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# Telemedicine for Patient Management in Remote Areas and Underserved Populations

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## Systematic Review

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**Abstract**

Access to care services in remote areas is challenging. The use of telemedicine technology in these areas facilitates access to health care. This study aimed to summarize the current research on telemedicine in remote areas such as mountains and forests. A systematic search was conducted in databases including Medline (through PubMed), Scopus, IEEE Xplore Digital Library, and ISI Web of Science to identify relevant studies published until May 12, 2021. Screening of retrieved articles for selection and inclusion in the study was performed based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyzes extension for Scoping Reviews (PRISMA-ScR) checklist. A total of 807 articles were identified after removing duplicates, from which 20 studies meeting our inclusion criteria were selected. Challenges, opportunities, and equipment required to use telemedicine in remote areas were extracted from the selected studies. The results revealed that telemedicine implementation in remote areas had many challenges, including harsh weather conditions, Internet connectivity problems, difficult equipment transportation, and ethical issues. Telemedicine also has many benefits, such as cost and time savings for patients, improving patients' quality of life, and improving patient satisfaction. Telemedicine for inhabitants of forested and mountainous areas facilitates rapid access to health care and enhances patient satisfaction. Distinguishing advantages and barriers as well as reducing restrictions will have an essential role in accelerating the use of this technology.

In developing countries, health-care services are not available to people living in remote areas. Physicians also live mainly in urban areas and do not desire to live in remote areas with fewer amenities. In geographically isolated areas, the situation is far more complicated, and it is challenging to provide health services to people living in these areas. People living in such areas may not receive the services they need, leading to social disparity and injustice in accessing health services.[1] In mountainous areas with complex orography, access to different places is difficult, increasing the time of patient transfer to the hospital.[2,3]

Today, the application of technology in health care has led to improved care delivery. Digital interventions and evolution in communication have significantly changed the way the services are delivered. Thus, telemedicine has become part of health care. The World Health Organization (WHO) defines telemedicine as the provision of remote health-care services by information and communication technologies (ICTs) to provide information on the diagnosis, treatment, and prevention of diseases, research, and education of health-care providers to promote the health of individuals and communities.[4]

Mountains cover 24% of the earth's surface, and a large percentage of the world's population lives in these areas.[5] The Himalayas is one of the most well-known mountain ranges stretching over India, Pakistan, China, Nepal, and Bhutan, with around 52.7 million people living in this region.[5] Forests cover approximately 30% of the earth's surface.[6] Thus, because many people dwell in these areas, by means of telemedicine, the desired medical services can be provided to the residents of these areas, which can reduce the need to travel for these people. Telemedicine can save time and money by reducing the number of travels.[7]

People who live in remote areas, such as mountains and forests, or people who do not live in these areas but are present as tourists can benefit from health-care services through telemedicine. Telemedicine, with its facilities, is a practical and low-cost solution for high altitude and expedition medicine.[8]

In addition to the mentioned reasons for needing telemedicine, mountainous and forested areas have always faced natural and man-made disasters, such as train accidents in mountainous areas, mountain falls, avalanches, landslides, floods, mudslides, debris, and forest fire.[9–11] They cause massive injuries and losses every year. In these cases, immediate disaster response is required, where the lack of facilities related to providing health services in these remote areas is more serious. Providing health services in disasters is one of the essential applications of telemedicine. In the event of a disaster, local health facilities can be severely damaged, local

**Table 1.** Search strategy for each database

| # | keywords | |
|---|---|---|
| PubMed | ("Telemedicine"[MeSH Terms] OR "Mobile Health" OR "Telehealth" OR "mHealth" OR "mobile health" OR "eHealth" OR " Remote Consultation " OR "Teleconsultation" OR "Teleconsultations" OR "teleconference" OR "Teleradiology" OR "Telepathology" OR "Telerehabilitation" OR "telemonitoring" OR "telecare" OR "videoconference" OR "telepractice" OR "telenursing" OR "televisit") AND ("Mountain" OR "Mountains " OR "Mountaineering" OR "Altitude"[Mesh] OR "Altitudes" OR "Jungle" OR "Forest") | 397 |
| Scopus | TITLE-ABS-KEY (("Telemedicine" OR "Mobile Health" OR "Telehealth" OR "mHealth" OR "mobile health" OR "eHealth" OR "Remote Consultation" OR "Teleconsultation" OR "Teleconsultations" OR "teleconference" OR "Teleradiology" OR "Telepathology" OR "Telerehabilitation" OR "telemonitoring" OR "telecare" OR "videoconference" OR "telepractice" OR "telenursing" OR "televisit") AND ("Mountain" OR "Mountains" OR "Mountaineering" OR "Altitude" OR "Altitudes" OR "Jungle" OR "Forest") | 399 |
| Web of Science | TS = ("Telemedicine" OR "Mobile Health" OR "Telehealth" OR "mHealth" OR "mobile health" OR "eHealth" OR "Remote Consultation" OR "Teleconsultation" OR "Teleconsultations" OR "teleconference" OR "Teleradiology" OR "Telepathology" OR "Telerehabilitation" OR "telemonitoring" OR "telecare" OR "videoconference" OR "telepractice" OR "telenursing" OR "televisit") AND TS = ("Mountain" OR "Mountains" OR "Mountaineering" OR "Altitude" OR "Altitudes" OR "Jungle" OR "Forest") | 126 |
| IEEE | ("Abstract":"Telemedicine") AND ("Abstract":"Mountain") OR ("Abstract":"Jungle") | 140 |

hospitals and clinics may be damaged or inaccessible, in which case various telemedicine services may be available.[12]

The use of telemedicine in remote areas is faced with advantages and challenges, requiring special equipment. This field demands a comprehensive study to examine the challenges, opportunities, and equipment required for telemedicine in these regions, guiding policy-makers and organizations that intend to implement telemedicine for peoples living in mountainous and forested areas. Thus, the purpose of this review is to comprehensively examine the studies conducted on the use of telemedicine in the mountains and forests, and to answer the following questions:

RQ1: What are the opportunities of telemedicine in forested and mountainous areas?
RQ2: What are the challenges of telemedicine in forested and mountainous areas?
RQ3: What equipment do we need to use telemedicine in these areas?

## Methods

The present study was performed based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyzes extension for Scoping Reviews (PRISMA-ScR) checklist.

A comprehensive search was conducted on May 12, 2021, in the Medline (through PubMed), Scopus, IEEE Xplore Digital Library, and ISI Web of Science databases to answer the mentioned questions. A combination of Medical Subject Headings (MeSH) terms and keywords related to telemedicine (eg, telehealth, mHealth, mobile health, remote consultation, teleconference, telecare), mountain (eg, mountaineering, altitude), and forest (eg, jungle) were used in the search strategy (Table 1).

The results of the search conducted in these 4 databases were entered into the EndNote library and duplicates were removed, so that from the 1062 articles identified, 807 articles remained after removing the duplicates (Figure 1).

Titles and abstracts of the articles were reviewed by 2 reviewers independently. After removing irrelevant items and considering the inclusion and exclusion criteria, 35 articles remained for full-text review. The full-text of selected articles was reviewed and required information was extracted by 2 researchers (S.S. and S.R.). Also, any disagreement between the authors in selecting eligible studies was resolved through consultation with N.M. No time limits were imposed, and articles that had examined the challenges, benefits, and equipment used to provide telemedicine services in forests and mountains were included in the final review. The inclusion and exclusion criteria for the articles are shown in Figure 2.

## Results

After reviewing the full text of selected articles, 20 articles met our inclusion and exclusion criteria, of which 3 were related to the use of telemedicine in the forest, and 17 dealt with the use of telemedicine in the mountains. After reviewing these articles, the opportunities, challenges, equipment, and services provided by telemedicine in these areas were extracted from the articles.

### *Forest*[1,13,14]

Of the studied articles, 3 were related to telemedicine in forested areas. The opportunities, challenges, and equipment required for implementing telemedicine in forests were examined in these articles.

#### *Opportunities*

The use of telemedicine in forested areas facilitates inhabitants' access to health care, diminishes the need to travel long distances to hospitals, reduces the number of travels, and plays an essential role in reducing costs.

#### *Challenges*

This study indicated that telemedicine and telehealth services in forested areas have many advantages, but their implementation is faced with many challenges and barriers. Groups that want to implement telemedicine in these regions should pay attention to these issues and consider appropriate solutions.

Challenges for telemedicine in the forested areas include: (1) poor communication in forested areas due to high trees, (2) dependence of communication on the atmospheric condition, (3) energy supply, (4) connection increment and attenuation due to heavy rains, (5) frequent storms, (6) vulnerability of electronic equipment against the rain and moisture, (7) network instability, (8) cost of maintenance and training of technicians and health-care workers, (9) the need for a large number of resources, people, and time to prepare telemedicine, (10) allocation of a suitable place for the installation of telemedicine equipment, (11) difficult transportation of equipment by small aircraft due to the high weight of the equipment, and (12) the need for a local guide for passing through difficult and dangerous terrains.

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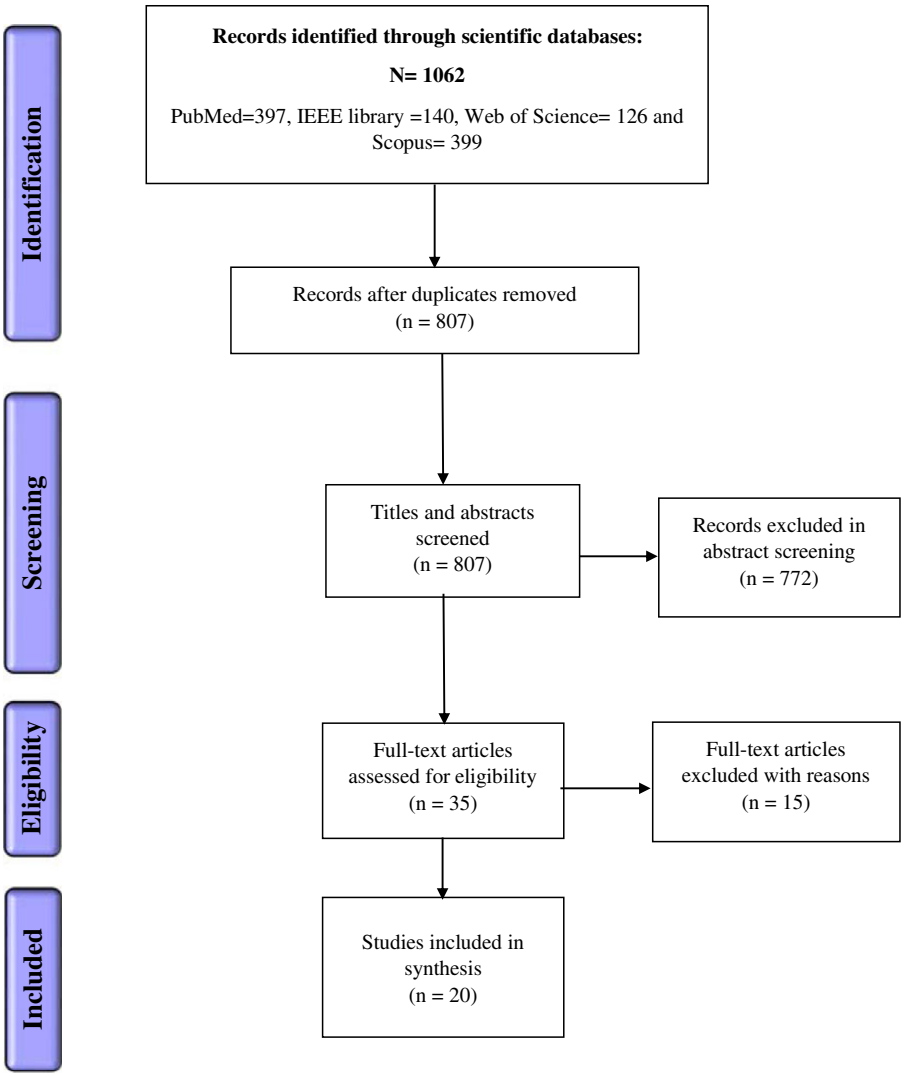


**Figure 1.** Flow diagram of the literature search and study selection.

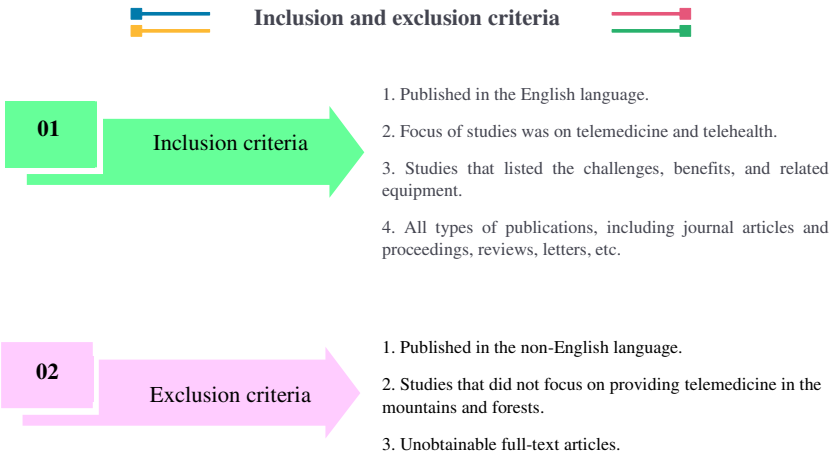


**Figure 2.** Inclusion and exclusion criteria for selecting articles.

### *Equipment*

Large numbers of equipment were needed to implement and use telemedicine in forested areas, which can be classified into 2 main categories; (1) general equipment such as telemedicine hardware and software and (2) special equipment needed for the implementation of telemedicine in forested areas that may not be used in

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**Table 2.** Equipment needed to implement telemedicine in the forest

| Category | Equipment |
|---|---|
| General equipment | • Voice over Internet protocol (VoIP) to provide voice connectivity on WiFi networks.<br>• Computers, antennas, wireless cards, router, printer, analog telephones, satellite or mobile phones, batteries, WiFi networks, and servers.<br>• Vital signs monitor and defibrillator.<br>• Skype for video connection.<br>• E-mail service.<br>• Very high frequency (VHF) radio equipped for store and forward telemedicine.<br>• Mobile satellite Broadband Global Area Network (BGAN).<br>• Telecommunications room in the hospital. |
| Special equipment for forest areas | • Towers with a height of at least 20 meters taller than the trees (in some cases up to 90 meters).<br>• Radio connection on high frequency and very high frequency spectra.<br>• Radio frequency planning software (Radio Mobile) for calculating the height of towers and the link budgets.<br>• Waterproof enclosures to protect electronic equipment from the rain.<br>• Solar panels required to supply electrical energy from solar power. |

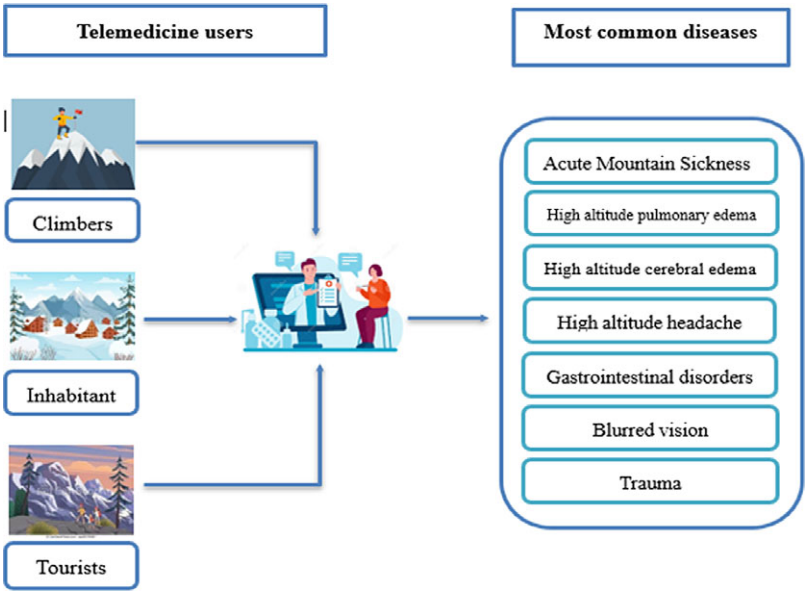


**Figure 3.** Telemedicine users and diseases that telemedicine is used to manage.

other areas. The required equipment for the implementation of telemedicine is listed in Table 2.

## *Mountain*

Seventeen articles were related to the use of telemedicine in mountainous areas. They have mentioned issues such as telemedicine users, the use of telemedicine to manage specific diseases, telemedicine services, and opportunities, challenges, and equipment required for telemedicine.

### *Telemedicine Users and Diseases*

Telemedicine users in the mountainous area and the use of telemedicine for most common diseases are presented in Figure 3.[8,15–21]

### *Service Provided*[2,8,15,21–26]

Telemedicine technology has been used in mountainous areas to provide many services to patients, as shown in Figure 4. These services are essential and can save patients' lives.

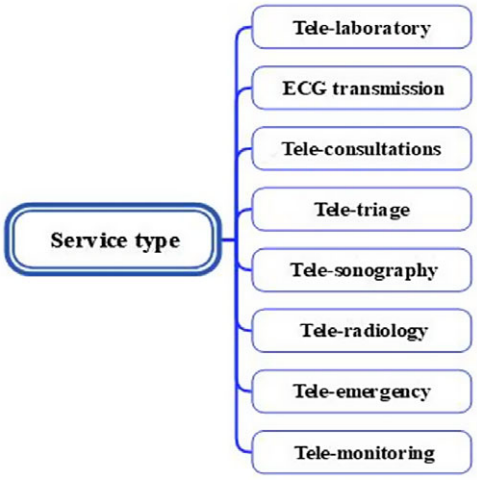


**Figure 4.** Telemedicine services provided for patients.

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### *Opportunities*[2,8,16,24,27]

The results of studies revealed that the use of telemedicine in mountainous areas has many benefits and opportunities, which are listed as follows: saving costs, avoiding inappropriate rescue interventions, reducing the distance between patients and health-care centers, facilitating patient follow-up, saving time for patients, shortening treatment time, improving patients' quality of life, reducing patient travel to seek medical consultation, improving the attractiveness of mountainous areas for tourists, providing real-time consultation with physicians, avoiding admission to emergency and specialized departments, mitigating traffic and pollution, reducing the waiting time, monitoring multiple pathologies, providing teleconsultation even from the doctors' home, reducing car traffic and carbon footprint, mitigating physical and emotional stress of users, improving patient satisfaction and happiness, providing opportunities for monitoring parameters that should be checked daily, and providing emergency services.

### *Challenges*[15,19,21,23,24,28]

Implementing and using telemedicine in mountainous areas has many challenges that can be divided into 2 categories of general challenges and ethical issues[29]:

#### *General Challenges*

- Reimbursement policies and licensing barriers.
- Device's failures in the cold and hypobaric conditions of extreme altitudes.
- Snowstorms may damage camps and health-care centers.
- Lack of continuous and reliable power supply.
- Costs related to equipment and implementation of telemedicine.
- Lack of necessary facilities for some diagnostic tests.
- Impossibility of sophisticated investigation for patients.
- Nonfamiliarity with software, hardware, and reluctance to use tools by health-care providers.
- Internet connectivity problems.
- Use of local dialect by patients.
- Lack of awareness and transport, and harsh weather conditions.
- Melting snow and landslides.
- Bandwidth issues.
- Local staff who perceived telehealth as a threat.
- Poor health-seeking behavior.
- Lack of definite regulations regarding the implementation of telemedicine in mountainous areas.
- Lack of support from the Ministry of Health for plans related to the implementation of telemedicine.
- Provision of convincing conditions for physicians to live in mountainous areas.

## Ethical Issues

- According to USA federal legislation known as the "Ryan Haight Act," which is related to the prescription of controlled drugs over the Internet, the prescription and distribution of drugs over the Internet without a valid prescription are not possible. According to this law, a prescription is valid if the practitioner has at least 1 in-person examination of the patient. Thus, it is impossible to prescribe medication for some patients in telemedicine.
- Obtaining patient consent for examination through telemedicine is 1 of the issues that should be considered.
- Confidentiality of information and management of legal aspects, and data security are also important issues that should be considered before implementing telemedicine.
- Most of the time, climbers ascend mountains in groups. In the event of an accident for a climber in the group, the medical team must provide medical information to the patient in the presence of group members, and in such cases, the confidentiality of patients' information is endangered.
- The patient's medical record and clinical information should be kept secure to facilitate the provision of clinical care as well as subsequent reviews and claims in the event of medical malpractice. Thus, due to the unfavorable weather conditions in the mountainous areas, necessary measures should be considered.

### *Equipment*

Studies have revealed that the use of telemedicine in mountainous areas requires a considerable amount of equipment.[8,15,17–19,21,22,24–26,28,29] Such equipment can be divided into 3 categories: (1) medical equipment, (2) software and hardware related to the implementation of telemedicine, and (3) special equipment that is used in mountainous areas and may not be applied in other areas. The list of equipment needed in mountainous areas is provided in Table 3.

### *Costs of Telemedicine in Forests and Mountains*

The costs related to the implementation of telemedicine in the mountains and forests include establishing telemedicine, maintenance, and training technicians and health-care workers. In telemedicine in forests, the cost of installing towers, sometimes more than 90 meters, is usually high. Transporting equipment by the river also augments the costs drastically.[1] However, in mountains, its use has led to direct and indirect savings by leaving helicopters, ambulances, structures, and personnel free where needed, reducing traffic and pollution.[8] Telemedicine in the mountains can also save considerable effort, time, physical discomfort, and emotional stress.[8,24]

## Discussion

In this study, the use of telemedicine in mountainous and forested areas was reviewed. In this review, the equipment, opportunities, and challenges of this technology were studied. Services provided by means of this technology in mountainous areas included prehospital triage, ECG transmission, teleconsultations, telelaboratory, telementoring, teleemergency services, teleradiology, and teleultrasound. In a systematic review by Ting and Wilkes examining the application of telemedicine in remote and austere environments, the most common services of telemedicine included telemonitoring, teleultrasound, teleradiology, ECG, and telementoring where an expert guides health-care providers on how to diagnose and treat patients.[30] Telemedicine is a perfect solution for managing acute conditions in mountainous areas as well as controlling hypotension and trauma.[8]

Implementing telemedicine in mountainous areas can have many benefits, the most important of which is access to health-care services in an emergency condition. Harsh weather conditions and difficult transportation in mountains are some of the reasons that hinder access to medical services for residents of mountainous regions. By implementing telemedicine in these areas, health-care providers can overcome these difficult conditions and provide health-care services to patients when needed.[24]

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**Table 3.** Equipment needed to implement telemedicine in mountains

| Category | Equipment |
|---|---|
| Medical equipment | • Emergency drugs.<br>• Ultrasonography, digital stethoscope, digital spirometry device, hand-held serum chemistry, blood gas analyzer, electrocardiogram (ECG) and electroencephalogram (EEG) telemetry, X-ray films, physiologic transport monitor, noninvasive (bio-impedance) cardiac output measurement system, digital ophthalmoscope, digital microscope, a portable ultra-sound machine capable of routine or duplex imaging, and visual function testing device. |
| Software and hardware for telemedicine implementation | • Satellite phone, portable computer, video streaming device to digitize and compress the video signal, digital camera, repeater, laptop, satellite dish, server, tablets equipped with a subscriber identity module (SIM) card, personal digital assistant (PDA) device.<br>• Web Real-Time Communications (webRTC).<br>• Satellite phone, video streaming device to digitize and compress the video signal, digital camera, repeater, laptop, satellite dish, server, tablets equipped with a SIM card, PDA device.<br>• Localstorage, a technology that provides novel approaches to save information securely and locally in a browser, and data stored using localstorage cannot be accessed from another host.<br>• Websocket, a new full-duplex communication protocol that can remain permanently active, allowing the exchange of information between the client and the server.<br>• Public switched telephone network (PSTN) and the public switched data network (PSDN).<br>• Information bulletin board service (IBBS) for data transfer within the PSTN.<br>• Designing and implementing a web platform to be accessible by means of tablet for the users.<br>• Design of a decision support system in the form of application and offline to help make decisions in disconnection.<br>• Skype for video connection.<br>• Videoconferencing systems for direct real-time interactions.<br>• Internet connections (including cable, satellite, and WiFi) with appropriate bandwidth. |
| Equipment related to mountain environment | • Placing camps in the mountains.<br>• Supplemental oxygen.<br>• The global positioning system (GPS).<br>• Diesel generators for supply electricity in mountainous areas.<br>• Establishment of huts for the installation of telemedicine equipment. |

From an economic point of view, use of telemedicine in these areas will have several benefits. From the patients' perspective, telemedicine services allow patients to gain access to medical services without traveling long distances, spending money, or absence from work. Patients can also have access to medical services at any time. From the health-care providers' point of view, telemedicine leads to a reduction in referrals to specialized centers and lowers the number of referrals, which consequently mitigates the workload of health-care providers. It can also be cost-effective in the long-term.

Some of the significant challenges mentioned regarding telemedicine in mountainous and forested areas included harsh weather conditions, difficult transportation, and lack of access to these areas. Unmanned aerial vehicles (UAV) or drones can help solve these problems.[31] This tool in telemedicine can have different applications. UAVs can enhance access to health-care services. Through this tool, the required tools and equipment can be transferred to remote areas. In various studies, the delivery of automated external defibrillators (AEDs), medical specimens, and vaccines were mentioned as UAVs' advantages.[32–34] This tool can also be used as a communication hotspot; an example of this technology is its application in telesurgery.[35] With UAVs' assistance, it will be possible to provide specialized services to the residents of inaccessible areas and reduce transportation costs.[36]

## Conclusions

This study revealed that telemedicine in forested and mountainous areas provides many opportunities for its users, facilitates easy access to health care for the residents of these areas, decreases costs, and increases patients' quality of life. Nevertheless, the implementation of telemedicine in these areas faces many challenges, the most important of which are difficult access to these areas and poor weather conditions, making telemedicine application challenging in these areas. Heavy rain and snow in these areas also make it very difficult to protect telemedicine equipment as well as to communicate and supply energy.

**Author Contributions.** S.S., S.R., and N.M. designed the review, search strategy, and conducted database searches. S.R. and S.S. conducted article screenings under N.M. supervision. S.S. carried out the analysis and interpretation under N.M. supervision. Finally, S.S. and S.R. drafted the manuscript. All authors reviewed the content and approved it.

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