

# Development Status and Prospect of Remote Diagnosis and Treatment of Echocardiography Worldwide

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**Abstract:** Telemedicine refers to a discipline in which medical personnel use modern communication technology, electronic technology, and computer technology to realize the remote collection, storage, processing, transmission, and inquiry of various medical information, so as to cross the barriers of time and space and provide medical services to a wider range of people. With the rapid development of Internet technology, telemedicine is being used more widely in case consultation, imaging, ECG and pathology. The demand for remote echocardiography is increasingly strong and its potential applications becoming more extensive, however, the development of remote ultrasound imaging, especially remote echocardiography, is lagging behind due to the limitation of dynamic image codec, immature multi-channel information synchronization technology, and slow network transmission speeds. This article reviews the development status and application prospects of remote diagnosis and treatment of echocardiography at home and abroad.

**Keywords:** Telemedicine; Echocardiography; Remote sensing technology; Remote medicine

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## Introduction

Telemedicine is a discipline in which medical personnel use modern communication technology, electronic technology, and computer technology to realize the remote collection, storage, processing, transmission and inquiry of various medical information, so as to transcend geographical barriers and provide telemedicine services to a wider range of patients and improve their health [1,2]. Against the background of the current rapid development of communication technology, use of telemedicine has grown rapidly in multiple disciplines of modern medicine, providing higher quality medical services to local hospitals with insufficient medical

resources, benefiting patients at the grassroots level and even remote areas, and also improving the medical service level of grass-roots hospitals [3]. Compared with remote imaging or remote pathology, which requires a large number of static images, remote echocardiography features dynamic and real-time performance of ultrasound images for the diagnosis, treatment and prognosis of cardiovascular disease [4]. Due to the limitations of dynamic image encoding and decoding, the immature multi-channel information synchronization technology, and slow network transmission speeds, however, the development of remote echocardiography is lagging behind [5]. This article aims to review the

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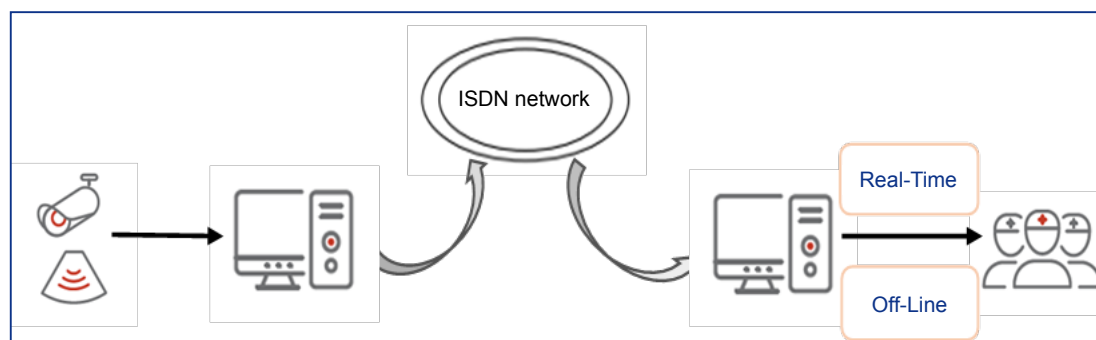
development status and application prospects of remote diagnosis and treatment of echocardiography at home and abroad.

## The Research and Development Status

### *International development*

Initial efforts in the field of remote echocardiography technology abroad were carried out by NASA. Astronauts performed real-time ultrasound examinations, including musculoskeletal ultrasound examinations and ocular trauma examinations, under the guidance of

ground experts without any other diagnostic imaging resources [6]. Remote echocardiography consultation was first reported by a Canadian doctor in the 1980s and was accomplished by sending audio and video through microwaves. Pediatric cardiologists 500 miles away received the transmissions and interpreted and diagnosed the echocardiograms [7]. With the development of communication technology (Fig. 1), scholars from the United States, Western Europe, and other countries have successfully reported the application of remote echocardiography by using integrated business data network (ISDN) and T1 communication lines [8].



**Figure 1** Schematic diagram of remote echocardiographic service using ISDN in real-time or offline mode.

Although this communication technology provides acceptable bandwidth and image quality, there are shortcomings such as transmission of black and white images, high cost, and long transmission time. After entering the information age of the 21st century, remote echocardiography based on the latest communication technology at this stage has entered a new stage of development. In recent years, remote echocardiography diagnosis and consultation based on Internet and cloud service technology have increased significantly. In 2014, a primary health care center in Sweden reported the use of robotic arm-assisted examination, long-distance ultrasonic image transmission by e-health technology, and consultation by heart experts in the superior hospital. Preliminary results were achieved, but the sample size was small, and the feasibility remained to be further studied [9].

In 2017, Korean physician Changsun Kim and others attempted to remotely instruct a primary hospital technician to conduct echocardiography using smartphone network video phone to visually measure patients' left ventricular ejection fraction. This method proved that network video phone could be used as a choice of telemedicine, but the quality of image transmission was affected by the light intensity, mobile phone specifications, and other factors [10]. In a 2019 report, Karthik Seetharam and other doctors in West Virginia introduced

the application of mobile medicine, telemedicine, and artificial intelligence in echocardiography, and these technologies will be more and more closely intertwined in the future, which will lead to precision medicine and greatly promote the development and progress of remote echocardiography [11].

### *Domestic development*

The ultrasound imaging examination mode in most Chinese hospitals is an integrated diagnosis mode of doctors and technicians. This diagnostic mode is highly dependent and flexible on ultrasound doctors. It not only requires ultrasound doctors to master the basic theoretical knowledge of various diseases, but also requires them to be proficient in the operation skills of the ultrasound probe. They can scan multiple angles and sections to obtain standard ultrasound images to make the most accurate diagnosis of patients. However, the technical level of different medical institutions in China is uneven due to its vast geographical area, and the medical technology level of primary hospitals, especially hospitals in remote areas, is still low. Meanwhile, there are still immature dynamic image codec, multi-channel information synchronization technology and slow network transmission speed, which limit the development of remote echocardiography in China. These are the reason that the remote echocardiography started

relatively late in China and is relatively undeveloped.

According to the report, telemedicine services in China began in the 1980s [12]. The earliest telemedicine activity was a telegram cross-sea consultation of an ocean freighter emergency crew in 1986 [13]. According to a report by Li Lishan and others in 2016, modern ultrasound distance education systems use hardware-accelerated codecs and software-specific optimizations to optimize codec technology to break the constraints of time and space, and to meet the learning requirements of different medical populations in different regions [14]. At the same time, the use of remote ultrasound education based on Internet live broadcast systems [15], intelligent portable color ultrasound cloud technology [16], and streaming media technology [17], is gradually increasing.

With the advancement of the Internet and technology, many large hospitals have set up remote consultation centers in recent years [18]. The units that have been used to date include the Fetal Echocardiography Remote Consultation Center led by Beijing Anzhen Hospital, Dalian Central Hospital, Tianjin First Central Hospital, Shanghai Sixth People's Hospital Ultrasound Remote Diagnosis Center, and Henan Provincial People's Hospital [19]. In April 2018, the State Council of China decided to develop the "Internet + medical health" measures, explicitly promoting telemedicine to cover all medical consortia and county-level hospitals nationwide. In the same year, our hospital and two grass-roots hospitals conducted a three-synchronous dual real-time interactive remote echocardiography consultation based on the current Internet technology (Fig. 2). A total of 45

patients were consulted, and initial results were achieved, boosting the construction of China's hierarchical diagnosis and treatment system and the implementation of "Internet + medical health" measures.

## Development Modes

There are currently two ways to develop remote echocardiography: real-time transmission (also known as synchronous mode) and storage-upload (also known as asynchronous mode) [20,21]. The former is based on the current communication technology, which transmits audio, video, and ultrasonic images simultaneously, so as to realize the purpose of diagnosis and consultation [1]. The advantage of this mode is that the two sides of the consultation can interact in real time, which is convenient for timely communication of the condition, and can remotely guide the operation of the ultrasound doctor to obtain a more standardized ultrasound image. The relative disadvantages are high network requirements and restrictions on consultation time between the two parties. In recent years, it is mainly carried out through video conference systems [20]. The methods adopted include network video calls [10] and Internet live broadcast [15]. The internet live broadcast is based on the current storage software, which combines ultrasound images, video, and audio, and sends them to a remote expert for diagnosis [1]. The advantage of this mode is that the consultation time is flexible, which facilitates the subsequent analysis and processing and reduces the diagnosis time [22]. The relative disadvantages are that a large amount of storage space is needed, the quality control of ultrasonic images cannot be carried out, dynamic images are lacking, and the scanning images cannot ensure the accuracy of the specifications needed for diagnosis [23]. In the past two years, "cloud storage", a new storage method, has emerged rapidly, and provided a new possibility for asynchronous mode. It is a new concept that is extended and developed on the concept of cloud computing. It has created a large number of special features reliant on its own Internet advantages, such as automatic synchronization and multi-platform sharing, which provide a new way for offsite backup of medical data [24].



**Figure 2** Consultation image of remote echocardiography based on cloud service. During the consultation, voice, video and ultrasonic images are transmitted simultaneously, and the two sides can communicate in real time.

## Clinical Significance of Remote Echocardiography

The development of remote echocardiography has great clinical significance and practical value whether at home or abroad. A multi-center study conducted by Catherine L. Webb and other doctors in Washington in 2013 proved that remote consultation could avoid unnecessary long-distance transfer of patients, save patients time and costs, and improve the quality of medical services [25]. Subsequently, in 2018, American

scholar Christopher A Rouse and other doctors reported the remote diagnosis of echocardiography performed in the asynchronous mode across the Pacific Ocean, which also confirmed the avoidance of long-term and potentially dangerous transshipment of patients across the Pacific Ocean, and greatly reduced the cost [8]. Cloud service-based triple synchronous dual real-time interactive remote echocardiography consultation between the People's Hospital of Henan Province and the grass-roots hospitals in China in 2019 not only solved difficult cases at the grass-roots hospitals, reduced unnecessary transfers of patients, but also provided real-time guidance to the operation methods of primary-level ultrasound doctors, improved the medical technology level of primary-level hospital doctors, and won unanimous praise from primary-level hospital doctors [5]. During the outbreak of "Corona Virus Disease-19 (COVID-19)" in 2020, ultrasound doctors at Hainan Hospital of PLA General Hospital used remote ultrasound robots to perform real-time cardiopulmonary function examinations for COVID-19 patients in the cabin hospital. It not only achieves the purpose of diagnosis by ultrasound experts, but also reduces the risk of infection of medical staff. At the same time, it confirmed the feasibility of remote ultrasound diagnosis and consultation during the outbreak of infectious diseases [26].

In summary, the advantages of remote echocardiography are summarized as follows: (1) Remote echocardiography consultation provides high-quality medical services to basic-level hospitals with insufficient medical resources to optimize the allocation of medical resources, helps diagnose clinically difficult cases, reduces the referral rate of patients at primary-level hospitals, and reduces unnecessary expenses for patients [25]. (2) Remote echocardiography diagnosis has established a good technology upgrading platform for basic-level ultrasound doctors, promoted information sharing among hospitals, and helped improve the service capabilities of basic-level ultrasound workers [5]. (3) Remote echocardiography education saves a lot of time and expenses for primary care doctors and students, enriches teaching content and arrangement, facilitates understanding and memory, expands the teaching population, and significantly improves teaching efficiency [14]. (4) The development of remote echocardiography has facilitated the practice of Internet + medical policies and the construction of a hierarchical diagnosis and treatment platform system of our country, which has provided a possibility and laid the foundation for the homogeneous service of intracardiac echocardiography in the Medical Union.

### Constraints and Prospects

At present, the development of remote echocardiography still has some urgent challenges that need to be resolved

[27]. These challenges include: (1) there is a lack of standardized management and systematic process for remote echocardiography, including structured electronic reports, standardized teaching plans, and voice recognition entry function; (2) national professional echocardiography training is lacking [28]; (3) remote diagnosis fee standards have yet to be approved; (4) it will take time to establish laws and regulations related to remote systems [21,29], such as the legal benefits of electronic reports, the certification of remote doctor qualifications, and the privacy protection of patient information and rights; (5) there are still difficulties in the development of big data.

With the ongoing advances in internet technology, the continued development of telemedicine is likely. As the most important cardiac examination method, echocardiography holds an irreplaceable role in the diagnosis of structural heart disease, such as heart valve disease and congenital heart disease [30,31]. The development of remote echocardiography conforms to the requirements of the national graded diagnosis and treatment system and solves the current situation of China's vast territory, large population, uneven level of ultrasound doctors' technical skills, and remote distances between medical institutions. In the next few years, with the continuous progress of technology, remote echocardiography will inevitably be combined with portable ultrasound and artificial intelligence to serve as a one-to-many or many-to-many Internet form, spreading throughout various medical institutions throughout the country and even the world, crossing geographical barriers, and serving more convenient services to wider population.

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### Conflicts of Interest

The authors have no conflict of interest to declare.

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