professionals serving a population of 118 million [22], highlights the urgent requirement for prompt intervention [23, 24]. If not addressed promptly, this shortage could result in delayed diagnoses, patient dissatisfaction [25, 26], and negative impacts on health outcomes, such as delays in clinical care [7, 27]. In addition, incomplete patient history, poor image quality, and insufficient communication between radiologists and clinicians [8] contribute to delays in clinical care, which in turn leads to prolonged length of hospital stays and compromised quality of care [7]. Access to timely radiographic reports is influenced by the requested study type and healthcare facility capacity [28, 29]. The lack of an efficient radiology service reporting system is strongly linked to patient adverse outcomes [7] and dissatisfaction in the overall healthcare delivery process [30]. Thus, to overcome these challenges, studies suggest resource-constrained countries to implement teleradiology which considers their local context [31–34]. The effectiveness and long-term sustainability of these systems depend on their compatibility with the implementation context [16, 35]. Implementing such systems in hospitals enhances patient care, reduces waiting times, improves accessibility, fosters collaboration, and provides cost-effective healthcare delivery [16].

However, the adoption of digital health technologies in Ethiopia is limited [36]. Consequently, the absence of technology implementations like teleradiology results in restricted access to specialized radiology expertise, increased dependence on physical film transportation, diminished collaboration and second opinions, as well as elevated healthcare expenses [37]. According to WHO guidelines, the development of context-specific digital health solutions is crucial for effective deployment by addressing local needs, improving accessibility, and fostering innovation [38]. Therefore, the study aimed to create and deploy a web-based teleradiology system tailored to the local context to evaluate its impact on patient waiting times and satisfaction in public hospitals in the Amhara Regional State of northwest

Ethiopia. The findings from this study hold the potential to offer valuable insights into the effectiveness and benefits of implementation, making it a valuable resource for policymakers and healthcare providers. This can lead to enhanced patient care and improved accessibility to radiography services.

## Methods

### Study design and period

This study employed a pre-post-study design approach. The pre-intervention period involved participants receiving the standard referral consultation approach, that is, patients were directed to referral hospitals or private clinics in Debre Tabor town and Bahir Dar city in order to receive radiology image interpretation services and subsequently returned to the referring hospitals with the radiology report, while the post-intervention period patients accessed the medical imaging interpretation and consultation service through the web-based teleradiology. Data collection for the pre-intervention period was done between October 20, 2021, and February 2, 2022, while the post-intervention was from May 12, 2022, to January 3, 2023.

### Study setting

The study was done in seven public hospitals of South Gondar Zone, Amhara Regional State for the pre-and post-study periods (Fig. 1). The Zone has a total surface area of 142,987 square km. Debre Tabor is the capital of the Zone, which is located 702 km away from Addis Ababa, the capital city of Ethiopia. According to the 2022/2023 nine-month report of the South Gondar health department, the Zone comprises 15 Woredas health offices, including city administrations, and 411 Kebeles (the smallest administrative unit of the government structure). Currently, the Zonal health department has 10 public hospitals, 93 health centres, and 405 health posts. The Zone has a total population of 2,696,597. However, the radiography services are provided by only two radiologists, two radio-technologists, and 23 radiographers/imaging technicians.

### Study population, sample size determination and sampling technique

This study encompassed the entire adult population of the South Gondar Zone as the sampling domain. The study included all eligible adult inpatients and outpatients receiving radiography services at the seven participating

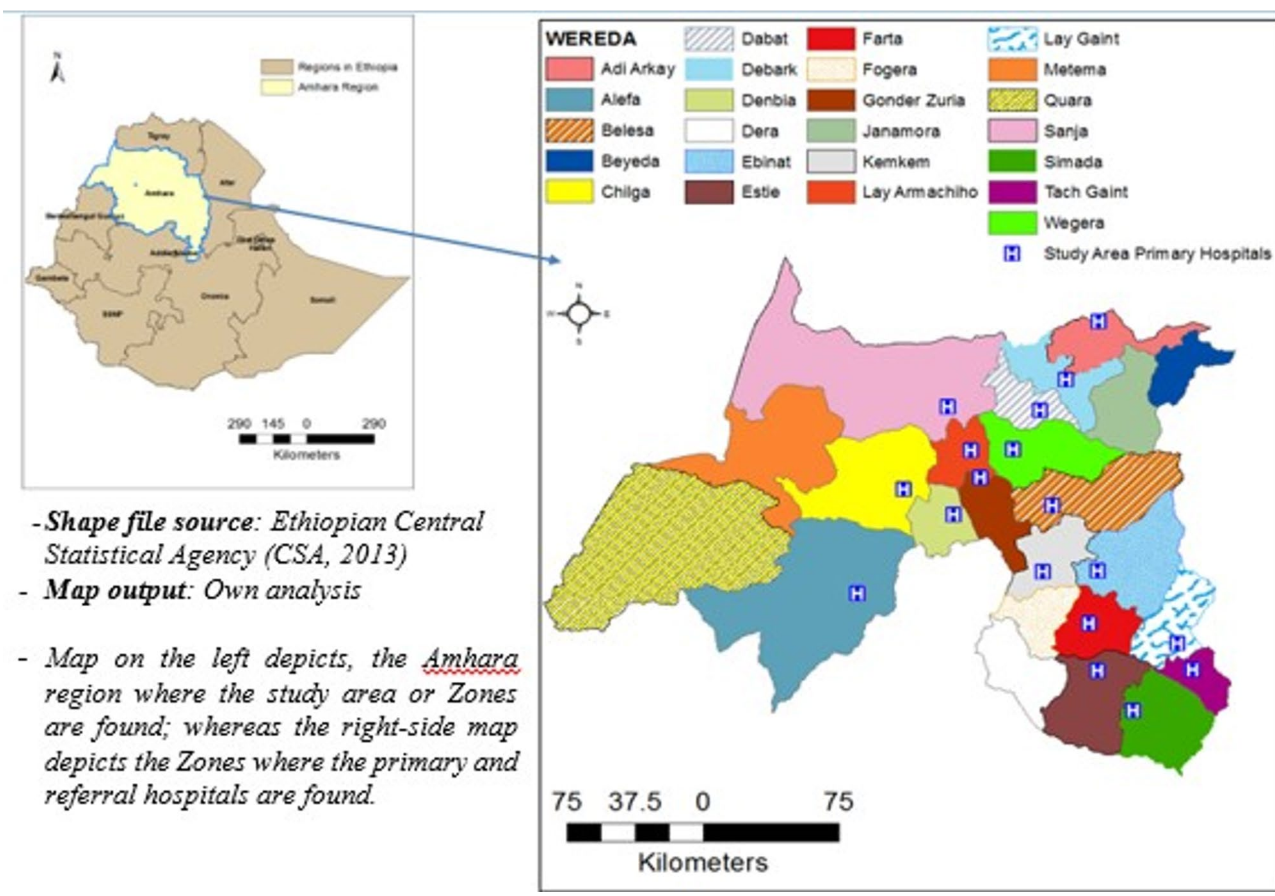


**Fig. 1** Map of the study area, North and South Gondar Zones of Northwest Ethiopia

public primary referring hospitals who voluntarily agreed to participate. The study included patients with any disease type, as the focus was on evaluating teleradiology's effect on waiting time and service satisfaction. However, patients requiring referral to other referral hospitals for advanced radiology services were excluded. The study excluded these patients as they were not required to provide images at the referring primary hospitals (instead at the referral hospital), preventing to capture the initial referral time. Furthermore, patients who sought the service for a second time during the data collection period were excluded from the study. This decision was s since we had already conducted interviews with them during their initial radiology service visit, and it was determined that each patient should only be interviewed once. Eligible participants were selected and interviewed at the referral hospital during the pre-intervention. Whereas, during the post intervention, participants were selected and interviewed at their respective primary hospital.

The sample size for both outcomes was determined using the G-Power software. The following parameters were considered to calculate the sample size for the waiting time: an alpha value of 0.05, a power of 80%, a pre-and post-group allocation ratio of 1:1, an effect size of 0.2 derived from a previous study [27], and a 5% non-response rate. The calculated sample size for each group was 414. Similarly, for satisfaction, using a proportion of 52.5% of satisfaction for the first group (from a pilot study with 101 participants), a 10% increase (62.5%) in the second group [39], 80% power, and a 5% non-response rate, 424 samples were estimated for each group. Given that the calculated sample size for the secondary outcome (848) exceeded that of the primary outcome (828), the final study sample size was determined to be 848. A consecutive sampling method was employed to approach all potential participants until we reached the desired final sample size.

### Data collection tools and procedures

The data collection tool used in this study remained consistent with the pre-intervention assessment. The questionnaire was initially developed in English and then translated into the local language, Amharic, followed by a back-translation into English to ensure reliability. Face-to-face exit interviews were applied to the data from participants who had received radiography services at the referring hospital's radiology department. Android mobile devices equipped with an Open Data Kit (ODK) tool were used for data collection. ODK is a free, open-source mobile data collection tool suite developed by the University of Washington resource-constrained environments [40]. Seven first-degree health informatics professionals carried out the exit interview. Two experienced public health professionals participated as supervisors. Prior to the data collection, the research team (data collectors and supervisors) received two days of training from the principal investigator on the study objectives, methods, and data collection process. Meanwhile, data from the web-based teleradiology system were exported as an Excel file from the central server and utilized for statistical analysis.

### Outcomes

The objective of the study was to assess two outcomes. The primary outcome focused on examining the impact of web-based teleradiology on patient waiting time. The secondary outcome aimed to measure patient satisfaction with radiography services, providing insights into how patients perceived the quality of the radiology services they received.

## Hypotheses

Based on our research questions, we formulated and tested the following two hypotheses:

- $H_a$: Web-based teleradiology significantly affects patient radiology service waiting time.
- $H_a$: Web-based teleradiology significantly affects patient radiology service satisfaction.

### Measurement and operational definitions

In order to measure waiting time during the pre-intervention period, a time-tracking format was utilized after undergoing a thorough review and pilot testing. This format included documenting the date and time at four distinct checkpoints: when the patient was referred for consultation (T1B); upon patient arrival at the referral hospital triage room (T2B); the assigned data collector conducted the time tracking process; during the visit to the radiology department (T3B); and upon receiving the radiography report (T4B) (Additional file 1 A). Following the implementation of web-based teleradiology, the system automatically recorded all relevant time points, including the time of image upload (T1A), image download (T2A), and submission of the radiography report (T3A). Therefore, the Total Waiting Time for the pre-intervention period (TWTB) was computed by summing the times at points T1B, T2B, T3B, and T4B. In contrast, the total waiting time for the post-intervention period (TWTA) was calculated by summing the times at T1A, T2A, and T3A.

To assess patient radiography service satisfaction after implementing the system, we utilized a validated tool adapted from a previous study [41], which had been piloted in our context during the pre-intervention assessment period. The questionnaire comprised 31 items divided into seven dimensions. A five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree), was employed to rate each item (Additional file 1B).The mean score for each participant was computed across all 31 Likert items. After standardizing the mean value, the percentage of the scale mean score (%SM) was calculated for each participant using the formula: $\%SM = \left(\frac{Actual\ score - Minimum\ scale}{Maximum\ scale\ - Minimum\ scale)}\right) \times 100$ [42, 43]. This percentage ranges from 0 to 100%. Finally, the overall mean %SM was computed to determine the level of patient satisfaction for each group.

Consulting clinicians are medical doctors and emergency surgeons at the referring hospitals who actively participate during the consultation process. Radiologists are medical doctors who specialize in diagnosing and interpreting medical images during the consultation process. On the other hand, radiographers/imaging technicians are healthcare professionals who specialize in performing medical imaging procedures.

#### Intervention description

The development of the web-based teleradiology system involved several key steps. First, requirements were gathered through literature reviews, workflow observations, interviews with radiologists and hospital managers, and consultations with experts. A pilot test with a limited user group helped finalize the second version by incorporating user feedback and assessing functionality, which revealed important issues. The second version of the teleradiology system was presented to a diverse audience, including academicians, students, radiologists, and senior experts. This presentation generated valuable feedback, which was carefully analysed and incorporated into the third version of the system. The primary focus of the improvements was enhancing user-friendliness to ensure a more intuitive experience for all users.

After rigorous review and extensive testing to validate the system's functionality and performance, the refined version was successfully deployed to the central server at the University of Gondar for full-scale implementation. This deployment marks a significant step in advancing the teleradiology capabilities within the institution.

#### Web-based teleradiology application development process

To evaluate the effect of teleradiology on patient waiting times and satisfaction, we developed a web-based teleradiology system for X-ray examinations using the Rapid Application Development (RAD) model. RAD was chosen for its advantages over traditional software development methods, allowing for faster and more cost-effective application building through an iterative process [44]. The development involved four key phases: requirement gathering, user design, rapid construction, and cutover [45], each completed sequentially (Additional file 2). A schematic representation illustrated the process of remote referral consultations in public hospitals, supported by the teleradiology system (Fig. 2).

Various front-end technologies (NetBeans, GlassFish, EdrawMax, Adobe Photoshop, and JavaScript) and a MySQL back-end were utilized based on their functionalities (Additional file 3). The system was ultimately deployed on a central server, enabling remote access for end-users via a URL (Universal Resource Locator) address.

#### Interface design and features of the teleradiology system

The web-based teleradiology system has distinct components (features) that work together seamlessly to facilitate the efficient delivery of radiological services. The login page allows users to access the system using their username and password, directing them to the home page upon successful login or displaying an error message for incorrect entries (Fig. 3).

The system has a dashboard which provides a summary of essential information, including the number of registered patients, pending requests, submitted results, and urgent cases.

The patient registration feature [a] that enables clinicians to input patient information such as ID, sociodemographic details, and case type. In the patient history window of the system [b], the feature helps clinicians to select study types, upload X-ray images, and document critical patient information, which assists radiologists in making accurate diagnoses.

Additionally, the facility registration feature [c], allows system administrators to register both referring and referral health facilities. Similarly, the users' registration window [d], helps to register users' demographics and granting access privileges, ensuring that only authorized personnel can enter the system.

The diagnosis list feature [e], enables clinicians to track the status of consultations, indicating whether images have been commented on and providing timestamps for key actions. Finally, the clinical report feature [f], helps referring clinicians access to radiologists' reports, which can be printed for inclusion in patient records, thereby ensuring comprehensive and up-to-date documentation for follow-up care (Additional file 4).

#### System actors and roles

The system comprised three main users: administrators, consulting clinicians, imaging technicians, and radiologists. Each user could access the system remotely using a distinct username and password. However, their access was restricted in accordance with the permissions granted by the administrator (Table 1).

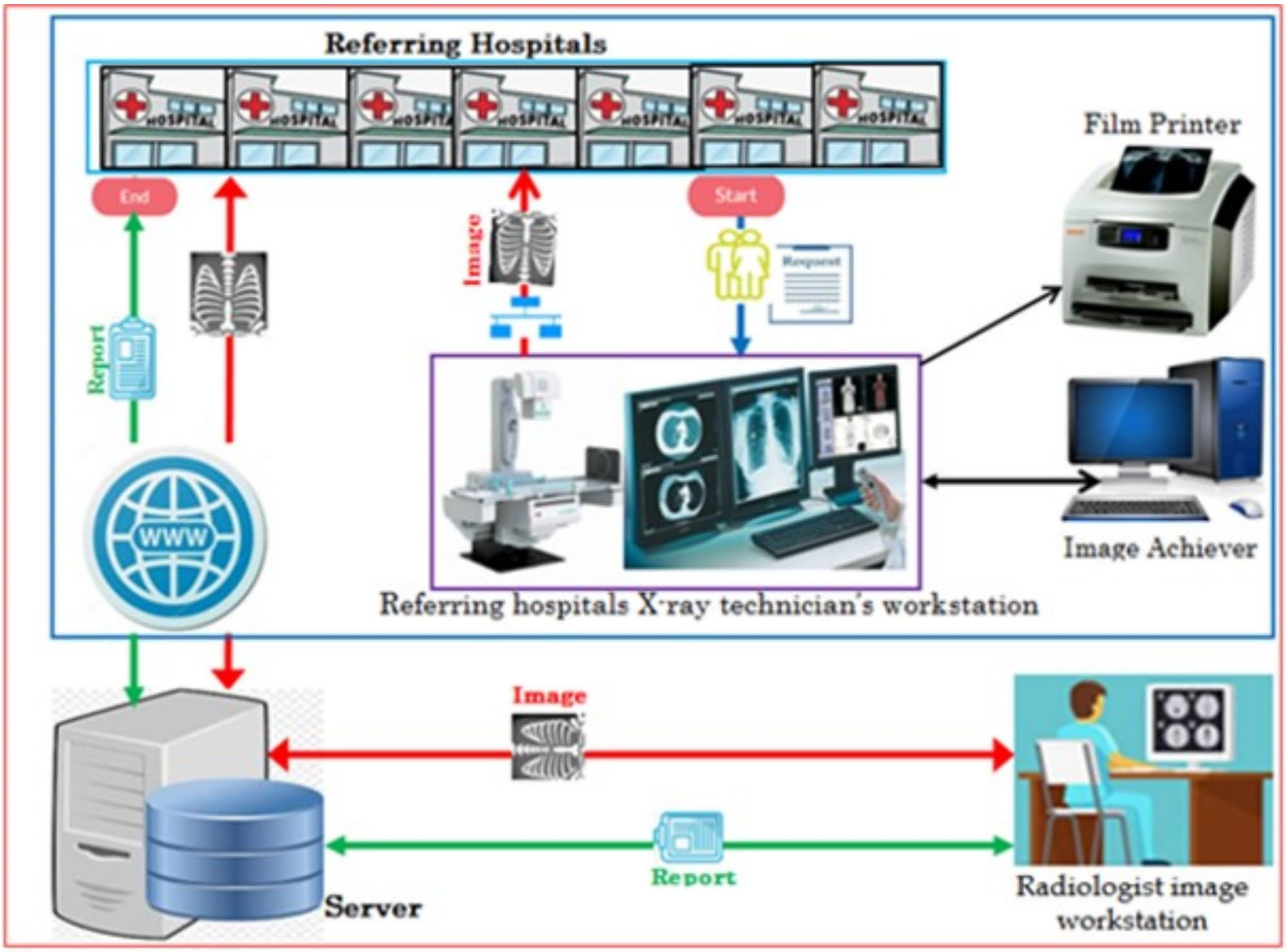


**Fig. 2** Web-based teleradiology system schematic diagram

### Training and system implementation duration

Before the introduction of web-based teleradiology, all hospital administrators, consulting clinicians/radiographers, and radiologists underwent practical training sessions conducted onsite at the primary hospital's conference hall. Each facility's end-users received training sessions lasting three to five hours. The training covered: (1) teleradiology overview, (2) system functionalities, (3) user roles and privileges, and (4) system usage (login, image upload/download, data entry, result export). After the practical sessions led by the corresponding author, participants demonstrated the system usage for evaluation. In addition to the onsite training, softcopies of end-user guides were provided for reference when using the system independently (Additional file 5). Furthermore, end-users received three rounds of onsite support following the initial training, as well as assistance through virtual platforms such as Google Meet, phone calls, and Telegram. The corresponding author provided practical trainings and onsite support. Radiologists were compensated per image request to account for the extra workload. The implementation of the system took place over eight months, spanning from May 2022 to January 2023.

## Statistical analysis

The Comma-Separated Values (CSV) data files obtained from ODK Collect and the web-based teleradiology system were transferred to STATA version 17 software for analysis. Descriptive statistics, including means and standard deviations (± SD), were applied to summarize continuous variables, while categorical variables were presented as numbers and percentages.

We performed tests for normality (Shapiro-Wilk) and homogeneity of variance (Levene's test) to confirm the validity of our parametric analysis. The results of the Shapiro-Wilk test revealed a considerable departure from normality ($p$-values $< 0.01$), which suggests that there is a violation of the normality assumption. Additionally, Levene's test revealed a significant $p$-value ($p < 0.01$) in the total waiting time of the patients between the pre-intervention and post-intervention groups, indicating homogeneity of variance assumption violation.

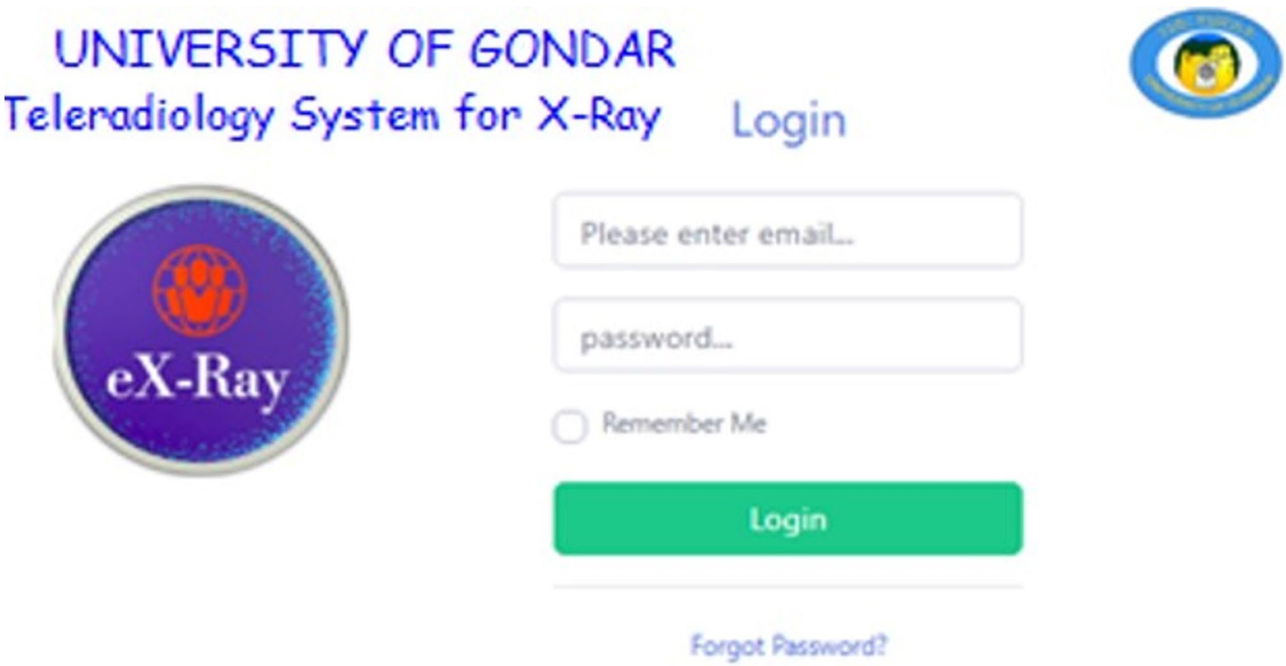


**Fig. 3** Web-based teleradiology system login page

**Table 1** Teleradiology actors and their roles

| No | System actors | Roles | Privilege |
|---|---|---|---|
| 1 | Administrator | ⇨ Log in using their username and password to perform the following tasks:<br>- Create usernames and passwords for consulting clinicians, radiographers, and radiologists.<br>- Register referring and referral health facilities, consulting clinicians, and radiologists.<br>- Reset passwords as needed.<br>- Add new or employed end-users.<br>- Add new functional health facilities.<br>- Delete end-users who have resigned from the health facility. | The administrator has the following privileges:<br>- Access to the dashboard<br>- Able to generate reports when necessary<br>- Able to check the status of image requests when necessary |
| 2 | Consulting clinicians and imaging technicians | Login into the system using their username and password to perform the following tasks:<br>- Register new patients and input their demographic and clinical history.<br>- Upload and send requested patient images to the central server for consultation.<br>- Access the radiology reports submitted by the radiologist. | The following mandates are given to the user:<br>- Access to the dashboard<br>- Ability to generate reports, print them out, and attach them to the patient folder<br>- Ability to check the status of image requests |
| 3 | Radiologists | Login with their username and password to accomplish the following tasks:<br>- Download the image for commenting<br>- Submit the radiology report to the central server.<br>- Provide feedback | The user is granted the following mandates:<br>- Access to the dashboard to view the number of pending requests and emergency cases.<br>- Ability to generate reports and print hard copies if needed. |

Due to the violation of the equality of variance and normality assumptions ($p$-value < 0.01), the satisfaction total sum score also failed to meet the required criteria. The Mann-Whitney U-test was utilized to assess the impact of teleradiology on waiting time and service satisfaction. The rank-biserial correlation effect size derived from the Mann-Whitney U-test result was employed to evaluate the magnitude of the difference between the pre- and post-intervention groups. A value of less than 0.1 indicates a trivial effect. At the same time, a range of 0.1 to 0.3 signifies a small effect, 0.3 to 0.5 corresponds to a moderate effect, and a value exceeding 0.5 represents a large effect [46–49]. This effect size measure is particularly suitable for nonparametric tests of differences [46].

Finally, we employed the Generalized Linear Model (GLM) to analyzed the impact of web-based teleradiology on patient waiting time and service satisfaction compared to the pre-intervention group. The group variable (pre-intervention vs. post-intervention) was included as a predictor in the GLM to determine its significance on waiting time and service satisfaction. The study conducted subgroup analyses to compare the intervention effect across different subgroups. The coefficient and *p*-value for the group variable indicate if there is a significant difference between the two groups. Statistical significance was determined at a 95% confidence interval (CI) with a *p*-value threshold of < 0.05. The analyses were conducted using STATA version 17.

### Application system and data quality assurances

To ensure the quality of the web-based teleradiology system, we conducted pilot testing to verify its performance and adherence to requirements. Username and password authentication were applied to ensure the data quality of the system by preventing unauthorized access. Validation rules were in place to minimize errors during data entry. Practical onsite training was given for consulting clinicians, radiographers, radiologists, and hospital managers.

**Table 2** Participants demographic characteristics in the pre-and post-intervention groups in Northwest Ethiopia (*N* = 836)

| Variables | Category | Pre-intervention (*n* = 417) | Post-intervention (*n* = 419) |
|---|---|---|---|
| Age | Mean (SD) | 41.03 (16.2) | 46.69 (17.4) |
| Gender | Male | 242 (58%) | 255 (60.9%) |
| | Female | 175 (42%) | 164 (39.1%) |
| Religion | Orthodox Christian | 343 (82.3%) | 374 (89.3%) |
| | Muslim | 63 (15.1%) | 36 (8.6%) |
| | Protestant | 11 (2.6%) | 9 (2.1%) |
| Marital status | Single | 116 (27.8%) | 62 (14.8%) |
| | Married | 256 (61.4%) | 340 (81.1%) |
| | Divorced | 45 (10.8%) | 8 (1.9%) |
| | Others[a] | 0 | 9 (2.1%) |
| Educational status | No formal education | 163 (39.1%) | 258 (61.6%) |
| | Primary education | 83 (19.9%) | 34 (8.1%) |
| | Secondary education | 69 (16.5%) | 38 (9.1%) |
| | Certificate and above | 102 (24.5%) | 89 (21.2%) |
| Occupation | Employed | 52 (12.5%) | 68 (16.2%) |
| | Unemployed | 19 (4.6%) | 28 (6.7%) |
| | Housewife | 88 (11.5%) | 50 (11.9%) |
| | Students | 48 (61.5%) | 30 (7.2%) |
| | Farmers | 108 (25.9%) | 154 (36.8%) |
| | Daily labourer | 47 (11.3%) | 15 (3.6%) |
| | Merchant | 55 (13.2%) | 74 (17.7%) |
| Residence | Rural | 199 (47.7%) | 218 (52%) |
| | Urban | 218 (52.3%) | 201 (48%) |
| Wealth Index | Very Poor | 69 (16.5%) | 82 (19.6%) |
| | Poor | 40 (9.6%) | 24 (0.5.7%) |
| | Medium | 139 (33.3%) | 223 (53.2%) |
| | Rich | 103 (24.7%) | 17 (4.1%) |
| | Very Rich | 66 (15.8%) | 73 (17.4%) |

[a]Others: Separated, Widowed

End-users' guides were provided for referring clinicians and radiologists for their reference. Furthermore, three rounds of virtual support via phone, Telegram) a social media platform), and Google Meet were provided, in addition to onsite supportive supervision. Similarly, the quality of the data was ensured throughout the study period, starting from the instrument design phase. Before collecting data, domain experts were invited to evaluate the content and face validity of the 5-item questionnaire. The relevance of variables and the simplicity of questions were assessed. A pilot test on 101 patients was conducted to determine the reliability of the variables. The questions were revised based on the pilot test findings. Cronbach's alpha test results showed the constructs' reliability ranged from $\alpha = 0.71$ to $\alpha = 0.89$, and the overall reliability of all study items was 0.91, within the acceptable range [50, 51]. Supervisors and data collectors had two days of training, and the primary investigator checked the data daily to make sure it was accurate and complete. Finally, the study followed Transparent Reporting of Evaluations with Nonrandomized Designs (TREND) checklist for reporting non-randomized evaluations and underwent manuscript review for publication (Additional file 6).

## Results

### Participant characteristics

The initially calculated sample size was 848 with 424 participants assigned to each group. However, for the final analysis, a total of 836 individuals participated, with 417 participants in the pre-intervention period and 419 participants in the post-intervention period. As a result, the response rates for the pre-intervention and post-intervention groups were 98.3% and 98.8%, respectively. In the pre-intervention period, the patients who underwent radiographic imaging included 242 (58%) males, 343 (82.3%) Orthodox Christians, 256 (61.4%) married individuals, 163 (39.1%) individuals with no formal education, 108 (25.9%) farmers, and 139 (33.3%) individuals with a medium wealth status. The mean age of the participants was 41 (16.2 SD) years, with a minimum and maximum age of 18 and 80 years, respectively. Similarly, in the post-intervention period, 255 (60.9%) male, 374 (89.3%) Orthodox Christians, 340 (81.1%) married individuals, 258 (61.6%) individuals with no formal education, 154 (36.8%) farmers, and 223 (53.2%) individuals with a medium wealth status. The mean age of the participants was 46.7 (17.4 SD) years, with a minimum and maximum age of 18 and 81 years (Table 2).

### Comparison between pre-and post-intervention periods

The Mann-Whitney U-Test indicates that there are notable variations in the waiting times for patients receiving radiography consultations. The post-intervention group had a median waiting time of 4.62 h, compared to 43.50

**Table 3** The effect of web-based teleradiology intervention on patient waiting time and satisfaction based on rank-biserial correlation effect size, Northwest Ethiopia ($N=836$)

| Variables | Category | Median (IQR) | Mean Rank | Rank-biserial correlation Effect size (95% CI) |
|---|---|---|---|---|
| Exposure to web-based teleradiology[a] | No (pre-intervention) | 43.50 (22.88, 71.63) | 593.52 | 1 |
| | Yes (post-intervention) | 4.62 (2.52, 10.53) | 244.32 | 0.84 (0.81, 0.86)* |
| Exposure to web-based teleradiology[b] | No (Pre-intervention) | 96 (89, 103) | 593.52 | 1 |
| | Yes (post-intervention) | 113 (105, 124) | 244.32 | –0.65 (–0.69, –0.60)* |

- The rank-biserial correlation can be computed as follows:

- $Effect\ size\ (rB) = \frac{2(M1-M2)}{n1+n2}$, where $M_1$= mean rank of the pre-intervention group; $M_2$= mean rank of the post-intervention group; $n_{1=417}$: sample size for pre-intervention group; and $n_{2=419}$: sample size for the post-intervention group

- The Rank-biserial correction (rB) value is an effect size where < 0.1 is trivial, 0.1–0.3 is a small effect, 0.3–0.5 is a moderate effect and > 0.5 a large effect [47]

- Positive sign of effect size mean that the mean rank of the pre-intervention group tends to be larger than the post-intervention group

- The negative sign indicates the mean rank of the pre-intervention group is smaller than the post-intervention group

*Represents for *p*-value < 0.01; 1- represents the comparison group

[a]represents for patient waiting time

[b]represents for patient service satisfaction

**Table 4** GLM regression analysis on patient radiography service waiting time, Northwest Ethiopia ($N=836$)

| Variables | Category | Median Waiting Time (IQR) | Crude exp (β) [95% CI] | Adjusted exp (β) [95% CI][a] |
|---|---|---|---|---|
| Web-based teleradiology exposure | Pre-intervention (No) | 43.50 (22.88, 71.63) | 1 | 1 |
| | Post-intervention (Yes) | 4.62 (2.52, 10.53) | 0.18 (0.16, 0.20) | 0.29 (0.20, 0.41) * |

*CI* Confidence Interval; 1- represents the comparison group

**P*-value < 0.05

[a]Adjusted for Types of X-ray studies, image uploaded/consulted by the weekdays, image get commented by the weekdays, parts of the day image uploaded/consulted, parts of the day image get commented, weekdays were images gest commented, parts of the day image uploaded/consulted, parts of the day image get commented

h for the pre-intervention group. This difference was statistically significant ($p<0.01$), leading to the rejection of the null hypothesis. The analysis revealed a large effect size ($r=0.84$), indicating a significant reduction in patient radiography service waiting time due to the intervention. Furthermore, the percentage change was calculated using the formula: Percentage change = ((post-intervention median waiting time - pre-intervention median waiting time))/(pre-intervention median waiting time) x100. By substituting the corresponding values from Table 4, we found the value −89.4%. This indicates a substantial 89.4% reduction in median waiting time for radiology services after implementing web-based teleradiology, demonstrating a significant impact.

Similarly, there is a significant difference in patient radiography service satisfaction scores between those who received the service before the intervention (median = 96) and after the implementation of web-based teleradiology (median = 113) ($p$-value of < 0.01). The magnitude of the analysis showed a large effect size ($r=0.65$), indicating a significant improvement in patient radiography service satisfaction due to the intervention (Table 3).

Additionally, the percentage of the scale mean score (%SM) also showed an increase in patient satisfaction levels from 52.6% (pre-implementation) [95% CI: 51.8–53.5] to 65.7% (post-implementation) [95% CI: 64.5 – 66.9%]. The calculated %SM percentage change showed the implementation of web-based teleradiology led to a significant 24.8% improvement in patient level of satisfaction with radiology services, reflecting a considerable improvement impact.

### Effect of web-based teleradiology intervention on patient waiting time

The GLM analysis demonstrates that the web-based teleradiology intervention demonstrated a reduction in patient radiology service waiting time by 71% (estimated effect = 0.29; 95% CI: 0.20, 0.41) compared to patients who accessed the radiography service before the implementation of web-based teleradiology, holding other variables constant (Table 4).

### Effect of web-based teleradiology intervention on patient radiography service satisfaction

GLM analysis revealed that implementing teleradiology improved the patient service satisfaction score by 11% (estimated effect of 1.11, 95% CI: 1.08–1.15) compared to patients who accessed the radiography service before the implementation of web-based teleradiology through in person referral consultation approach, holding other variables constant (Table 5).

**Table 5** GLM regression analysis on patient radiography service satisfaction, Northwest Ethiopia ($N=836$)

| Variables | Category | Median Satisfaction Score (IQR) | Crude exp (β) [95% CI] | Adjusted exp (β) [95% CI] [a] |
|---|---|---|---|---|
| Web-based teleradiology exposure | No (pre-intervention) | 96 (89, 103) | 1 | 1 |
| | Yes (post-intervention) | 113 (105, 124) | 1.17 (1.15, 1.19) | 1.11 (1.08, 1.15) * |

*CI* Confidence Interval; 1- represents the comparison group

**P*-value < 0.05

[a]Adjusted for gender, marital status, occupation, types of X-ray studies requested, educational status, mode of payment, wealth status, total waiting time

**Table 6** Total median waiting time by the type of X-ray examination request in public hospitals in Northwest Ethiopia ($N=836$)

| X-ray image request types | Frequency ($n=417$) | Pre-intervention (MT2B) Median (IQR) hrs. | Pre-intervention (MTWTB) Median (IQR) hrs. | Frequency ($n=419$) | Post-intervention-MT2A) Median (IQR) in hrs. | Post-intervention-MTWTA Median (IQR) in hrs. |
|---|---|---|---|---|---|---|
| Chest | 85 | 2.83 (1.25–4.83) | 46.00 (24.67–75) | 355 | 0.15 (0.07–0.47) | 4.78 (2.50–10.59) |
| Upper Extremities | 38 | 2.17 (1.37–6.12) | 25.59 (21.00–68.21) | 12 | 0.24 (0.09–0.49) | 8.53 (3.62–14.59) |
| Lower Extremities | 63 | 2.08 (0.96–5.50) | 30.83 (23.59–67.00) | 16 | 0.13 (0.08–0.37) | 3.32 (2.02–4.36) |
| Skull | 75 | 2.50 (1.17–12.79) | 44.0 (22.38–69.88) | 6 | 0.22 (0.19–0.28) | 3.32 (2.37–3.62) |
| Spine | 62 | 1.75 (0.94–4.56) | 47.25 (23.17–72.0) | 3 | 0.43 (0.28–0.72) | 3.87(3.21–7.18) |
| Abdominal | 59 | 2.67 (1.21–12.38) | 44.0 (21.96–70.75 | 11 | 0.10 (0.08–0.16) | 4.8 (3.43–9.52) |
| Pelvic | 17 | 3.67 (2.25–18.75) | 54.92 (28.25–97.83) | 9 | 0.13 (0.07–0.28) | 3.22 (2.55–6.22) |
| [a]Others | 18 | 2.58 (1.50–13.73) | 23.34 (19.98–29.77) | 7 | 0.15 (0.12–0.93) | 10.58 (2.71–14.68) |

- MT2B (Median Time before-intervention): The median time from the radiology department visit at the referral public hospital to report completion by radiologists

- MT2A (Median Total Time after-intervention): The median time from radiologists' image download to report completion at the referral hospital

- MTWTB (Median Total Waiting Time Before-intervention): The median total waiting time from referral to clinical report completion

- MTWTA (Median Total Waiting Time After-intervention): The median total waiting time is from the time of radiology image upload by the consulting clinicians to the time of clinical radiology report completion and submission by the radiologist

[a]Others: Dental, Sinus, Mammogram, Barium Swallow

#### Waiting time by X-ray image study requests

Prior to the implementation of web-based teleradiology, the median waiting times (MT2) for various X-ray requests were as follows: upper extremities 2.83 h (IQR: 1.25–4.83), chest 2.83 h (IQR: 1.25–4.83), skull 2.50 h (IQR: 1.17–12.79), lower extremities 2.08 h (IQR: 0.96–5.50), abdominal 2.67 h (IQR: 1.21–12.38), and pelvic – 3.67 h (IQR: 2.25–18.75). After implementing web-based eX-ray teleradiology, the median waiting times (MT2) were changed: chest 0.15 h (IQR: 0.07–0.47), upper extremities 0.24 h (IQR: 0.09–0.49), lower extremities 0.13 h (IQR: 0.08–0.37), skull 0.22 h (IQR: 0.19–0.28), spine 54.92 h (IQR: 28.25–97.83), abdominal 0.10 h (IQR: 0.08–0.16), and pelvic 0.13 h (IQR: 0.07–0.28) (Table 6).

#### X-ray image consultation and report submission by weekdays

Before the introduction of web-based teleradiology, a greater number of X-ray images were consulted and commented on during specific days of the week, namely Monday (68 vs. 88) and Friday (71 vs. 77) (Fig. 4). Following the implementation of web-based teleradiology, the central server received 79, 74, and 69 X-ray images for consultation on Monday, Saturday, and Sunday, respectively. Furthermore, a higher number of X-ray images were commented on Monday (79), Thursday (73), and Friday (71) (Fig. 5).

#### Timing of x-ray image consultations and interpretations

Before the implementation of web-based teleradiology, the consultations and interpretation times were limited to daytime hours. In the mornings, 197 X-ray images were consulted, and 236 X-ray images were commented. In the afternoons, 220 X-ray images were consulted, and 181 were commented. However, after the system implementation, X-ray image consultation and interpretation were carried out during the evening and night timings in addition to the morning and afternoon times. In the evening time, 150 X-ray images were consulted, and 159 were commented. Similarly, during the night-time, 72 X-ray images were consulted, and 183 images were commented on (Figs. 6 and 7).

#### *Subgroup analysis for patient radiology service waiting time*

We performed a post-hoc analysis to evaluate the effect of the web based teleradiology system on specific categories of variables, including image consultation and commenting during various times of the day and days of the

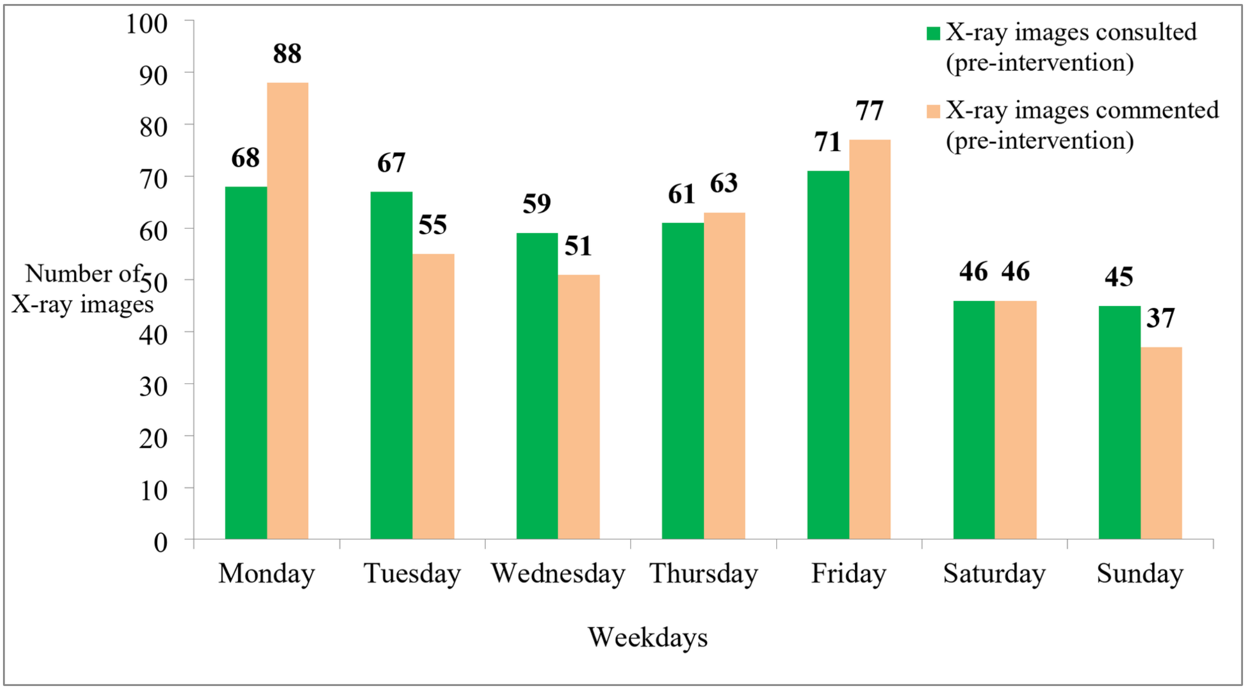


**Fig. 4** Distribution of X-ray image consultation and interpretation by weekday in the pre-intervention period
Note: The total number of commented images on a given day may exceed the total number of consulted images due to the inclusion of backlog images from previous days

week. The findings were reported using a 95% confidence interval.

The subgroup analysis found that in the post-intervention group, patient waiting time was reduced by 87% for images consulted in the afternoon compared to the pre-intervention group [(exp(β) = 0.13, 95% CI: 0.11, 0.16), ($p < 0.001$)]. Similarly, images commented on in the afternoon for the post-intervention group showed a 75% decrease in patient waiting time compared to the post-intervention group [(exp(β) = 0.25, 95% CI: 0.17, 0.35), ($p < 0.001$)]. This suggests patients benefited more from the intervention during afternoon consultations.

The subgroup analysis found significant reductions in patient waiting time for images consulted on different days of the week in the post-intervention group compared to the pre-intervention group ($p < 0.001$). Specifically, image consultations on Wednesdays in the post-intervention group showed an 88% reduction in patient waiting time compared to the pre-intervention group [(exp(β) = 0.12 (95% CI: 0.08, 0.18)], suggesting patients benefited more from the intervention on specific days of the week (Table 7).

## Discussion

Patient waiting time and satisfaction are key indicators to ensure healthcare service quality and are often used to evaluate the performance of healthcare systems [52]. Unless waiting time is effectively managed, delays in patient imaging can negatively impact patient care in several ways, including compromising the quality of care [53]. Our study provides evidence that the use of web-based teleradiology is an effective way to reduce patient radiography service consultation waiting time and improve patient satisfaction. Our findings revealed a significant effect size favouring the implementation of teleradiology. The utilization had a noteworthy impact in reducing patient waiting time and improving overall service satisfaction. The Generalized Linear Model analysis showed that the implementation of teleradiology contributed to a significant 71% reduction in patient waiting time and an 11% improvement in patient satisfaction with radiology services (Tables 5 and 6).

The findings of this study align with previous research conducted in Tripura (India), which reported a mean turnaround time of 3.19 h [54]. Furthermore, a study conducted in China demonstrated a significantly shorter median waiting time of 0.38 h for imaging examinations with the implementation of Artificial Intelligence (AI), compared to a median waiting time of 1.97 h in the conventional group [55]. Moreover, the study conducted at Osaka University Hospital in Japan demonstrated that the implementation of the radiology information system led to a substantial decrease in the total turnaround time, with an average reduction of over 23 h [56]. These findings provide additional support for the effectiveness of teleradiology in enhancing patient diagnosis and

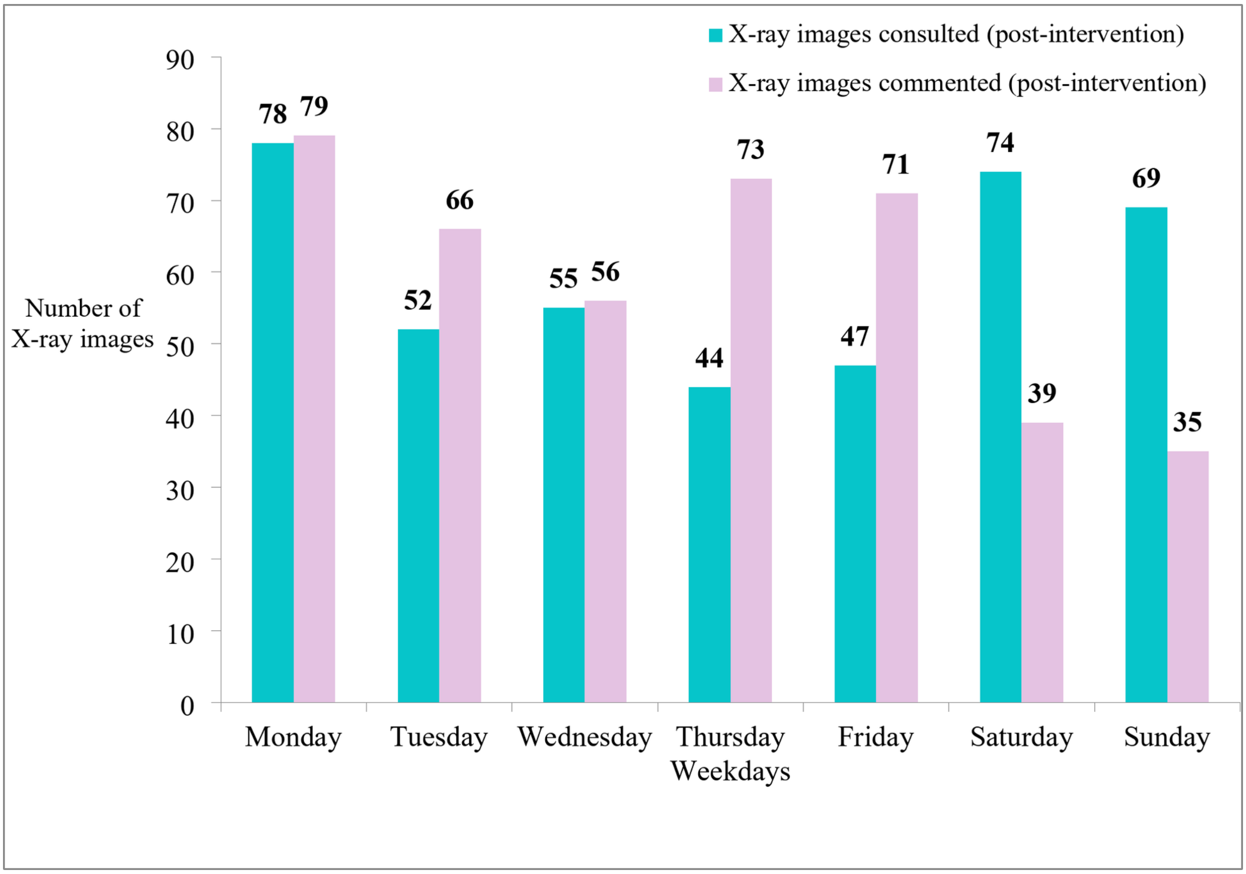


**Fig. 5** Distribution of X-ray image consultation and interpretation by weekday in the post-intervention period
The total number of commented images on a given day may exceed the total number of consulted images due to the inclusion of backlog images from previous days

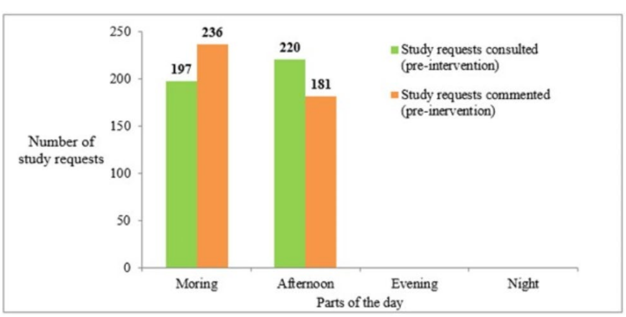


**Fig. 6** Study requests consulted and commented before the implementation of the web-based teleradiology

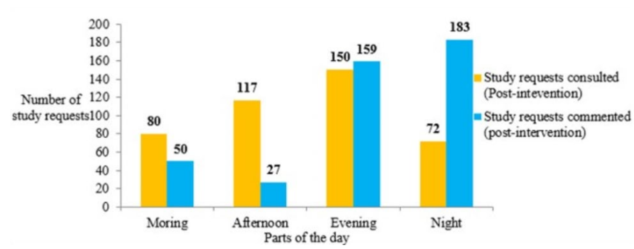


**Fig. 7** Study requests consulted and commented after the implementation of the web-based teleradiology
*-Morning 6: 00 AM– 12:00 PM; Afternoon: 12:00 PM– 6:00 PM; Evening: 6:00 PM– 9:00 PM; Night: 9:00 PM– 6:00 AM.*
*-The total number of commented images on a given day may exceed the total number of consulted images due to the inclusion of backlog images from previous days*

treatment [57], achieved by reducing the waiting time for radiology reports and enabling radiologists to interpret additional images during off-hours [58].

After implementing a web-based teleradiology system in this study, a significant reduction in the median total waiting time for radiography report completion and submission was observed (from 2.5 h to 0.15 h), improving the efficiency of healthcare service delivery. However, our study found shorter median waiting times for radiologist responses compared to a previous study (median radiologists' response time = 6.1 h) [59]. However, our study found longer waiting times compared to a study conducted at the University of Arizona's radiology department, which reported an average turnaround time of 1.3 h [60], and another study conducted by an independent medical humanitarian organization, which reported a median response time of 6.1 h [59]. The complexity of the imaging modality could potentially explain why these

**Table 7** Subgroup analysis of the effect of web-based teleradiology on patient waiting time in South Gondar zone, Northwest Ethiopia

| Characteristics | Pre-intervention (*n*=417), n (%) | Post-intervention (*n*=419), n (%) | Stratum Specific exp(β) [95% CI] |
|---|---|---|---|
| Parts of the day image consulted | | | |
| Morning | 197 (47.24) | 80 (19.09) | 0.29 [0.23, 0.36] |
| Afternoon | 220 (52.76) | 117 (27.92) | 0.13 [0.11, 0.16] |
| Evening | 0 | 150 (35.86) | - |
| Night | 0 | 72 (17.18) | - |
| Parts of the day image commented | | | |
| Morning | 236 (56.59) | 286 (34.21) | 0.31 [0.25, 0.38] |
| Afternoon | 181 (43.41) | 208 (24.88) | 0.25 [0.17, 0.35] |
| Evening | 0 | 159 (19.02) | - |
| Night | 0 | 183 (21.89) | - |
| Weekdays image consulted | | | |
| Monday | 68 (16.31) | 146 (17.46) | 0.20 [0.14, 0.27] |
| Tuesday | 67 (16.07) | 114 (13.64) | 0.10 [0.07, 0.15] |
| Wednesday | 59 (14.15) | 105 (12.56) | 0.12 [0.08, 0.18] |
| Thursday | 61 (14.63) | 118 (14.11) | 0.39 [0.25, 0.59] |
| Friday | 71 (17.03) | 47 (11.22) | 0.15 [0.09, 0.23] |
| Saturday | 46 (11.03) | 74 (17.66) | 0.14 [0.11, 0.18] |
| Sunday | 445 (10.79 | 69 (16.47 | 0.20 [0.14, 0.27] |
| Weekdays image commented | | | |
| Monday | 88 (21.10) | 79 (18.85) | 0.19 [0.15, 0.27] |
| Tuesday | 55 (13.19) | 66 (15.75) | 0.16 [0.11, 0.23] |
| Wednesday | 51 (12.23) | 56 (13.37) | 0.11 [0.07, 0.17] |
| Thursday | 63 (15.11) | 73 (17.42) | 0.23 [0.17, 0.29] |
| Friday | 77 (18.47) | 71 (16.95) | 0.28 [0.20, 0.38] |
| Saturday | 46 (11.03) | 39 (9.31) | 0.07 [0.05, 0.09] |
| Sunday | 37 (8.87) | 35 (8.35) | 0.14 [0.09, 0.19] |

studies observed longer response times compared to our current study. This study focused on X-ray images, while the other study included various imaging modalities like computed tomography (CT) and Magnetic Resonance Imaging (MRI). As a result, CT and MRI modalities are more complex, requiring the review of a larger volume of images, resulting in a more time-consuming interpretation process compared to the interpretation time needed for X-ray images [61, 62].

Even though web-based teleradiology decreases patient waiting time by enhancing the consultation process, it is still influenced by the day and timing of image commenting and report submission. Image commented done on Friday have significantly longer waiting times compared to those conducted on Mondays. The implication of the higher patient waiting time on Friday, compared to Mondays, could be attributed to the transfer of additional backlog images from previous regular office days, which could not be completed and submitted during the same day. This increased workload may contribute to delays in radiology consultations and subsequently prolong the waiting time for patients. Conversely, Sundays have shorter waiting times, due to lower patient flow. In this study, more medical images were consulted during the weekend (Saturday and Sunday) after the intervention, compared to other office-hour day. This finding aligns with a study conducted in Germany, which also reported a higher volume of teleradiology requests during weekends [63]. The increased utilization of medical imaging services during weekends highlights the importance of ensuring adequate resources and staffing to meet the demand for imaging consultations during non-traditional working hours. Healthcare facilities should consider optimizing their services and staffing models to accommodate the higher volume of consultations during weekends and provide timely and efficient patient care. However, a study conducted in Saudi Arabia found that Wednesdays had the longest waiting times, exceeding three hours, despite Mondays and Tuesdays being the busiest days [64]. The patient's flow during weekdays has the potential to impact their radiology waiting time. The prolonged waiting times could potentially be attributed to the presence of backlog images from the preceding busiest days (Monday and Tuesday).

The study revealed that the implementation of teleradiology resulted in improved patient satisfaction, consistent with a prior investigation in an Island community where 90% of patients expressed satisfaction with primary care clinics utilizing teleradiology services [65]. Furthermore, there is additional evidence demonstrating the crucial role of teleradiology in increasing overall patient satisfaction [66]. The explanation could be teleradiology improves patient satisfaction through uninterrupted access to radiology reports, reduced waiting times, and enhanced convenience. It also achieves cost-effectiveness by eliminating travel expenses and reducing fees for multiple consultations, while granting rural patients access to high-quality services previously limited by a shortage of trained professionals, enhancing overall healthcare quality.

## Limitations of the study

The study has several limitations that should be acknowledged. Firstly, the groups in the study were not randomly assigned, which could introduce the potential for confounding variables that may influence the results. However, to address this concern, we utilized the same measurement tool and study settings to assess patient satisfaction both before and after the implementation of web-based teleradiology, aiming to minimize the impact of confounding factors. Second, it is important to note that we approached the study participants at the referral hospital due to the possibility of some participants not returning in a timely manner or potentially being absent altogether after receiving medical imaging consultation services. However, it is worth considering that this approach may have influenced participants' perceptions, which could subsequently impact their satisfaction scores.

Thirdly, staff turnover and negligence create significant challenges in system usage, affecting patient waiting times. Moreover, the study did not account for seasonal variations, which could have influenced the outcomes..

### Future implication

The successful implementation of a teleradiology system that significantly reduces waiting times and improves patient service satisfaction would have wide-ranging practical and theoretical implications. Practically, it could lead to quicker access to diagnostics, improved patient experiences, and optimized resource allocation. Theoretical implications include the validation of teleradiology as an effective solution for enhancing healthcare delivery, specifically in terms of workflow efficiency and patient satisfaction.

## Conclusion

The implementation of a web based teleradiology system led to a remarkable reduction in waiting time within the post-intervention group compared to the pre-intervention group. Additionally, the post-intervention group demonstrated a significant improvement in patient medical imaging service satisfaction, providing conclusive evidence of the intervention's effectiveness in elevating the overall patient experience. These positive outcomes not only address critical delays in diagnosis and treatment but also empower healthcare providers to administer prompt and more efficient care. The authors advise the regional government to scale up the web-teleradiology service. However, optimizing the timing of image upload and interpretation is crucial to further minimize waiting times and improve healthcare delivery. Further research is needed to conduct economic analysis to gain insights into its feasibility. Furthermore, policymakers could prioritize supporting the integration of web-based teleradiology with PACS and Electronic Medical Record (EMR), enabling healthcare organizations to maximize the benefits of both technologies and enhance patient health outcomes through efficient image interpretation, timely consultations, and improved patient care.

## Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12913-025-12545-8.

Additional file 1. A. Time tracking format. B. Questionnaire.

Additional file 2. RAD model phases and activities.

Additional file 3. Description of software.

Additional file 4. Features of the teleradiology system.

Additional file 5. End-users' guide.

Additional file 6. TREND checklist.


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#### Authors' contributions

A.M. developed the concept with contributions to the methodology from B.T., T.M., L.D., Y.G., M.G., and S.M. A.M. wrote the first draft of the manuscript with support from B.T., T.M., L.D., Y.G., M.G., and S.M. A.M. led the process of revision, with contributions from B.T., T.M., L.D., Y.G., M.G., and SM, including critical feedback. B.T., T.M., L.D., Y.G., M.G., and S.M. supervised the development of the manuscript. All authors read and approved the final version of the submitted manuscript for publication.


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#### Data availability

The datasets used in the present study and which underpin the study's findings are available from the corresponding author, AM, upon reasonable request.

## Declarations

### Ethics approval and consent to participate
The Institutional Review Board of the University of Gondar (Ref No: VP/RTT/2554/2021) approved the study protocol, and all methods were conducted in accordance with the relevant guidelines and regulations, as well as the World Medical Association Helsinki Declaration. In addition, permission was obtained from the Amhara Public Health Institute (APHI). Participants who were able to read and write were given written information about the study's purpose and risks and provided their agreement through a signed document. However, participants who were unable to read and write were verbally informed about the study and gave their consent through a verbal agreement and fingerprint data. In addition, the consent process involved caregivers to aid participants in comprehending the study's consent information. The review committee approved an information sheet and consent form for the study, which provided details about the participants, benefits and risks, and duration. Personal information was excluded from the analysis for anonymity and secured to prevent unauthorized access.

### Consent for publication
Not applicable.

### Competing interests
The authors declare no competing interests.

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