

PROOF OF CONCEPT/PILOTS/METHODOLOGIES

Super-Specialty Medical Teleconsultations to Remote Areas of Ladakh, India, via Esanjeevani Under the Hub-and-Spoke Model: A Pilot Study

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Abstract

Objectives: To assess the feasibility, spectrum, outcomes, and challenges of delivering super-specialty consultations through telemedicine to remote areas of the Union Territory (UT) of Ladakh.

Methodology: The authors report on a prospective, observational (descriptive), pilot study. Super-specialty medical teleconsultations were provided to healthcare providers in UT Ladakh by specialists in the Department of Telemedicine, Postgraduate Institute of Medical Education and Research, Chandigarh, India, from October 2021 to May 2022, employing the Hub-and-Spoke model of the Ayushman Bharat Digital Mission. Doctor-to-doctor teleconsultations were initiated by treating doctors at healthcare facilities in UT Ladakh on the eSanjeevani™ platform. An audio-video model was used for teleconsultation, and digitally signed prescriptions were shared. The outcome measures **included** demand and spectrum of super-specialty teleconsultations, the outcome of consults (whether managed successfully at the teleconsultation level or required referral for in-person visits), and technical challenges faced.

Results: A total of 26 super-specialty teleconsultations were provided: 14 (54%) were for women. Patient distribution was uniform across all age groups. The super-specialty-wise distribution of consultations was nine from endocrinology, nine from neurology, three from hepatology, two from cardiology, and three from neonatology. Reasons for seeking consultation were assistance in diagnosis (3, 12%), optimization of therapy (10, 38%), or both diagnostic evaluation and treatment optimization (13, 50%). Five cases (19%) were referred for physical visits to a higher center for advanced diagnostic testing like liver biopsy, brain biopsy, upper GI endoscopy, etc.; other cases were managed remotely. Problems with audio-visual connectivity were encountered in three patients.

Conclusion: This pilot study demonstrates that telemedicine can effectively deliver complex, super-specialty medical consultations to remote areas. Future research should focus on assessing long-term outcomes, patient satisfaction, and cost-effectiveness to evaluate this model's impact better.

Plain Language Summary

In this pilot study, we investigated the feasibility, outcomes, and challenges of providing super-specialty medical teleconsultations using a doctor-to-doctor teleconsultation model in the remote areas of Ladakh, India. The goal was to understand how this innovative approach could improve access to specialized healthcare, otherwise scarce in such regions due to geographical challenges.

A significant demand was found for super-specialty consultations, averaging approximately one consult per unit population per km² per month, catering to complex problems. Consultations were uniformly sought for patients of all ages (children and adults) and both genders to help diagnose intricate medical conditions and

manage them appropriately. The consultations involved diverse super-specialties, including endocrinology, neurology, hepatology, cardiology, and neonatology. Eighty one percent of patients were successfully managed remotely, and 19% were referred for in-person visits to a super-specialist (equivalent to a subspecialist in the West) for advanced diagnostic tests and/or detailed clinical assessment.

The results underscore the pivotal role of telemedicine in bridging healthcare disparities and making specialized care universally accessible. Through technology, patients in remote regions can receive the same high-quality, super-specialty care as in urban areas, ensuring improved patient outcomes. Studies in India and worldwide have shown that telemedicine has the potential to revolutionize healthcare delivery and advance healthcare equity, not only in Ladakh but also in other remote regions.

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Telemedicine has transcended geographical boundaries, providing a lifeline to medically underserved regions. In northern India, Ladakh is one such remote, hilly area where specialized medical care, particularly super-specialty care, is not readily available.¹ The vast expanse of this Union Territory (UT), coupled with its harsh weather conditions and a paucity of healthcare infrastructure, including trained medical personnel, has made delivery of specialist and super-specialist (equivalent to a subspecialist in the West) medical expertise difficult.

In recent years, India's "Digital India" campaign has been harnessing digital technology to bridge the gap in access to healthcare and education.² The National Health Authority's Ayushman Bharat Digital Mission (ABDM) aims to leverage digital technology and data-driven solutions to enhance healthcare access, delivery, and efficiency across the country.^{3,4} It strives to make healthcare accessible, affordable, and equitable for every citizen through a digital health ecosystem. Telemedicine, employing the Hub-and-Spoke model, is playing a pivotal role in this effort. Healthcare "Hubs," located in tertiary care facilities, provide expert guidance to healthcare "Spokes" in far-flung regions.⁵ This model can also be leveraged to provide complex, super-specialty medical teleconsultations.

Although numerous studies⁶⁻¹¹ have explored the implementation and outcomes of teleconsultations across various medical and surgical specialties, most of these have employed a public-private partnership model and have been rather limited in their coverage of the diversity of medical super-specialties. This pilot study is the first study in UT Ladakh demonstrating the successful deployment of telemedicine (via the eSanjeevani platform) for delivering complex, diverse, super-specialty medical consultations to healthcare providers in the UT. This preliminary report outlines the clinical spectrum of these consultations, describes their outcomes, and highlights the challenges encountered.

Background/Study Rationale and Objectives

Access to specialized healthcare in remote and challenging geographical regions is a major concern. UT Ladakh,

situated in northernmost India, exemplifies this challenge (Figure 1). The gap is the widest when it comes to super-specialty healthcare. With technological advancements, telemedicine offers a promising solution, enabling patients to connect with super-specialists remotely through a Hub-and-Spoke model. This study was initiated to explore the feasibility and outcomes of super-specialty medical consultations delivered through telemedicine to healthcare providers in UT Ladakh, aiming to address the gaps in healthcare. The study's objectives were to evaluate the demand for super-specialty medical consultations, explore the clinical spectrum of super-specialty consultations received and the impact/outcomes of teleconsultations, and identify the challenges encountered.

Methods

Study Design and Setting

This study employed a prospective observational design to assess the implementation, clinical spectrum, and outcomes of super-specialty medical teleconsultations provided to healthcare providers in UT Ladakh, India, by specialists in the Department of Telemedicine, Postgraduate Institute of Medical Education and Research (PGIMER), Chandigarh, India. This study was conducted between October 2021 and May 2022. The teleconsultations were facilitated using the Hub-and-Spoke model, where PGIMER Chandigarh functioned as the Hub, and the healthcare facilities/providers in UT Ladakh seeking consultation served as Spokes (Figures 1 and 2 and Table 1).

Telemedicine Platform and Study Procedures

eSanjeevani—National Telemedicine Service of India,¹² a cloud-based web platform of the Ministry of Health and Family Welfare, Government of India, designed, deployed, and maintained by The Centre for Development and Advanced Computing (C-DAC), Mohali, was used in this study to facilitate doctor-to-doctor teleconsultations through its Ayushman Bharat-Health and Wellness Centre (AB-HWC) mode, instead of the eSanjeevani outpatient department (OPD) mode (which facilitates



Fig. 1. Map showing the geographical distribution and the area covered under the study.

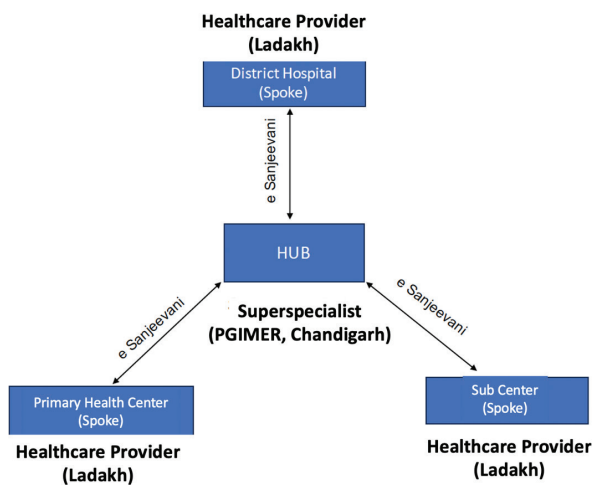


Fig. 2. Hub-and-spoke model. PGIMER: Postgraduate Institute of Medical Education and Research.

direct patient-to-doctor consultations, which are of lesser importance in super-specialty medical consultations wherein the involvement of the primary treating physician is preferable).

Table 1. Participating healthcare centers.

Spoke (n)	Hospital Name	Type of Healthcare Facility	Doctors Registered (n)
1	Dist. Hospital Kargil	District Hospital	16
2	SNM hospital Leh	District Hospital	44
3	Khaltsi	Primary Health Center	3
4	Nubra	Subdistrict Hospital	1
5	Skurbuchan Leh	Primary Health Center	2
6	Tangste	Primary Health Center	1

The details of the teleconsultation model are provided in Figure 3. Teleconsultations were initiated by healthcare providers treating patients at healthcare facilities (district hospitals/primary health centers/subcenters) in UT Ladakh with specialists at the central Hub (PGIMER, Chandigarh) for guidance on complex medical cases. Teleconsultations were conducted in a hybrid audio-video mode, enabling the specialist to interact with patients and their healthcare providers in real-time. C-DAC Mohali provided hands-on training to all healthcare providers for

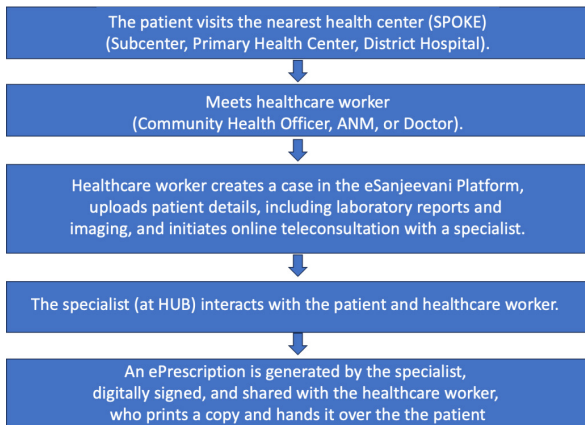


Fig. 3. Workflow of the teleconsultation model. ANM: auxiliary nurse midwife or nurse hybrid.

the use of telemedicine software. Clinical history and/or relevant virtual physical examination were added in the predesigned format of the telemedicine software by the healthcare provider at the Spoke end.

The healthcare provider could also upload laboratory tests and radiographic images on this platform. Following the interaction between the specialist and the healthcare provider/patient, the relevant columns of provisional diagnosis, investigations suggested, treatment advised, and subsequent follow-up were recorded in the e-prescription. This was digitally signed and electronically sent by the specialist. A printout of the prescription was given to the patient at the remote end. The e-prescription had four sections: the first part included the date and time of teleconsultation, unique patient ID, patient name, age, gender, and address. The second part included patient data uploaded on the teleconsultation platform by the healthcare provider at the Spoke, such as clinical history, examination findings, results of laboratory investigations, and clinical queries to be answered by the specialist at the Hub. The third part comprised the provisional diagnosis made by the specialist, details of treatment(s) prescribed, further investigations (if any), and other advice, including timing of follow-up teleconsultation or referral for in-person (physical) assessment. The last part of the e-prescription included the details (name, location, and digital signature) of the healthcare provider at the Spoke and the specialist at the Hub involved in the teleconsultation encounter. All prescriptions generated at the Hub were subjected to audit by the prescription audit committee.

Patient privacy and confidentiality were ensured by using separate private rooms for consultation at both the patient and specialist ends. In the standardized and highly secure telemedicine platform used in this study, patient information is encrypted before cloud upload and stored in secure encrypted servers.

The technical infrastructure for the study included computers (desktop and/or laptop), printers, web cameras, headphones, speakers, an internet connection, and eSanjeevani software. There was a one-time cost for setting up this infrastructure. The e-Sanjeevani software was provided without charge by the Ministry of Health and Family Welfare, Government of India. The sustainment costs were minimal and included only the internet charges.

Data analyzed included (1) demographic information, including age and gender, (2) medical super-specialty the consultation belonged to (e.g., endocrinology, neurology, hepatology, or cardiology), (3) reason for seeking teleconsultation, categorized as assistance in the diagnosis, optimization of therapy, or both diagnostic evaluation and treatment optimization, (4) outcome of teleconsultation, including recommendations made and referral status (managed at the remote center, or required referral to higher center for in-person visits and evaluation through advanced diagnostic testing), and (5) technical issues encountered during teleconsultations, including audio-visual connectivity.

Statistical Analysis

Data were entered into an Excel spreadsheet. Descriptive statistics summarized demographic characteristics, including age, gender, frequency of consults, distribution of teleconsultations by super-specialty, and indication(s) for and outcomes of the teleconsultations.

Institutional Review Board and Informed Consent Statement

This study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Ethics Committee of the Postgraduate Institute of Medical Education and Research, Chandigarh (NK/6291/study/021).

An informed consent was obtained from all patients involved in this study.

Results

Demographics

Twenty-six super-specialty medical teleconsultations were provided during the study period, and the data were analyzed Table 2. Fourteen (54%) were provided to female patients and 12 (46%) to males. The age distribution was uniform across all age groups until 60, with the median age being 31.5 years (range 51 years).

Super-Specialty Consults-Demand, Super-specialty-Wise Distribution, and Indications for Seeking Consultations

With a population density of 4.6/km² for Ladakh, the monthly consultation frequency averaged around one consult per unit population per km² per month. There were 9 (35%) consultations each in endocrinology and neurology, 3 (11.5%) each in hepatology and neonatology, and 2 (7%) in cardiology (Table 1).

Table 2. Details of individual super-specialty medical consultations (grouped by specialty).

Spoke (n)	Age (yr)/ Gender	Super-Specialty	Diagnosis	Indication for Teleconsultation	Outcome of Teleconsultation
1	13/F	Endocrinology	Type I diabetes mellitus (newly diagnosed)	Insulin dose optimization (basal bolus regime) for poorly controlled blood sugars	Insulin dosing optimized.
2	12/F	Endocrinology	Type I diabetes mellitus	Advice on switch from basal bolus insulin to split dose regimen	Insulin regimen changed.
3	33/M	Endocrinology	Hypocalcemic tetany	Management	Started replacement high-dose calcium, suggested investigations for cause.
4	12/F	Endocrinology	Type I diabetes mellitus with diabetic ketoacidosis	Optimization of insulin dosing	Insulin dosing optimized based on a review of blood sugar charts, with a suggestion to repeat a teleconsult after 3 days with 7-point blood sugar charting.
5	51/M	Endocrinology	Hypocalcemic tetany	Management	Optimized oral calcium supplementation and stopped vitamin D supplements in view of iatrogenic hypervitaminosis D.
6	33/M	Endocrinology	Hypoparathyroidism	Review consult with reports of suggested investigations	Patient reassured and advised periodic monitoring of biochemical parameters under tele-OPD
7	14/F	Endocrinology	Type I diabetes mellitus	Review consult for insulin dose optimization	Insulin dose increased (bedtime and before breakfast). Advised teleconsultation under PGIMER Endocrinology on patient request.
8	51/M	Endocrinology	Hypoparathyroidism	Review consult with reports of suggested investigations	Started on vitamin D and calcium, with a plan to repeat biochemical investigations after 2 weeks and a repeat teleconsult.
9	35/F	Endocrinology	Gestational hyperthyroidism at 6 months gestation	Management	Advised to review with investigations.
10	30/F	Neurology	Intracranial space occupying lesion	Diagnosis	Advised to review face-to-face with a neurologist and neurosurgeon for further management, including brain biopsy.
11	47/M	Neurology	Abnormal involuntary movements under evaluation	Diagnostic evaluation and management	Suggested etiological investigations and asked to take a review teleconsult with reports. Symptomatic treatment continued.
12	47/M	Neurology	Chronic abnormal involuntary movements	Diagnosis and management	Suggested a face-to-face review with a neurologist at a nearby tertiary care center for detailed clinical assessment.
13	41/M	Neurology	Memory loss (immediate and recent) under evaluation	Diagnostic evaluation and management	Suggested etiological investigations and asked to take a review teleconsult with reports.
14	7/M	Neurology	Epilepsy	Investigation and management	No reports visible on the online platform, AV connectivity issues at the end of the health-care providers in Ladakh. Teleconsultation failed (it can only be initiated at the Spoke not the Hub).
15	7/M	Neurology	Unprovoked seizure with abnormal MRI findings	Investigation and management	Suggested etiological investigations including blood workup and imaging including MR spectroscopy, and physical follow-up with a neurologist at nearest tertiary care center
16	36/M	Neurology	Large subarachnoid hemorrhage with brain stem death	Management	Counselled the patient attendant about the likely irreversibility of the situation. Confirmation of demise of the patient to be done by doctors on site.
17	41/M	Neurology	Memory loss (immediate and recent) under evaluation	Review consult with reports of suggested investigations for diagnosis and management	Started Vitamin B 12 supplements and referred to a neurologist at nearby tertiary care center for in-depth neurocognitive and neuropsychiatric assessment.

Table 2. (Continued)

Spoke (n)	Age (yr)/ Gender	Super-Specialty	Diagnosis	Indication for Teleconsultation	Outcome of Teleconsultation
18	47/M	Neurology	Abnormal involuntary movements under evaluation	Diagnosis and management	No reports visible on the online platform, AV connectivity issues at the end of the health-care provider in Ladakh. Teleconsultation failed (it can only be initiated at the Spoke not the Hub).
19	42/F	Hepatology	Unconjugated hyperbilirubinemia, incidentally detected (preoperatively)	Diagnostic evaluation and management	Suggested etiological investigations and asked to take a review teleconsult with reports. Continued tablet ursodeoxycholic acid.
20	6/F	Hepatology	Incidentally detected portal cavernoma	Diagnosis and management	Suggested face-to-face review with a gastroenterologist for upper GI endoscopy and FibroScan.
21	42/F	Hepatology	Unconjugated hyperbilirubinemia	Review consult with reports of suggested investigations	Suggested a face-to-face review at the nearest tertiary care center for liver biopsy.
22	1 mo/F	Neonatology	Non-resolving neonatal jaundice	Diagnosis and management	Suggested relevant investigations for non-resolving hyperbilirubinemia and improved nutrition through fortification of expressed breast milk ongoing.
23	1 mo/F	Neonatology	Neonatal hypernatremia	Management	Advised extra (top) feeds, reduction of evaporative heat losses by oil application and keeping the head and extremities covered.
24	1 mo/F	Neonatology	Neonatal hyperbilirubinemia, being managed with phototherapy	Management	Advised need for exchange transfusion after close monitoring of serial bilirubin levels during phototherapy.
25	14/F	Cardiology	CHD (ASD post-device closure) with occasional deviation of angle of mouth	Diagnosis	Suggested the relevant examination be done, investigations sent, and a review of old CHD-related treatment records followed by a fresh review teleconsult.
26	14/F	Cardiology	CHD	Diagnosis	No reports visible on the online platform, AV connectivity issues at the end of the health-care provider in Ladakh. Teleconsultation failed (it can only be initiated at the Spoke not the Hub).

ASD: atrial septal defect; AV: audio-visual; CHD: congenital heart disease; MR: magnetic resonance; MRI: magnetic resonance imaging; OPD: outpatient department.

The reasons for taking consultations varied—three consultations (12%) were for assistance in diagnosis, 10 (38%) for therapy optimization, and the majority (50%) were for both diagnosis and treatment optimization.

Outcome of Teleconsultations

There were 81% effectively managed cases at the remote site. Five cases (19%) were referred for physical, face-to-face visits to a regional tertiary care-level medical facility for advanced diagnostic procedures, including liver biopsy (1), brain biopsy (1), upper gastrointestinal endoscopy (1), and for detailed physical examination and clinical assessment (2).

Challenges Encountered

Audio-visual connectivity issues were encountered in 3 (11%) consultations, impeding effective care delivery.

Discussion

The COVID-19 pandemic has reinforced the role of telemedicine in transforming healthcare delivery. Numerous telemedicine models are now in effect in different parts of the country and worldwide, providing general and specialist outpatient care, promotive and preventive services, emergency services, and public health education services.^{13–16} This pilot study reports for the first time the successful delivery of complex, super-specialty medical teleconsultations to UT Ladakh (India) through a Hub-and-Spoke model via eSanjeevani. The results of our study give key insights into the feasibility, effectiveness, utilization, and outcomes of super-specialty medical teleconsultations in this unique healthcare setting, the principles of which can be extrapolated to other similar geographically and infrastructurally challenged settings.

A teleconsultation demand of approximately one consult per unit population per km² per month for complex medical super-specialties highlights the growing demand for specialized medical expertise in the region. The average number of monthly consults (per unit population per unit area) indicates the demand for these services and is a good metric to assess utilization. When measured over a longer period, it can help in resource allocation, planning, and rationing.

There was no gender bias among the recipients of teleconsultations, suggesting that telemedicine may also help women in remote regions who otherwise may face greater difficulties in accessing healthcare. Women have been shown to have poorer health-seeking behavior in multiple studies done in the past.¹⁷ The uniform inclusivity across all age groups highlights the ability of telemedicine to ensure equitable access to healthcare.

The distribution of teleconsultations across different super-specialties suggests the versatility of the telemedicine program and its ability to deal with the requirements of most medical super-specialties. The demand for these super-specialty consultations needs to be studied over longer periods in future research to help plan specific strategies to meet the evolving needs of the local population. Although this was a pilot study with small numbers, understanding the distribution of teleconsultations sought in various super-specialties through such studies can guide informed decisions regarding the scheduling of specialists in these areas to meet healthcare demands effectively.

The diversity of reasons for seeking teleconsultations, including a substantial number requiring diagnostic evaluation and treatment optimization, reaffirms telemedicine's fundamental capacity to deliver comprehensive patient care even in challenging, super-specialty cases. Only 19% of the cases required referral for physical visits to higher centers for advanced diagnostic testing or detailed in-person clinical assessment, illustrating and reinforcing the utility of teletriage in super-specialty medical cases.

In remote areas where healthcare accessibility and delivery are issues, telemedicine has enabled expert guidance and diagnostic evaluations, optimized therapeutic interventions, and served as a triage system, identifying cases that necessitate in-person assessments, thus reducing the burden on larger hospitals. Its role as a gatekeeper to specialized care is particularly crucial in resource-constrained regions.¹⁸ Sharing digitally signed prescriptions enhances the authenticity of medical recommendations and helps maintain a clear record of patient care. The doctor-to-doctor teleconsultation model of eSanjeevani also serves as an educational tool for local healthcare providers, enabling them to learn from specialists, thereby improving the quality of regional healthcare.

This model is cost-effective for both patients and healthcare providers and helps maintain a sophisticated databank of patients, which will facilitate future clinical follow-up and can also be used for research purposes (e.g., developing disease-specific prediction models through artificial intelligence). Compared to other Hub-and-Spoke models, the Indian model has distinct advantages in terms of its wider coverage of patient healthcare in both rural and urban setups through a coordinated chain of healthcare delivery, better cost-effectiveness, use of a national telemedicine platform ensuring homogeneity across states, and a wider scope encompassing telemedicine, tele-education, and other diverse aspects of health and wellness.

Limitations

Certain limitations were noticed during the telemedicine encounters. The biggest hurdles in initiating teleconsultations were found to be issues with internet connectivity (being a remote hilly area) and the low population density of the UT. All Spoke providers did not utilize these telemedicine services. Being a doctor-to-doctor teleconsultation model, some degree of hesitation was noted in doctors at a few Spokes toward initiating teleconsultations with the super specialists at the Hub due to the wide knowledge gap between them. However, repeated reassurances to the contrary were given to them by the specialists at the Hub. Apart from the sporadic connectivity issues, no difficulties were faced at the super specialist side. Other limitations of the study include: (1) being a pilot study, the number of consultations was small, although this needs to be seen in light of the sparse population of UT Ladakh, (2) lack of follow-up for patients receiving teleconsultations, and (3) absence of an option of scheduling appointments on the telemedicine platform at a later time to circumvent connectivity issues.

Teleconsultations heavily rely on auditory and visual cues, which can sometimes affect the accuracy of diagnoses and treatment recommendations. Additionally, on-site diagnostic tests may not be immediately available. Technical glitches and audio-visual connectivity issues, as encountered in a subset of cases, emphasize the need for robust infrastructure and support systems. Ensuring the privacy and security of patient data is a constant challenge with teleconsultations, given the risk of data breaches and unauthorized access. However, this risk is minimized when using standard, secure platforms like eSanjeevani.¹⁹ With the success of this pilot, we intend to strengthen our model further and overcome the challenges faced in buy-in and utilization through stronger administrative commitment, more frequent training sessions, and policy-level strengthening of infrastructural capacities.

Conclusions

This pilot study demonstrates that telemedicine can effectively deliver complex, super-specialty medical consultations to remote areas. It indicates the potential of telemedicine to bridge healthcare disparities in remote regions by offering super-specialty expertise and demonstrates both the benefits and limitations of this transformative approach. Future research should focus on assessing long-term outcomes, patient satisfaction, and cost-effectiveness to better evaluate the impact of telemedicine in delivering super-specialty medical care to remote regions.

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Contributions

Drs. Singh, Saikia, Agrawal, and Chauhan conceptualized the study. Drs. Jain and Arora collected and analyzed the data. Drs. Jain and Arora wrote the initial draft of the manuscript. Drs. Chauhan and Agrawal contributed revisions. Drs. Saikia and Singh provided critical comments and valuable inputs. Drs. Jain, Agrawal, and Chauhan responded to reviewer comments and incorporated their suggestions in the final version of the manuscript, which was accepted for publication. As first authors, Drs. Jain and Arora contributed equally to the development of the article.

Data Availability Statement

Data underlying the results presented in this paper are not publicly available but may be obtained from the authors upon reasonable request.

Application of AI-Generated Text or Related Technology

The authors adhered to the WAME recommendations regarding using ChatGPT and chatbots in our manuscript. ChatGPT/Chatbots/AI tools were not used in drafting this manuscript.

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None.

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