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REVIEW ARTICLE

# Home Blood Pressure and Telemedicine: A Modern Approach for Managing Hypertension During and After COVID-19 Pandemic

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**Abstract**
Hypertension is the most common cardiovascular risk factor for acute cardiovascular outcomes, including acute coronary disease, stroke, chronic kidney disease and congestive heart failure. Despite the fact that it represents the most prevalent risk factor in the general population, mostly in elderly individuals, its awareness is still relatively low, being about one third of patients living with undiagnosed hypertension and high risk of experiencing acute cardiovascular events. In addition, though recent improvement in pharmacological and non-pharmacological therapeutic options, hypertension is largely uncontrolled, with about 35–40% of treated hypertensive patients achieving the recommended therapeutic targets. Among different modern interventions proposed for improving blood pressure control in treated hypertensive patients, a systematic adoption of home BP monitoring has demonstrated to be one of the most effective. Indeed, it improves patients' awareness of the disease and adherence to prescribed medications and allows tailoring and personalizing BP lowering therapies. Home BP monitoring is particularly suitable for telemedicine and mobile-health solutions. Indeed, in specific conditions, when face-to-face interactions between patients and physicians are not allowed or even suspended, as in case of COVID-19 pandemic, telemedicine may ensure effective management of hypertension, as well as other cardiovascular and non-cardiovascular comorbidities. This review will summarize strengths and limitations of telemedicine in the clinical management of hypertension with a particular focus on the lessons learned during the COVID-19 pandemic.

**Keywords** Hypertension · Blood pressure · Telemedicine · Telemonitoring · Home blood pressure monitoring · COVID-19

## 1 Introduction

Hypertension is still the most common cardiovascular risk factor, being associated with an increased risk of cardiovascular morbidity and mortality at global level. It affects almost one third of adult population and about two thirds of elderly patients in Western Countries [1], counting for more than 1 billion people worldwide [2]. In spite of the impressive progress in the development of new, effective and safe pharmacological and non-pharmacological therapies, hypertension still remains poorly controlled in the real world practice. Indeed, less than 50% of treated hypertensive patients achieve the recommended blood pressure (BP) therapeutic targets [3, 4], and even lower proportions of BP control are achieved in high or very high risk categories of patients with hypertension [5–7].

There are multiple reasons underlying the poor BP control reported in treated hypertensive patients, though the most relevant items are the low adherence to prescribed medications, as well as the poor awareness of hypertension's consequences [8]. In order to overcome these points, recent hypertension guidelines have proposed two synergistic approaches [9]. The first one is based on a more extended use of fixed (single-pill) combination therapies with two or three antihypertensive drug classes in one pill, to be adopted as first-line strategy in the vast majority of patients with hypertension [9]. Similar approach has been proposed by the Italian Society of Hypertension [10].

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The second one is founded on the widespread diffusion of automated and semi-automated devices for measuring BP levels at home [9]. This latter point has particular relevance, since the recent availability of web-based supports and mobile health (M-health) solutions for sharing out-of-office information, such as home BP measurements, with treating physicians might be viewed as highly effective way to improve hypertension awareness and control in the modern era [11].

In this view, the lessons learned during the outbreak of the infection of the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), also called COVID-19 [12, 13], should be now implemented in daily clinical practice for ameliorating the out-of-office, self-management of BP monitoring at home and, thus, reducing the incidence of hypertension-related cardiovascular diseases.

At the beginning of 2020, almost all countries in the world were hit by the COVID-19 pandemic and health-care systems around the globe were put under an enormous and unexpected pressure [14, 15]. An indirect stunning and threatening consequence of the COVID-19 pandemic was the impact on the daily management of many other acute and chronic non-communicable diseases, including cardiovascular, neoplastic, degenerative and psychological disorders, which have heavily down-sided due to the overwhelming impact of COVID-19 on health care systems.

Restrictive measures progressively adopted by national governments all over the world forced many patients with chronic cardiovascular diseases, including hypertension, at home. In many hospitals, in fact, outpatient visits were suspended or delayed, and there were major difficulties for patients to reach doctors or hospitals during national or local lock-down. Preventive programs, planned visits or interventions, and even access to the emergency rooms were rapidly reduced, and in most cases stopped. Among the patients who suffered a long interruption of their clinical management, also because they were forced to stay at home, those with essential hypertension represented the vast majority [16]. In addition, hypertension represents the most common comorbidity in patients suffering from COVID-19 pulmonary infection [17]. This critical situation was temporarily aggravated by initial reports claiming that hypertension “per se” was a risk factor both for COIVD-19 infection and for more severe course of the pulmonary disease. Besides, some antihypertensive drug classes (mostly ACE inhibitors) were suspected to facilitate the entrance of virus in the human cells, these initial hypotheses were subsequently mitigated or denied by more solid evidence [18–20]. These evidence were also reinforced by international scientific societies, which clearly stated the not to interrupt antihypertensive medications, including ACE inhibitors, during COVID-19 pandemic [21].

This article is aimed at critically discussing the potential clinical advantages offered by telemedicine and M-health solutions, for ensuring home BP monitoring and effective clinical management of hypertension, also during COVID-19 pandemic disease.

## 2 Telemedicine for the Clinical Management of Hypertension

Telemedicine originated in the United States in the late 1960s with the aim of monitoring health status of astronauts during space missions. At that time, electrocardiograms were firstly transmitted between the Logan International Airport Medical Station and the Massachusetts General Hospital in Boston. After this pioneering experience, several definitions and potential clinical applications have been proposed, though the idea behind the concept has been substantially unchanged over the years: it is not the patient who moves to health care providers, yet health-care tools and supports directly get to the patients at their home or work. In 1997 the World Health Organization (WHO) proposed the following unifying definition of telemedicine: "*The delivery of health care services, where distance is a critical factor, by all health care professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment and prevention of disease and injuries, research and evaluation, and for the continuing education of health care providers, all in the interests of advancing the health of individuals and their communities*".

Over the last decades, the progressive improvement in both technical devices and software availabilities allowed rapid transmissions of high-quality data between individual patients and referring physicians even through distant states or countries. This novel approach has been adopted with benefits in the clinical management of different cardiovascular diseases, including hypertension [22, 23], coronary artery disease and heart failure [24, 25], cardiac arrhythmias and sudden cardiac death [26], and, more recently, atrial fibrillation and stroke prevention [27].

In particular, the daily management of hypertension has been progressively and markedly modified by telemedicine, mostly throughout the use of validated, automated BP devices for measuring out-of-office BP levels. These devices have been recommended for improving awareness of the disease, personalizing antihypertensive therapies, ameliorating BP control and reducing incidence of major cardiovascular events [9]. Indeed, the integration of out-of-office BP measurement approach with office BP measurement has several potential advantages, such as a control of white-coat effect, little or limited cost (related to the acquisition of the BP measuring device), and the

availability of numerous BP data in different settings (home, work, holidays), time periods (morning, afternoon, night) and seasons, health status, and positions (supine, sitting, standing) [28, 29]. In addition, the possibility to have repeated BP measurements and personalized BP diaries on the basis of individual characteristics, job-related attitudes and antihypertensive therapies, represents an important advantage with respect to office BP measurement [28, 29]. More recently, the automated transmission of stored BP data from hypertensive patients to their treating physicians introduced a novel clinical advantage for the clinical management of hypertension, by limiting the potential bias introduced by patients' manipulation of the BP diary, as well as the white-coat phenomenon. A schematic representation of Telemedicine applied for the clinical management of hypertension is illustrated in Fig. 1 [30].

All these facilities have been recently busted during COVID-19 pandemic, due to the need of maintaining adequate levels of health care in chronic, non-communicable

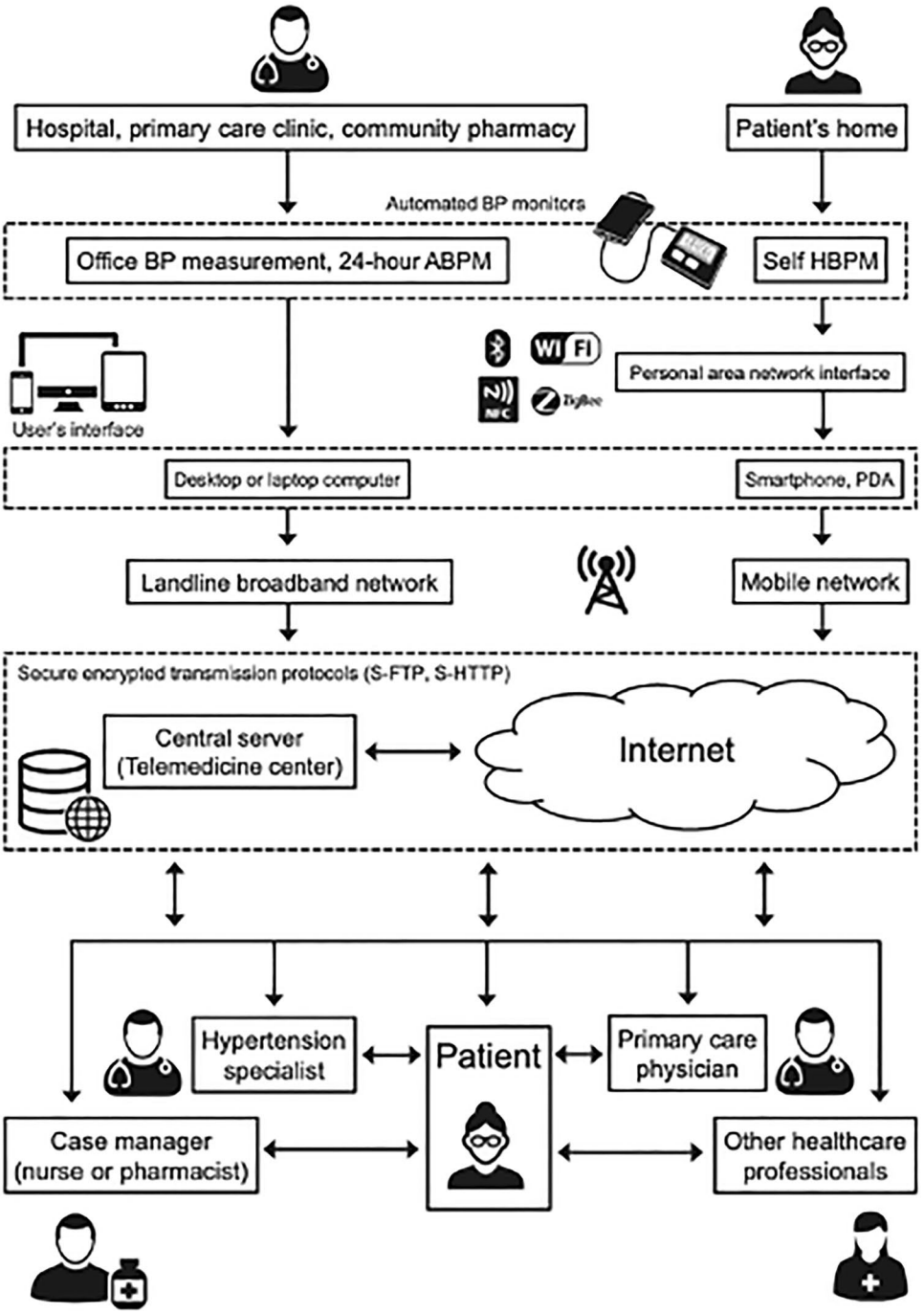


**Fig. 1** Schematic representation of an integrated system of telemedicine and Home BP telemonitoring service. In the figure: *BP* blood pressure, *ABPM* ambulatory blood pressure monitoring, *HBPM* home blood pressure monitoring, *PDA* personal digital assistant, *S-FTP* secure file transfer protocol, *S-HTTP* secure hypertext transfer protocol. Derived from reference num [30]

conditions, such as hypertension and other cardiovascular diseases, and reducing the need of hospitalizations and access to outpatient clinics for routine or follow-up visits. In this view, telemedicine applied to hypertension represented the best option for maintaining the connections between patients and care providers, also in case of home isolation [31].

## 3 Home Blood Pressure and Telemedicine

Over the last decades, home BP measurement has gained increasing importance for the clinical management of hypertension. The latest guidelines on hypertension encouraged a more extensive adoption of home BP measurements for improving awareness and control of hypertension in treated patients, and proposed—for the first time—this approach as an useful complement to clinical BP readings performed by treating physicians [32]. Indeed, available evidence suggests that incorporating self-management behaviours, such as home BP monitoring, in educational interventions may be an effective approach for ameliorating BP control, as an example by promoting physical activity and weight loss [33]. In this way, an extended use of home BP measurements might be a cost-effective approach for improving BP control in general population, particularly in those categories of high risk patients with hypertension, such as frail elderly, diabetic, and individuals with comorbidities.

Compared to the previous European guidelines on hypertension [34], the 2018 ESC/ESH guidelines added in class IA the use of home BP measurements for the diagnosis of arterial hypertension [9]. Out-of-office BP measurement is specifically recommended for a number of clinical indications, such as white-coat and masked hypertension, quantifying the effects of treatment and identifying possible causes of side effects [9]. Indeed, evidence are available demonstrating that HBPM is as reliable as 24-h ambulatory BP monitoring in predicting hypertension-mediated organ damage, and it is even superior to office BP measurements [35]. Given the demonstrated importance of HBPM, the interest in telemonitoring of BP levels at home is growing. Telemedicine, in fact, can reinforce and empower the physician-patient relationship, and even individualize this relationship, thus further ameliorating BP control and reduced the risk of major cardiovascular outcomes.

In line with these purposes, several cohort clinical studies [36–39] and randomized controlled clinical trials [40–43] have been conducted so far in different populations. General characteristics of these studies are reported in Table 1.

The Japan Morning Surge-Home blood pressure (J-HOP) study included 4310 participants with at least one cardiovascular risk factor and demonstrated that BP measurements taken at home in the morning are associated with increased risk of cardiovascular disease, mostly stroke [36, 37]. Similarly, the ongoing HBPM-iCloud study is an open prospective, multicenter cohort study among participants recruited from three participating health check-up centers in southern China. This study will help to determine the best way to implement telemedicine technology in BP control for better prevention and treatment of hypertension [44].

In 2015 a group of Koreans researchers performed a randomized clinical trial aimed to assess the effectiveness of remote patient monitoring and physician care in reducing office BP [40]. They randomized 374 hypertensive patients in three groups: in the first group patients received usual clinical care with HBPM; in the second group, the patients were remotely monitored and received office follow-up; and in the third group the patients received remote monitoring without physician office care using the remote monitoring device. For each group, in-office follow-up care was scheduled every 8 weeks for 24 weeks. The primary endpoint was the difference in sitting systolic BP at the 24-week follow-up. No differences among the three groups were observed. They assessed that remote monitoring alone or remote monitoring coupled with remote physician care was as efficacious as the usual office care for reducing BP with comparable safety and efficacy in hypertensive patients.

In a recent meta-analysis, Omboni and his group collected data from 7037 hypertensive patients enrolled in 23 selected high quality randomized controlled studies [45]. Overall, regular BP telemonitoring at home was associated with a significantly larger reduction in both office and ambulatory BP as compared to usual care. In fact, the mean office systolic and diastolic BP reductions were 4.7 and 2.5 mmHg larger in the BP telemonitoring group. Moreover, a significantly ($p < 0.001$) larger proportion of patients achieved office BP normalization (< 140/90 mmHg for non-diabetic and < 130/80 mmHg for diabetic patients) in the intervention group.

## 4 Telemedicine, Home Blood Pressure and COVID-19

After COVID-19 pandemic onset and diffusion, the rapid involvement of millions of people worldwide forced local and national healthcare systems to adopt telemedicine for ensuring baseline and, in some selected cases, advanced healthcare supports. This was the case for several chronic progressive cardiovascular diseases, such as pulmonary hypertension [46], congestive heart failure [47–49] and chronic kidney disease [50], but also for non-cardiovascular diseases, mostly onco-hematologic diseases [51, 52].

Among these conditions, essential hypertension represents an ideal target for telemedicine, since: (1) it affects

**Table 1** General characteristics of clinical studies, randomized controlled clinical trials and meta-analyses addressing the impact of Telemedicine and Home BP monitoring on the clinical management of hypertension

| Study | Acronym | Year of Publication | Population Sample | Study design | Country | Aim | Duration | Outcomes | References |
|---|---|---|---|---|---|---|---|---|---|
| **Open-label studies** | | | | | | | | | |
| Hoshide S, et al | J-HOP | 2016 | 4310 | Nationwide practice-based study | Japan | To investigate the impact of HBPM on major health outcomes in population participating in regular health check-ups | 4 years | Incidence of major cardiovascular events | [36, 37] |
| Postel-Vinay N, et al. | Hy-Result | 2020 | 512 | Online survey | France | To assess the experience of patients with the functionalities and medical content of mHealth, their feelings and expectations, and the impact of Hy-Result on the physician-patient relationship | 1 year | Most patients welcomed Hy-Result as an adjunct tool to facilitate discussion with their physician. Patients are more comfortable to use it if it is endorsed by their physician | [38] |
| Zhu H, et al. | HBPM-iCloud Study | 2020 | n.a. | Open prospective, multicenter | China | To investigate the impact of HBPM on major health outcomes in population participating in regular health check-ups | 5 years (ongoing) | Incidence of major cardiovascular events | [39] |

**Table 1** (continued)

| Study | Acronym | Year of Publication | Population Sample | Study design | Country | Aim | Duration | Outcomes | References |
|---|---|---|---|---|---|---|---|---|---|
| **Randomized Controlled Clinical Trials (RCTs)** | | | | | | | | | |
| Parati G, et al. | TeleBPCare study | 2009 | 391 | RCT | Italy | To assess the impact of HBPM and data teletransmission on the achievement of ambulatory blood pressure control by hypertensive patients followed in general practice | n.a. | Patients' management based on home blood pressure teletransmission led to a better control of ambulatory BP than with usual care, with a more regular treatment regimen | [41] |
| McManus RJ, et al. | TASMINH2 | 2010 | 527 | RCT | United Kingdom | To examine the effectiveness of self-management of hypertension in combination with telemonitoring of BP measurements as a new addition to control of hypertension in primary care | n.a. | Primary endpoint was change in mean systolic BP between baseline and each follow-up point (6 months and 12 months) | [42] |

**Table 1** (continued)

| Study | Acronym | Year of Publication | Population Sample | Study design | Country | Aim | Duration | Outcomes | References |
|---|---|---|---|---|---|---|---|---|---|
| Yoon-Nyun Kim et al. | n.a. | 2015 | 374 | RCT | Korea | To evaluate the effectiveness of remote patient monitoring with or without remote physician care in reducing office blood pressure in patients with hypertension | n.a. | The primary endpoint was the difference in sitting systolic BP at the 24-week follow-up. No difference between the three groups was observed. Remote monitoring alone or remote monitoring coupled with remote physician care was as efficacious as the usual office care for reducing BP with comparable safety and efficacy in hypertensive patients | [40] |
| Cuffee YL, et al. | n.a. | 2018 | 213 | RCT used 2×2 factorial design | Central Pennsylvania (US) | To examine the efficacy of HBPM combined with health information in reducing BP and improving medication adherence among patients with hypertension | 3 months | (1) Medication adherence;<br>(2) 24-h Systolic and diastolic BP changes between baseline and final observations | [43] |

**Table 1** (continued)

| Study | Acronym | Year of Publication | Population Sample | Study design | Country | Aim | Duration | Outcomes | References |
|---|---|---|---|---|---|---|---|---|---|
| **Systematic review and meta-analyses** | | | | | | | | | |
| Niznik et al | n.a. | 2017 | 3336 | Meta-Analyses of Studies (7 RCTs ) | United States | To identify the impact of clinical pharmacist telemedicine interventions on clinical outcomes, subsequently defined as clinical disease management, patient self-management, and adherence, in outpatient or ambulatory settings | n.a | Clinical pharmacy telemedicine interventions in the outpatient or ambulatory setting have an overall positive impact on outcomes related to clinical disease management, patient self-management, and adherence in the management of chronic diseases. | [60] |
| Tucker KL, et al. | n.a. | 2017 | 9175 | Systematic review and meta-analysis (18 RCTs) | United Kingdom | To better understand the effect of self-monitoring on BP lowering and BP control<br>Specifically, to examine the effect of self-monitoring in combination with various co-interventions, and in different groups of patients | n.a. | Self-monitoring alone is not associated with lower BP or better control, but in conjunction with co-interventions (including systematic medication titration by doctors, pharmacists, or patients; education; or lifestyle counselling) leads to clinically significant BP reduction which persists for at least 12 months. | [61] |

**Table 1** (continued)

| Study | Acronym | Year of Publication | Population Sample | Study design | Country | Aim | Duration | Outcomes | References |
|---|---|---|---|---|---|---|---|---|---|
| McLean G, et al | n.a. | 2015 | 1259 | Systematic review and meta-analysis (18 RCTs) | United Kingdom | To synthesize the evidence for using digital interventions to support patient self-management of hypertension, and determine their impact on control and reduction of BP, other clinical outcomes, quality of life, medication adherence, health service utilization, and economic benefits | n.a. | Primary outcomes are systolic and diastolic BP, and quality of life indicators. Secondary outcomes include cost- effectiveness, medication adherence, emotional well-being, and physical activity | [62] |

**Table 1** (continued)

| Study | Acronym | Year of Publication | Population Sample | Study design | Country | Aim | Duration | Outcomes | References |
|---|---|---|---|---|---|---|---|---|---|
| Xiaomei L, et al. | n.a. | 2019 | 4271 | Systematic review and meta-analysis of randomized controlled trials (11 RCTs) | China | To explore the effects of interactive mobile health (mHealth) intervention on BP management and find out the optimal target population | n.a. | Compared with the control group, mHealth intervention was associated with significant changes in systolic BP and diastolic BP<br>Subgroup analyses revealed consistent effects across study duration and intervention intensity subgroups.<br>In addition, participants with inadequate BP control at recruitment might gain more benefits with mHealth intervention | [63] |

millions of people across all age, gender, and ethnic groups almost in all countries all over the world; (2) it requires periodic assessment of both vital signs (i.e., BP levels) and adherence to prescribed interventions (life-style changes and/or drug therapies); it is highly affected and positively influenced by frequent interactions between patients and health care providers from both educational and therapeutic point of views. High levels of compliance and effectiveness of telemedicine in hypertension have been demonstrated in several interventional studies performed in Italy [41, 53, 54], United Kingdom [42, 55], Scotland [56, 57], and Canada [58]. Unfortunately, none of these studies were conducted during the COVID-19 pandemic and, mostly, they often involved relatively small sample of treated/untreated hypertensive patients and/or highly selected general practitioners or specialized physicians, who were trained and compliant with modern facilities of telemedicine.

What we have observed during the first months of the COVID-19 pandemic was the extremely heterogenous methodology adopted by physicians for contrasting this unconventional and exceptional condition. In a very short period, almost all doctors were forced to simultaneously use telemedicine, not within the assistance of a given protocol, but in the setting of real-life practice. Most of these physicians who had to use telemedicine for monitoring their patients during the COVID-19 pandemic, did not have proper training or education, did not adopted uniform protocols for patients' interactions (synchronized or asynchronized interventions), used different devices (smartphones, tablets, computers), facilities (phone contacts, text messages, e-mails, video-interviews, vocal messages), and medical programs. In addition, most of these devices were not validated and did not ensure proper level of privacy and confidentiality for patients' clinical data.

As expected, all these aspects further generated confusion and, potentially, improper medical decisions, thus negatively affecting hypertension control and, possibly, further promoting anxiety and concern by the patients. In line with these considerations, a recent international expert position paper has been published for providing evidence and recommendations on the use of telemedicine for the clinical management of hypertension also in case of home isolation and limited access to health care points [31]. Similar recommendations have been also provided by the Hypertension Cardiovascular Outcome Prevention, Evidence in Asia (HOPE Asia) Network [59].

In line with these recommendations, some interventions might be proposed for a more extended use of telemedicine for the clinical management of hypertension, when direct (face-to-face) interactions are not allowed or in case of home isolation, physical inabilities or geographical limitations. First of all, extensive upgrading towards high speed internet connections is an urgent and mandatory element for allowing the use of telemedicine in daily clinical practice, particularly in low-income countries or in specific regional areas of high-income countries. Secondly, the systematic adoption of a validated protocol for measuring BP levels at home, such as those promoted by the Italian Society of Hypertension or other international hypertension societies, will render clinical BP information more easy to interpret and less affected by individual characteristics or conditions. Thirdly, clear identification of which physical parameters (age, gender, ethnicity, height, weight) and vital signs (BP, heart rate, oxygen saturation) should be transmitted to treating physicians, as well as guidance on how to interpret these information would help doctors in ameliorating clinical interventions in hypertension and avoiding legal consequences.

Diagnostic and therapeutic algorithms based on artificial intelligence and machine learning have been recently proposed for helping physicians with large amount of clinical data, thought the clinical effectiveness of this approach should be confirmed in large clinical studies.

## 5 Potential Limitations of Telemedicine and Home Blood Pressure Monitoring

Some potential limitations should be acknowledged. First of all, there is still large heterogeneity in internet connections across different countries, particularly in low-income countries, which render the transmission of high quality data particularly difficult in some selected areas or regions. In addition, socio-economic considerations should be made for those users who have limited access to modern devices and high quality technologies, which represent mandatory aspects for sharing clinical data throughout the clouds. Some other considerations can be made, regarding several psychological aspects of telemedicine, such as low empathy between patients and doctors, absence of physical interaction and impossibility to perform proper physical examination, cultural or emotional barriers for using telemedicine instead of conventional medical consultation.

## 6 Conclusions

Hypertension is the major driven for the increased risk of acute cardiovascular events, worldwide. Despite the availability of safe and effective drug therapies, the percentage of treated patients with adequate clinic BP control remains low.

E-health solutions, specifically telemedicine, may help to establish and build an enduring and long-term relationship between patients and their treating doctors, particularly in case of hypertension, a lifetime condition needing

continuous medical supervision and frequent patient-doctor interactions or clinical consultations.

The COVID-19 pandemic forced doctors to use telemedicine for monitoring and treating a large spectrum of chronic clinical conditions, among which hypertension represented the most frequent one. Despite the large heterogeneity reported by physicians in the protocols and attitudes for managing hypertension during this dramatic period, a common conclusion was the high patients' compliance and the relatively good rate of acceptance of this novel approach, also by elderly individuals.

More studies and recommendations are needed to improve the systematic adoption of telemedicine in the daily clinical practice of hypertension, also in "COVID-free" future periods.

## Declarations

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