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REVIEW
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Advances in telemedicine for the management of the elderly cardiac patient

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ABSTRACT Telemedicine is the use of information and communication technology to deliver healthcare at a distance. It has been resorted to during the COVID-19 pandemic to lessen the need for in-person patient care decreasing the risk of transmission, and it can be of benefit afterward in the management of cardiac disease. The elderly population has unique challenges concerning the use of telehealth technologies. We thus review the advances in telemedicine technologies in treating elderly cardiac patients including in our discussion only studies with a mean age of participants above 60. Remote monitoring of blood pressure, weight, and symptoms, along with home ECG recording has been found to be superior to usual in-clinic follow up. Combining remote monitoring with video conferencing with physicians, patient education websites, and applications is also of benefit. Remote monitoring of Implantable Cardioverter Defibrillators (ICD) and Cardiac Resynchronization Therapy Defibrillators (CRT-D) is also beneficial but can be at the cost of an increase in both appropriate and inappropriate interventions. Implantable sensing devices compatible with remote monitoring have been developed and have been shown to improve care and cost-effectiveness. New smartphone software can detect arrhythmias using home ECG recordings and can detect atrial fibrillation using smartphone cameras. Remote monitoring of implanted pacemakers has shown non-inferiority to in clinic follow up. On the other hand, small-scale questionnaire-based studies demonstrated the willingness of the elderly cardiac patients to use such technologies, and their satisfaction with their use and ease of use. Large-scale studies should further investigate useability in samples more representative of the general elderly population with more diverse socioeconomic and educational backgrounds. Accordingly, it seems that studying integrating multiple technologies into telehealth programs is of great value. Further efforts should also be put in validating the technologies for specific diseases along with the legal and reimbursement aspects of the use of telehealth.

Telemedicine is the delivery of healthcare services, at a distance, using information and communications technology.[1] Recently the importance of telemedicine became evident during the COVID-19 pandemic, where it was activated to provide care while decreasing physical exposure of healthcare workers and patients to situations with potential risk of transmission.[2] Historically, the first published accounts of its use were for transmitting ECG data over telephone wires in the early 20th century.[1] In our current time telemedicine is used to deliver care through real time audio-video tools, remote patient monitoring tools (telemonitoring), virtual check-ins that use audio or messaging based technologies, and technologies that collect images and data to be later interpreted.[3] There are more than 350,000 mobile health applications accessible to consumers of commercial mobile application stores.[4]

The elderly population is particularly susceptible to more severe disease and mortality due to COVID-19,[5] and patients with cardiac disease have a poorer prognosis.[6] Elderly cardiac patients can benefit from telecardiology services to ensure they receive needed care while staying safely away from possible viral transmission while heading to outpatient clinics. Also, telecardiology can become a more available choice after it has been used during the COVID-19 pandemic. With the unique challenges, the elderly population has regarding the use of technology,[7] a focus on studying the efficacy and useability of telehealth on the aging population is of significant importance.

In this review, we discuss the recent advances in the use of telemedicine by the geriatric cardiac population present in the literature. We also focus on the useability and willingness of the elderly population to adopt such technologies in their care.

METHODS

We searched the online literature for articles doc-

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umenting studies on the application of recent advances in telemedicine to the care of elderly cardiac patients. We limited our searches to studies that included patients aged 65 and above. We included articles that studied the use of such technologies by the elderly population for the provision of cardiac healthcare rather than those studying their use by healthcare providers to enhance care. We excluded studies with a mean age of participants below 60. Because heart failure and arrhythmias are common chronic conditions that require significant follow up, these became the focus of our review.

TELEMEDICINE FOR HEART FAILURE

The prevalence of heart failure (HF) increases with age and is highest in individuals above 80 years of age.[8] Heart failure is the leading cause of hospitalizations in patients above the age of 65, and readmission rates are high in the elderly.[9] As such every patient with chronic HF should have a long-term treatment plan that includes adequate education on lifestyle changes, symptom monitoring, and timely follow-up with the treatment team.[10] Telemedicine interventions can facilitate such treatment plans.

Telemonitoring involves the remote recording and electronic transmission of physiologic data to healthcare teams. It permits the remote monitoring of prognostic indicators (blood pressure, heart rate, weight, arrhythmias).[11] In a trial on 426 HF patients at risk of readmission or death, home telemonitoring of blood pressure and weight combined with a home ECG recording was shown to be superior to usual outpatient care. It decreased the days lost to hospitalizations or mortality and had a lower mortality rate on long term follow up (450 days) when compared to usual outpatient care. When compared to a nurse telephone service, statistical significance was only seen in decreasing the length of hospital stays.[12] Similar results were seen in another large scale trial (TIM-HF2) where remote monitoring combined with patient education and home physician communication with the telehealth team lowered the percentage of days lost to unplanned cardiovascular disease hospitalizations and the all-cause mortality rate. The decrease in cardiovascular disease mortality rate was not significantly different between the telemonitoring and the usual care groups.[13] In a sub-study of the TIM-HF2 trial, NT-proBNP and MR-proADM were shown to be predictors of disease severity and were positively correlated with benefit from remote monitoring making them possible factors for effective allocation of patients to telemonitoring services.[14] Home telemonitoring also demonstrated higher cost effectiveness than usual care or nurse telephone support.[15] Combining telemonitoring with videoconference visits with the treatment team can also have beneficial effects in decreasing hospitalizations due to HF, all cause hospitalizations, and non-fatal HF events,[16] along with amelioration of quality of life.[17] Adding access to online patient education resources can be of good value as well.[18]

Telemonitoring in in patients with implanted devices was also shown to be beneficial. Remote monitoring of Implantable Cardioverter Defibrillators (ICD) and Cardiac Resynchronization Therapy Defibrillators (CRT-D) has produced a decrease in mortality rates.[19,20] Patients with remote monitoring of their devices were also less likely to have a worsening clinical status.[20] However, this was associated with an increased rate of both appropriate and inappropriate life threatening interventions.[21]

Implantable devices for invasive remote monitoring of HF patients have been developed. The V-LAP™ device that measures left atrial pressures and sends the measurements via cloud services to the treatment team did demonstrate reliable measurements when compared with right heart catheterization, along with decreasing rehospitalization rates, improving New York Heart Association (NYHA) status, and quality of life during the COVID-19 pandemic.[22] Similarly, the CHAMPION Trial demonstrated reduced rate of hospitalization, low rate of device related adverse event, a greater reduction in mean pulmonary artery pressure, better quality of life, decreased hospital length of stay, and higher cost effectiveness in patients with implanted pulmonary artery sensor (Cardio MEMS™ Heart Sensor) as compared with usual care for 6[23] and 13 month[24] follow up.

Participating in cardiac rehabilitation programs was of concern during the COVID-19 pandemic. Home based cardiac rehabilitation programs were studied during this time period and showed the same effect of decreasing emergency department

hospitalizations for both remote rehabilitation programs and regular outpatient rehabilitation programs compared to no cardiac rehabilitation. Home based rehabilitation programs were superior to regular outpatient programs by improving quality of life.[25] Home based cardiac rehabilitation programs were also shown to be more cost effective than center based programs.[26] Combining home rehabilitation with home patient education and remote follow up with specialized nurse also improved quality of life and had significant amelioration of clinical status measured by 6 min walk distance.[27]

RHYTHM DISORDERS

Atrial Fibrillation (AF) is the most common of all rhythm disorders worldwide.[28] Its incidence increases with age and is highest among those above 65 years of age. The same trend can be seen for supraventricular tachycardias, and sinus node dysfunction which is the most common indication for pacemaker placement.[8]

Technology for the home detection of arrhythmias has been advancing. The mSToPS trial (mHealth Screening to Prevent Strokes) measured rates of undiagnosed AF in a high-risk population using patch monitors sent via mail.[29] Smartphone software has been developed to be easily used by older adults and found to have high sensitivity, specificity, accuracy and precision using machine learning analysis and neural network approach to identify arrhythmias on a home ECG recording then sending an email to the healthcare provider.[30] Regular twice daily home ECG recordings with tele-transmission to healthcare providers have shown higher diagnostic yield than conventional in-clinic ECG recordings, and significantly reduced mortality.[31] More accessible technologies such as smart phone camera (photoplethysmography) detection of AF have also been tried and showed high sensitivity and specificity in AF detection when compared to home electrode based ECG recordings read remotely by a cardiologist.[32] In Figure 1, we describe an anecdote from our center where a patient's smartphone application lead to the diagnosis of AF. Studies on photoplethysmography using smart watches for AF detection were done in a mostly young population and showed favorable results for AF screening and detection.[33,34] The Apple Heart Study was a virtual clinical trial utilizing participant-owned smartwatches (Apple Inc, Cupertino CA), a virtual telehealth study doctor visit using a smartphone, ECG patch monitoring via mail and online questionnaires to assess outcomes. Of the 419,297 participants who were enrolled within 8 months, an irregular pulse was found in 0.52% of participants. The sensor-based irregular rhythm notification occurred in 3.1% of individuals 65 years and older and 0.16% in those 22 to 40 years of age. Of the enrollees who

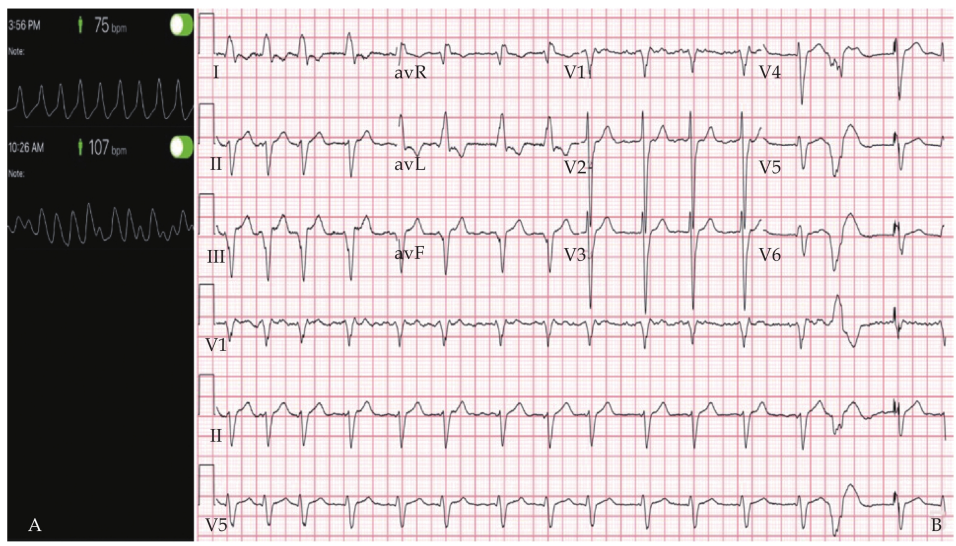

Figure 1 Smart phone arrhythmia detection. (A): Smart phone application helped detect start time of arrhythmia at 10:26 am; (B): the patient was admitted to hospital where ECG confirmed atrial fibrillation. The patient felt his rhythm normalize at the hospital before starting therapy for cardioversion at 3: 56 pm and was also verified.

had irregular pulse notifications during simultaneous use of an ECG patch, the positive predictive value for the irregular pulse notification was 0.84.[34] The Huawei heart study was a similar study was performed using smart devices but with a validation achieved in 87% (PPV >90%) compared to 34% in Apple Heart.[33]

Aside from remote monitoring, patients with AF post ablation reported satisfaction and cost savings in virtual arrhythmia clinics.[35] Smartphone application targeting patient involvement in AF care, patient education, and structured follow up components was embraced by AF patients, increased their quality of life scores, improved their knowledge of their condition, lead to better drug adherence, and decreased the burden of anticoagulation.[36] A significant observation was that clinical decision-support tools provided enabled management decisions, for example, almost 80% high-risk patients were anticoagulated. Subsequent enrollment into the mAFA II trial showed significantly reduced risk of rehospitalization and clinical adverse events.[37] These trial results encourage incorporation of such technology effectively into the AF management pathways at multiple levels, that is, screening and detection of AF, as well as early interventions to reduce stroke and other AF-related complications.

Remote management of patients with implanted devices has also been shown to be beneficial. The European society of Cardiology guidelines do recommend remote monitoring for arrhythmias and in patients with implanted devices due to the benefit of earlier detection.[38] The heart rhythm society expert consensus statement also recommends remote monitoring strategies for patients with implanted devices.[39] Home monitoring of implantable cardiac devices can permit shorter post implantation hospital stays with lower costs while being non-inferior to usual care with a later discharge.[40] In a randomized controlled trial, remote monitoring of pacemakers by the pacemaker sending data via a mobile network to the provider center to be reviewed by a physician at regular intervals showed reduced cost and non-inferiority to usual care with regard to death, stroke, and undertaking a cardiovascular or surgical procedure.[41] Another trial on patients with implanted pacemakers showed no significant difference between in-clinic follow-up and remote monitoring at 12 months of enrollment with regard to quality of life, cardiovascular adverse events, change of medications, pacemaker reprograming, and hospitalizations.[42]

We summarize discussed studies that showed a potential benefit for telemedicine compared to in-person care in Table 1.

USEABILITY BY THE ELDERLY POPULATION

Many factors influence the adoption and the intention to use new technologies. The unified theory of acceptance and use of technology (UTAT) proposes performance expectancy (expected benefits), effort expectancy (degree of ease of use perceived), social influence (degree of important others' believe they should use it), facilitating conditions (resources and support for usage), hedonic motivation (enjoyment), price value (cognitive tradeoff between perceived benefits and monetary cost), and habit influence intention to use technology and how that technology is used. This influence is moderated by age, gender, and experience.[43] In a semi-structured questionnaire study on 20 elderly heart failure patients based on the UTAT model, perceived usefullness, availability of technical/clinical support, and the opinion of others influenced the decisions to adopt telehealth care. Ease of use was not an influencing factor. Other factors such as prior experience using telehealth, knowledge of telehealth technologies, and knowledge of HF also appeared to influence participant decision to use these technologies.[44] Another small survey-based study where elderly with chronic HF were asked about the usage of scales, blood pressure cuffs, and home ECG devices connected to a mobile apply along with answering yes or no questions demonstrated a willingness to use, ease of use expectation, and a high degree of family support.[45] In a larger quasi experimental study, physicians and patients were satisfied with the ease of use of a remote monitoring platform coupled with a mobile app that provides data uploading, remote consultations, electronic medical record viewing, and appointment scheduling. Patients in this study had a mean age of 69, chronic heart failure, demonstrated a good level of adherence to usage of the technology and had a positive effect on self-management.[46] A larger questionnaire based study on 300 heart failure patients with mean age of 66, participants were highly satisfied with a remote monitoring system. However, around

Table 1 Potential benefits of telemedicine compared to in-person care among discussed studies.

Author	Population (mean age of study/treatment arm)	Potential benefit
Cleland, *et al.*[12]	HF patients (67)	Decreased mortality, and days in hospital
Koehler, *et al.*[13]	HF patients (70)	Decreased mortality and hospitalizations
Grustam, *et al.*[15]	Hypothetical HF cohort (Older than 70)	Higher cost effectiveness
Jimenez-Marrero, *et al.*[16]	HF patients (77)	Decreased hospitalizations and unfatal events
Boygi, *et al.*[19]	HF patients with CRT-D (64)	Decreased mortality
Geller, *et al.*[20]	HF patients with CRT-D (68)	Decreased mortality, maintenance of clinical status
D'Amario, *et al.*[22]	HF patient (75)	Decreasing rehospitalization, improving NYHA class, improving quality of life.
Abraham, *et al.*[23,24]	HF patients (61)	Decreased hospitalizations, length of hospital stay, better quality of life, higher cost effectiveness.
Nakayama, *et al.*[25]	HF patients (70)	Improved quality of life
Hwang, *et al.*[26]	HF patients (67)	Higher cost effectiveness
Peng, *et al.*[27]	HF patients (60)	Improved quality of life, amelioration of clinical status.
Steinhubl, *et al.*[29]	Healthy participants (72)	Higher rates of AF diagnosis
Busch, *et al.*[31]	Healthy participants (64)	Higher arrhythmia diagnostic yield, mortality reduction
Manimaran, *et al.*[35]	AF patients post ablation (62)	Cost savings
Guo, *et al.*[36]	AF patients (67)	Improved quality of life, better medication adherence, better patient education.
Guo, *et al.*[37]	AF patients (70)	Reduced risk of rehospitalization and adverse events
Parahuleva, *et al.*[40]	Patients with implanted devices (65)	Shorter hospital stays
Watanabe, *et al.*[41]	Patients with implanted pacemaker (77)	Reduced costs

AF: atrial fibrillation; HF: heart failure; CRT-D: cardiac resynchronization therapy-defibrillator; NYHA: New York Heart Association.

50% of participants experienced a failure in data transmission, and 19% preferred in-clinic follow-up. Those who preferred the use of the remote monitoring system were more likely to be more educated.[47] In 26 patients with heart failure of mean age 75, a home tablet based telemonitoring system was seen to be efficient with patients showing high rates of adherence to its use.[48] In another study adherence to smart phone based remote monitoring technology was high as well, however this adherence decreased as enrollment time increased. Adherence was higher in the older patients while disease severity and sex were not associated with the level of adherence.[49]

A questionnaire-based study probed the receptiveness of telehealth in the care of AF in a rural population of elderly AF patients and their providers. Factors associated with receptiveness were the previous use of telehealth (many patients were not familiar with the technology), the presence of specialized care in the community (the non-availability of cardiology specialists made telehealth of good benefit), a rural mindset in patients who found intrusion in telehealth and had pride in their ability to take care of themselves, and perceived gaps in AF care were their presence was associated with a higher receptiveness.[50] Regarding virtual visits; In a prospective survey-based study on 64 arrhythmia patients (mean age 65) and 14 cardiac electrophysiologist who participated in virtual follow up visits a significant majority of patients were satisfied and around 60% of patients preferred a virtual visit for their next visit. Physicians were also overall satisfied with the virtual visits, 68% of the positions preferred virtual visit for their next visit.[51]

These studies are small studies and are questionnaire-based and might not be representative of populations. A recent study done on 4,525 US elderly citizens showed that 38% of these citizens are not ready for video visits due to difficulties in vision, speech, hearing, dementia, lack of internet devices, or the lack of knowledge to use them.[52] More large scale studies should be done with diverse populations to ensure generalizability of results. We sum-

marize perceived barriers to telemedicine use and adherence in Table 2.

LEGAL CONSIDERATIONS AND REIMBURSEMENT

In a comprehensive review of the literature discussing barriers faced by organizations in adopting telemedicine approaches to care, legal liability, confidentiality, and security of personal information, were frequent barriers cited.[53] The European society of cardiology issued guidance on legal requirements and ethical principles of remote monitoring of implanted devices. These guidelines addressed questions tackling transmission and encryption of data, parties the data is shared with, who is responsible for the data, informed consent principles, and clinician liability all under the General Data Protection Regulation implemented in the European union.[54] Similar efforts should be taken by professional societies in different countries in accordance to the laws and regulations in place. Gaps in legislation and regulation with regard to remote practice of medicine should be addressed to ensure safe and secure patient care. Studies should also be performed for validating these technologies for specific use in specific conditions in order for these technologies to gain approval by regulatory bodies such as the U.S. Food and Drug Administration (FDA). Some sensing devices have FDA clearance, others do not. Of those that have, many are indicated for use in the general population and not in specific diseases. The software, hardware, and workflow may not be suited for the specific disease and will need studies to validate their use and give them approval by regulatory bodies.[55]

Many studies also mention reimbursement as a barrier for organizations to adopt telemedicine in patient treatment.[53] A recent statement by the Heart Failure Society of America indicated that reimbursement for virtual visits was limited prior to the coronavirus pandemic. Only certain cases were re-imbursed by the public Medicaid and Medicare services. During the pandemic these virtual visits were more widely re-imbursed by both public and private financing agencies.[56] Financing agencies both public and private should incorporate telehealth in their reimbursement schemes to ensure continued access to care for all patients specially when in person care can be a hazard for an already vulnerable population. As the studies discussed above have demonstrated reduced hospitalizations, and higher cost effectiveness, facilitating use of telehealth can lead to reduced costs incurred on payers. A centralized technology system that connects patients, providers, and payers can be a step towards that.[57]

FURTHER RESEARCH

The advances in telehealth technologies discussed above can be combined to produce an integrated home health program. These virtual visits can be enhanced by the telemonitoring technologies that provide the physician with measurements they would have obtained in the clinic, regular telemonitoring for early interventions preventing the need for hospitalization, and better patient education and patient involvement in their care through innovative mobile applications. Most studies so far have focused on an isolated application of each technology where they were found to be effective alone. Studies on an integrative approach can be beneficial in determining the extent to which such an approach can substitute traditional in clinic visits and enhance patient care. Based on the above discussed studies we propose in Figure 2 such an integrative approach in creating a single electronic platform that

Table 2 Perceived barriers to telemedicine use and adherence.

Author	Population (age, yrs)	Barriers to use and adherence
Timmermans, *et al.*[47]	HF patients with ICD or CRT-D (66)	Data transmission failure, education
Rush, *et al.*[50]	Rural AF patients (77)	Unfamiliarity with the technology, perceived intrusion of telemedicine
Lam, *et al.*[52]	Community dwelling adults (80)	Difficulties in vision, speech, and hearing, dementia, unavailability of internet devices, lack of knowledge to use devices.
Kruse, *et al.*[53]	(Systematic review)	Age, level of education, socioeconomic status, apathy, unawareness, bandwidth, computer literacy, unavailability of device.

CRT-D: cardiac resynchronization therapy-defibrillator; ICD: implantable cardioverter defibrillator.

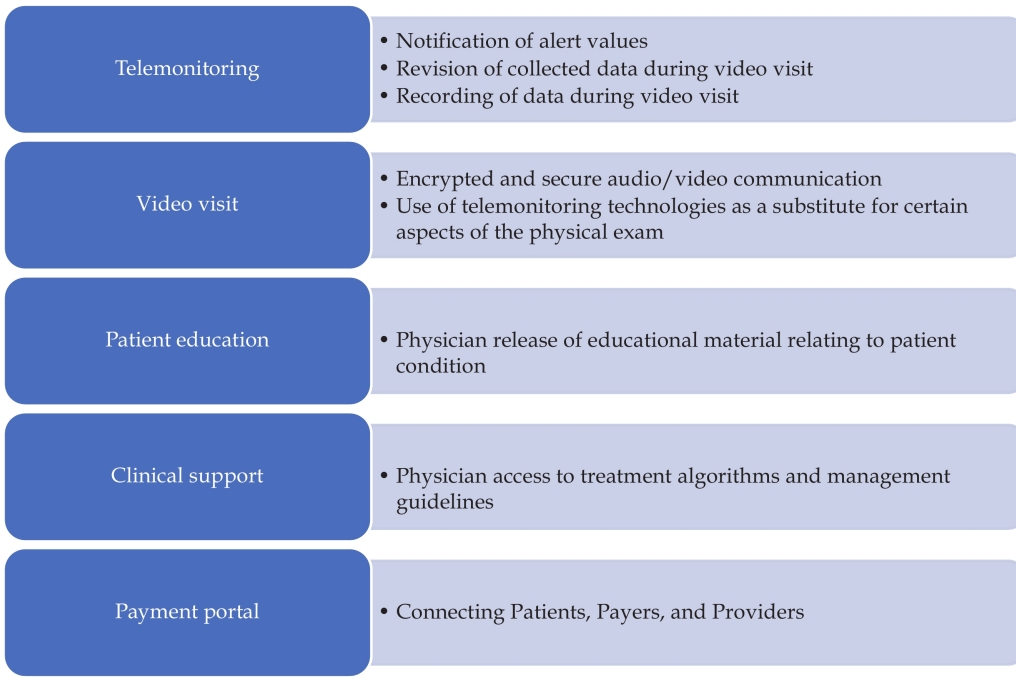

Figure 2 Integrative electronic platform. Proposed features of an electronic platform combining all aspects of telemedicine into a single interface.

combines the different technologies into a single interface providing all the benefits to patients and providers. Tools permitting a comprehensive exam at home such as electronic stethoscopes which transmit data remotely to providers have been tested and found feasible for use in virtual visits.[58] More advanced devices integrated with mobile phones have also been developed.[59]

More studies should be done to determine the ease of use and willingness of the elderly population to adopt telehealth technologies. There is a risk of selection bias in the above-mentioned studies where a patient who would want to be recruited in a study on telehealth technologies would most likely already have access to internet compatible devices and would have familiarity with the use of telecommunication technologies. Large scale population-based studies might be more representative of the general population in this regard. Post marketing studies on usage rates and patient feedback can also provide larger sample sizes and achieve better statistical significance in answering the questions of intention to use these technologies and their usability in the elderly population.

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