International Journal of Health Technology and Innovation
An Official Journal of **Kalam Institute of Health Technology**

RESEARCH ARTICLE

Teleradiology in Tripura: Effectiveness of a Telehealth Model for the Rural Health Sector

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Received: 23rd May 2022; Revised: 19th June, 2022; Accepted: 3rd July, 2022; Available Online: 17th August, 2022

ABSTRACT

With the aim of facilitating early diagnosis and improving health care outcomes in the rural areas of northeast India, Teleradiology Solutions in Bangalore, Karnataka established an alliance with 26 Community Healthcare Centers (CHC), District (DH), and Sub-district (SDH) hospitals located over 3000 km away in Tripura. Digital Imaging and Communications in Medicine (DICOM) images of radiographs of patients from the sites were uploaded to a cloud-based Radiology Information System and Picture Archiving and Communication System (RIS-PACS) for interpretation by expert radiologists at a Teleradiology reporting hub in Bangalore. Over a period of 3 years, starting from January 2018, 78622 studies were interpreted via teleradiology. All age groups and study types were included. The mean turnaround time (TAT) for the report to reach the site once the images had been received in Bangalore for all studies was 3.19 hours (95% confidence interval [CI]: 3.22 - 3.16). This meant that patients could consult their physician with the report on the same day, enabling delivery of optimal care at the same visit. We conclude that teleradiology has proven to be a value-added service in rural healthcare in the remote North East of India.

Keywords: Teleradiology, rural, healthcare, radiography, digital cameras, turn-around-time.

International Journal of Health Technology and Innovation. (2022)

How to cite this article: Kalyanpur A., Meka S., Joshi K., TS H., Mathur N. Teleradiology in Tripura: Effectiveness of a Telehealth Model for the Rural Health Sector. International Journal of Health Technology and Innovation. 2022;1(2):7-12.

Source of support: Nil.

Conflict of interest: None

INTRODUCTION

In India, the public health care system was primarily developed to provide preventive and curative healthcare access to all its people regardless of location, urban or rural, socioeconomic status, or caste.[1] In the current scenario, the healthcare system in India faces a chronic shortfall in medical professionals and infrastructure facilities.[2] This state of affairs is most significant in rural areas, especially in the remote northeast of India.

Tripura is a state in north-east India, and the third-smallest state in the country with a population of 36.7 lakh (as per 2011 census) spread across 10,491.69 km^2 with 73.83 % people living in rural regions. Poverty, unemployment, inadequate infrastructure facilities, geographical isolation (only one major national highway), and communication bottlenecks continue to scourge Tripura. The majority of locals are involved in agriculture and allied activities, the service sector is the largest contributor to the state's gross domestic product. Healthcare facilities in Tripura are extended by the Ministry of Health & Family Welfare of the Government of Tripura. However, the distance of the public sector facilities, long waiting time, inconvenient hours of operation, and poor quality of care are the quoted reasons for nonreliability in the public health sector by the residents.

Teleradiology is the transmission of digital medical images such as x-ray, CT and MRI scans from remote locations to the location of expert trained radiologists using telecommunications technology.[3] It has made a significant contribution in extending access to and improving the quality of rural healthcare. It has become transformative in patient care by reducing the time of diagnosis, optimizing quality by promoting subspecialist review, and bringing down healthcare costs by utilizing manpower efficiently.

However, a number of challenges were faced while implementing teleradiology practices in the rural areas of Tripura. These were as follows:

- The healthcare centers in Tripura were small peripheral rural centers, namely CHC and Subdivisional Hospitals which were equipped with legacy analog equipment using film-based technology.
- Under-staffing: The radiology departments of government hospitals in Tripura are short-staffed.[4] The few, available on-site radiologists are burdened with a large volume of

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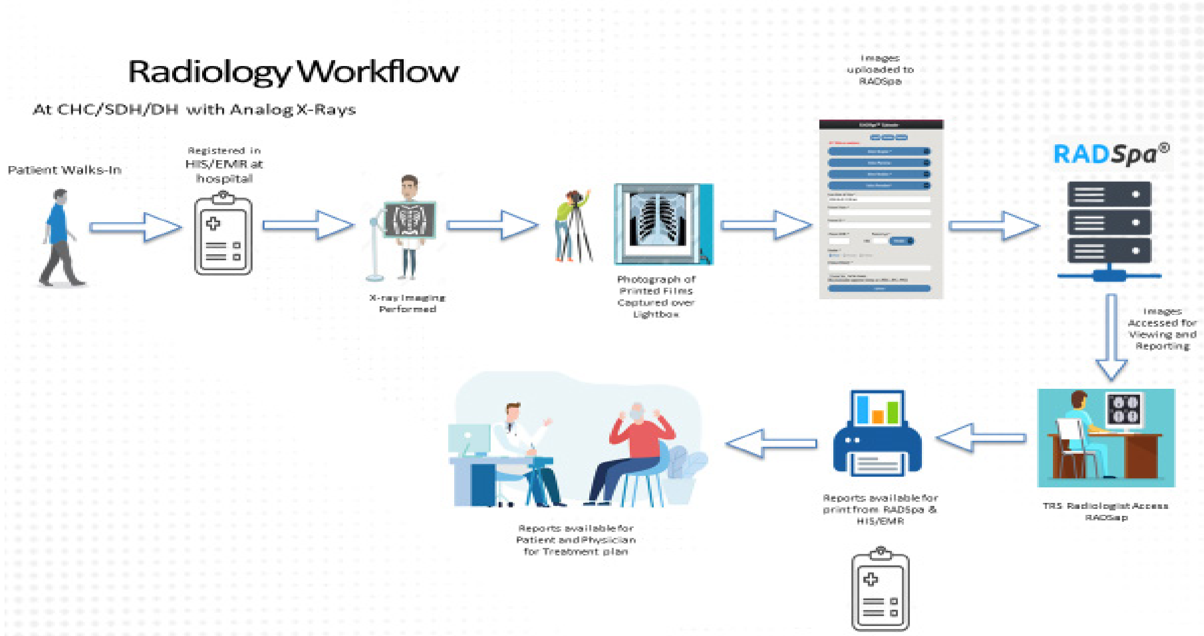


Figure 1: Teleradiology workflow using RADSpa.

images to be interpreted and the need for a second opinion from subspecialists adds an additional layer of complexity to the clinical scenario.

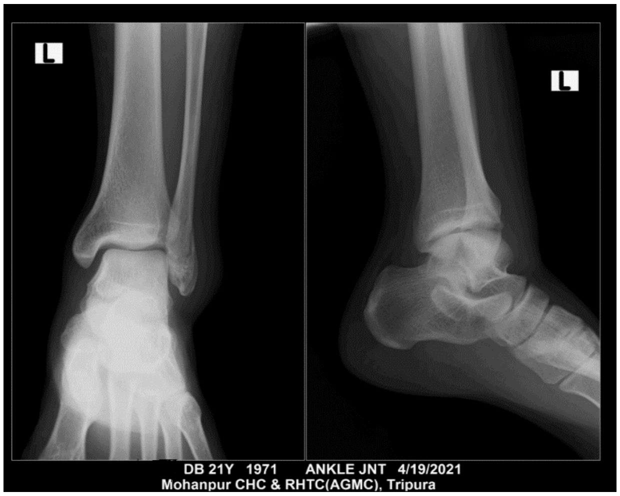
- Quality issue: Qualified radiologists were few and far between. Rural centers did not have radiologists on-site, thus the referring clinicians were obliged to interpret the images themselves.
- Lack of service engineers for the available diagnostic equipment in rural areas led to underutilization of the services.[5]
- Travel time and cost: The local people had to travel from their village to the healthcare facility which not only took time on an average of 1 to 3 hours but also resulted in travel costs.
- Poor infrastructure facilities: Some patients may not avail of treatment in health centers due to poor transportation facilities connecting to the villages.
- Social beliefs: The local tribal people were sometimes resistant to modern diagnostic medical facilities and believe in age-old remedies.
- Non-availability of internet and electricity connectivity was another challenge.

Empirically, instead of placing medical specialists or replacing legacy analog equipment in these areas, it is much simpler to set up or leverage existing telecommunication infrastructure in rural India.[6] Most of the government units are analog legacy machines and conversion to digital would be a substantial upfront investment. As compared to this, our ideology for digitizing using a Phone or camera based solution is a cost effective approach, which has been scientifically validated in the literature.[7,8] Moreover, the earlier challenge related to the nonavailability of adequate bandwidth was overcome due to the rapid growth of telecommunication facilities.

Teleradiology Solutions has been providing reporting services to hospitals across the globe since 2002, including the Ministry of Health in Singapore and centers in the Maldives, and many parts of India. A program that we have undertaken with the Ramakrishna Mission Hospital in Itanagar, Arunachal Pradesh, where subspecialty level reports were available to a poor tribal population, was successfully executed through teleradiology.[9,10] We are the first teleradiology services provider to Tripura. In a precursor project, Teleradiology Solutions collaborated with the National Health System Resource Centre (NHSRC) (which has been set up under the National Rural Health Mission (NRHM) of the Government of India) under a research project to study the potential for and adequacy of teleradiology for improving healthcare among different CHC, District and Sub-divisional hospitals in rural areas of Karnataka as an investigative project, whose learnings were leveraged to develop solutions for the current study. The aim of this article is to provide insight and perspective on the implementation of teleradiology in rural areas of Tripura.

METHODOLOGY

The study was carried out between January 2018 to November 2021 and involved the alliance between a governmental network of 26 CHC, District (DH), and Sub-district (SDH) Hospitals of Tripura, and Teleradiology Solutions in Bangalore, Karnataka. At these sites, only the traditional analog X-ray imaging technology was available. Therefore, the analog X-rays of patients from these sites were digitized at the site using 8–10 Megapixel digital cameras, in accordance with a standardized procedure developed by our group, which the radiographers on site were trained to follow. The resulting JPEG images were converted into Digital Imaging and Communications in Medicine (DICOM) format using a web-based application and uploaded onto a cloud-based Teleradiology workflow system



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ত্রিপুরা সরকার

Teleradiology Solutions
Mohanpur CHC, Tripura
Radiologist Report Sheet

Patient Name:		**Medical Record Number:**	mchc80
Age:	21Y	**Location:**	Inpatient
Gender:	M	**Physician:**	DR. V DEB MBBS
Image Count:	1	**Date of Exam:**	19/04/2021
Order Arrival Time:	02:13	**Date of Report:**	19/04/2021

Final Report

Clinical History: rta

Radiographs of the left ankle joint (AP and lateral views):

Findings:
An acute nondisplaced fracture of the lateral malleolus is seen with soft tissue swelling adjacent to it. The tibiotalar and subtalar joints are normal in configuration and alignment.

Impression:
Acute nondisplaced fracture of the lateral malleolus with adjacent soft tissue swelling.

Radiologist: FRCR.

Teleradiology SOLUTIONS

Figure 2: DICOM image of radiograph of left ankle joint of a patient uploaded in RADSpa and the final report.

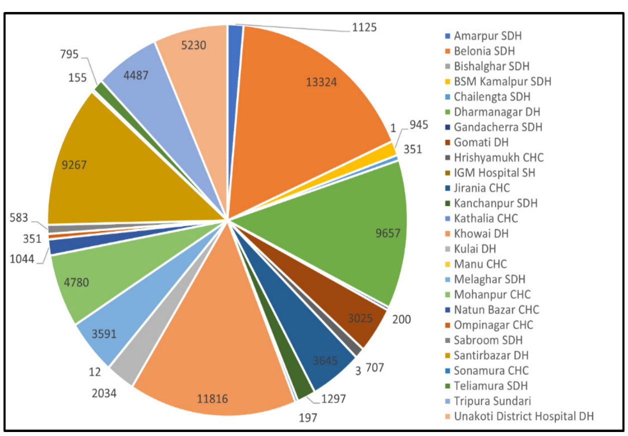

Figure 3: Number of cases from different CHC, DH and SDH of Tripura.

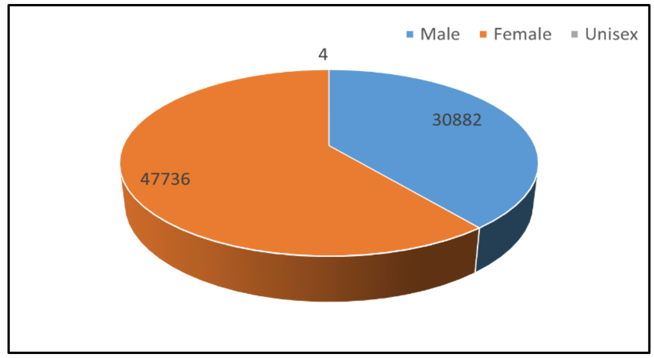

Figure 4: Number of males and females under studies

Table No 1

S.No.	*Hospitals of Tripura under study*
1	Amarpur SDH
2	Belonia SDH
3	Bishalghar SDH
4	BSM Kamalpur SDH
5	Chailengta SDH
6	Dharmanagar DH
7	Gandacherra SDH
8	Gomati DH
9	Hrishyamukh CHC
10	IGM Hospital SH
11	Jirania CHC
12	Kanchanpur SDH
13	Kathalia CHC
14	Khowai DH
15	Kulai DH
16	Manu CHC
17	Melaghar SDH
18	Mohanpur CHC
19	Natun Bazar CHC
20	Ompinagar CHC
21	Sabroom SDH
22	Santirbazar DH
23	Sonamura CHC
24	Teliamura SDH
25	Tripura Sundari
26	Unakoti District Hospital DH

(RADSpa) over a high-speed (4 Mbps and above) internet connection (Figure 1) using standard internet security protocols to maintain patient data confidentiality.

In Bangalore, this electronic workflow platform which has a radiology information system (RIS) integrated with a picture archival and communication system (PACS), was used for the distribution of the images to the reporting radiologists as well as the archival of the reporting data. A RIS is a networked software system that is used in conjunction with PACS to manage image archives, record-keeping, and billing.[11]

Documentation involving patient demographics and other information such as prior reports, patient history records, etc. were digitized and converted to DICOM and loaded into the RIS so that they were available to the radiologists along with the image. Once the images were uploaded, they were accessed by the TRS radiologist, who read the images and reported in the standard format. The RIS system was also configured at on-site hospitals to generate the report (Figure 2).

RESULTS

Over the duration of the project, a total of 78622 studies were uploaded to the RADSpa cloud server from 26 CHC, DH, and SDH hospitals of Tripura (Table 1, Figure 3). All of these were digital radiographs, analog radiographs digitized by a manual process.

A sampling of the digital radiographs based on gender was done as given in Figure 4. The study indicated that the imaging studies were not biased toward any gender.

The age of patients in this study ranged from one day old to 150 years. The mean age of the cases was 41 years (19.80 SD) confidence interval CI (95%) (41.14 – 40.85). A significant number of patients (67.47%) were between 21 and 60 years of age (Table 2).

The entire spectrum of radiographs was covered as part of this project as indicated in Table 3.

The turn-around-time (TAT) for the report to reach the hospital once the images had been received in Bangalore for all the studies ranged from 1.08 hours to 7.03 hours (Figure 5). The

Table 2

Age groups	*Number of cases*
0-20	13197
21-40	25622
41-60	27429
Above 60	12348
Unknown	26

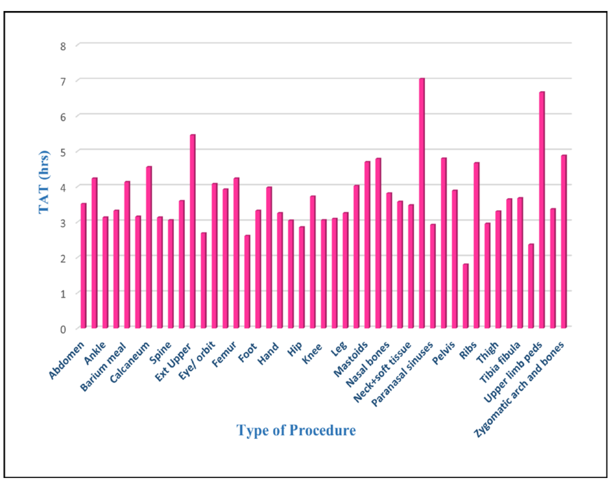

Figure 5: Comparative TAT values in hours for different procedures.

Table 3

Type of Procedure	*Number of cases*
Abdomen	545
Adenoids	1
Ankle	3161
Arm	240
Barium meal/swallow/esophagogram	45
Shoulder	4114
Calcaneum	53w
Chest	31693
Spine	10271
Elbow	3016
Ext Upper	4
Ext lower	2
Eye/ orbit	13
Facial	17
Femur	141
Fingers	368
Foot	4656
Forearm+ wrist+elbow	1144
Hand	2677
Heel	96
Hip	842
Humerus	37
Knee	5597
KUB	492
Leg	878
Mandible	129
Mastoids	73
Maxilla	17
Nasal bones	353
Nasopharynx	31
Neck+soft tissue	681
Nose to rectum/babygram	20
Paranasal sinuses	1156
Patella	11
Pelvis	908
Radius ulna	8
Ribs	9
Skull	558
Thigh	251
Thumb	106
Tibia fibula	149
Toe	134
Upper limb peds	5
Wrist	3900
Zygomatic arch and bones	20
Total cases	78622

mean TAT was 3.19 hours (95% confidence interval [CI]: 3.22 – 3.16). In the case of patients with suspected fracture, the TAT values ranged from 49 min to 7.95 hours while the mean TAT was 3.70 hours (95% confidence interval [CI]: 3.78 - 3.61).

Based on the information from the requisition forms, whether outpatient priority or a routine examination, etc., the technologists sorted out the priority cases to be sent to the radiologists for interpretation. Out of 78622 cases, the maximum number of studies i.e., 75322 were priority examinations. For these prioritized examinations, the mean TAT was 3.11 hours, with 28% (20953) of these cases being reported in TAT less than an hour. But for the patients with routine examination, mean TAT was 8.28 hours. Among all studies, 232 (0.3%) were marked suboptimal. As the image acquisition was suboptimal, the DICOM image replicated the defects in the radiographs and resulted in discrepant radiological analysis/errors. The mean TAT value in such cases was 3.57 hours.

DISCUSSION

Since the beginning of radiologic practice, x-ray film-based capture and subsequent viewing of the images on a lightbox has been traditionally performed. These x-ray films of the patient had to be physically carried throughout the hospital, between hospitals, and even at distant locations for interpretation by the radiologists or for viewing by the clinicians. This is a tedious, laborious, unreliable system. Further, in the district hospitals in rural areas of India, desired healthcare equipment like x-ray machines and even CT scanners are lying idle due to the unavailability of the radiologist, which makes the scenario more concerning.[12] Studies have shown that the implementation of innovative technologies such as digital imaging (CR, CT, and MRI scan) and data sharing through electronic workflow platforms RIS and PACS could enhance the delivery of healthcare in rural communities.[13]

In the project, technologists at small peripheral sites in Tripura, which were equipped with legacy analog X-ray equipment were trained to digitize the images of analog X-ray films using handheld devices such as digital cameras and smartphones. The upload of images via an internet connection to a cloud-based RIS-PACS further magnified the value proposition by permitting interpretation by a nationwide pool of radiologists. The electronic transmission of digitized radiographic images has proven to have the potential to improve clinical decision making for the care of patients, avoid unnecessary patient transfers, and helped in carrying out emergency consultations.[14-17] Furthermore, in our study, the mean turnaround time (TAT) for all procedures was 3.19 hours. This meant that patients could consult their physician with the report on the same day. A similar study was carried out by Char et al (2007) where DICOM CT images were sent in the form of compressed ZIP files by secure-file transfer protocol (sFTP) using the FTP client in Internet Explorer transmitting data via a 256 kbit./s ADSL (asymmetric digital subscriber line) connection. The mean TAT for non-emergency cases was 6 hours.[9]

Telehealth can be used as an integrative approach if participating providers and organizations adopt the same technology.[18] The training of rural healthcare professionals operating in primary healthcare settings is proposed to improve their skills in using e-healthcare systems.

A literature review by Kruse et al deduced that telehealth reduces travel time, refines communication with providers, increases self-awareness, and empowers patients to care and manage their chronic conditions.[19,20] The cardinal implications of the results of our study on Telehealth Model for the rural Health Sector of Tripura are that in areas where radiologists are unavailable and the technology is analog, a process of digitization and teleradiology transmission of the images can enable access to immediate radiologist reports for a rural/tribal population. As a result, physicians can quickly start treatment without any delay and this will help speed up care. Moreover, it will address the issue of access, costs, and travel time. A digital repository of all legacy x-ray films can be created. Digitalization of patient diagnostic reports and findings will make all information available to the network healthcare facilities seamlessly which will further lead to better patient care.

Looking ahead to future perspective, Artificial intelligence in radiology reporting and mobile applications will speed up screen reporting and will make it more approachable to remote locations by integrating with teleradiology workflow.

CONCLUSION

In conclusion, we can say that teleradiology not only enables rapid and reliable analysis of data, but it has also unfolded novel avenues for establishing networks and collaboration between radiologists and centers in remote rural areas of India. Additionally, teleradiology is gaining significant traction in healthcare, and its benefits can be leveraged for the welfare of the rural areas of remote locations in the country providing critical healthcare access, enhancing emergency radiology services, increasing the reach of specialty diagnosis, and thus overall benefitting patient care.

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