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New perspectives for hypertension management: progress in methodological and technological developments

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Hypertension is the most common and preventable risk factor for cardiovascular disease (CVD), accounting for 20% of deaths worldwide. However, 2/3 of people with hypertension are undiagnosed, untreated, or under treated. A multi-pronged approach is needed to improve hypertension management. Elevated blood pressure (BP) in childhood is a predictor of hypertension and CVD in adulthood; therefore, screening and education programmes should start early and continue throughout the lifespan. Home BP monitoring can be used to engage patients and improve BP control rates. Progress in imaging technology allows for the detection of preclinical disease, which may help identify patients who are at greatest risk of CV events. There is a need to optimize the use of current BP control strategies including lifestyle modifications, antihypertensive agents, and devices. Reducing the complexity of pharmacological therapy using single-pill combinations can improve patient adherence and BP control and may reduce physician inertia. Other strategies that can improve patient adherence include education and reassurance to address misconceptions, engaging patients in management decisions, and using digital tools. Strategies to improve physician therapeutic inertia, such as reminders, education, physician–peer visits, and task-sharing may improve BP control rates. Digital health technologies, such as telemonitoring, wearables, and other mobile health platforms, are becoming frequently adopted tools in hypertension management, particularly those that have undergone regulatory approval. Finally, to fight the consequences of hypertension on a global scale, healthcare system approaches to cardiovascular risk factor management are needed. Government policies should promote routine BP screening, salt-, sugar-, and alcohol reduction programmes, encourage physical activity, and target obesity control.

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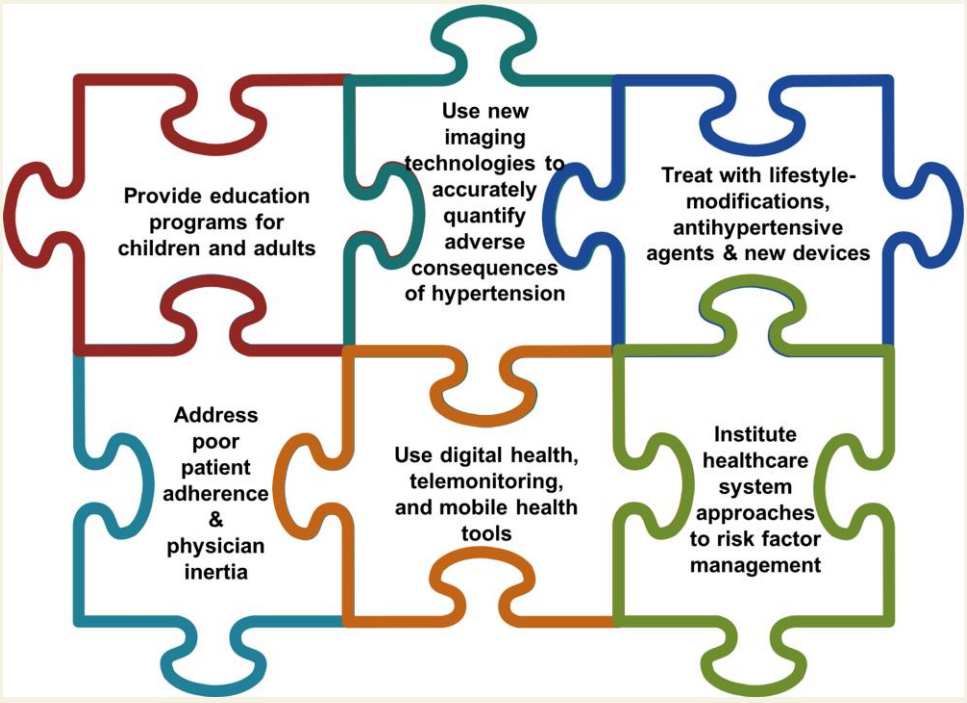
Graphical Abstract



Combined strategies to reduce hypertension-related cardiovascular risk

Keywords Screening • Education • Lifestyle • Inertia • Adherence • Control

Introduction

Hypertension is the single most common risk factor for cardiovascular disease (CVD) burden and mortality worldwide. In 2019, hypertension was reported as the number 1 cause of death in women, and the number 2 cause of death in men, accounting for almost 20% of deaths (~11 million) globally.[1] There is robust evidence that treatment of hypertension can substantially lower blood pressure (BP) and reduce premature morbidity and mortality.[2] Despite this, and recommendations from national and international guidelines, approximately 2/3 of people with hypertension are undiagnosed, untreated, or under treated,[3] and hypertension remains the major preventable cause of CVD and mortality.[2]

This document is the product of in-depth discussions among hypertension experts involved in clinical medicine or in technological development, during a Cardiovascular Round Table workshop supported by the European Society of Cardiology (ESC), with the aim of developing new solutions for better hypertension control. The goal of this paper is to discuss current perspectives to improve hypertension management using new technologies and methodologies. In particular, this work focuses on (i) education programmes for children and adults, (ii) progress in imaging technology for more accurate quantification of adverse consequences of hypertension, (iii) progress in hypertension treatment with lifestyle modifications, antihypertensive agents, and new devices, (iv) tools for addressing poor patient adherence and physician inertia, (v) digital health, telemonitoring, and mobile health approaches, and (vi) healthcare system approaches to CV risk factor management.

Preventing hypertension: early BP screening and the importance of education at younger ages

Elevated BP in childhood predicts hypertension in adulthood.[4] In a meta-analysis of 50 studies in diverse populations the correlation increased with age, from infancy through adolescence. Childhood BP elevations are associated with long-term increased risks of coronary heart disease, acute myocardial infarction, ischaemic or haemorrhagic stroke, and CVD mortality in adulthood.[5–7] These findings suggest that diagnosing and controlling high BP in children and adolescents may be an effective primary prevention strategy for adult CVD. Thus, systematic screening and management of elevated BP is recommended in children and adolescents, beginning as early as age 3 years.[8] An overview of strategies to prevent hypertension and its complications are shown in *Figure 1*.[9]

The risk factor landscape is changing, and hypertension awareness programmes will need to adapt (*Table 1*).[10,11] Obesity, fuelled by poor nutritional habits and physical inactivity, is a major risk factor for hypertension, diabetes, dyslipidaemia, and metabolic syndrome, and its prevention and treatment can be targeted by education and public health policies.[10,11]

A report from the National Heart, Lung, and Blood Institute (NHLBI) suggested two main strategies targeted to young adults to help maintain CV health, which they called primordial and primary prevention.[12] Many of these are appropriate for targeting paediatric

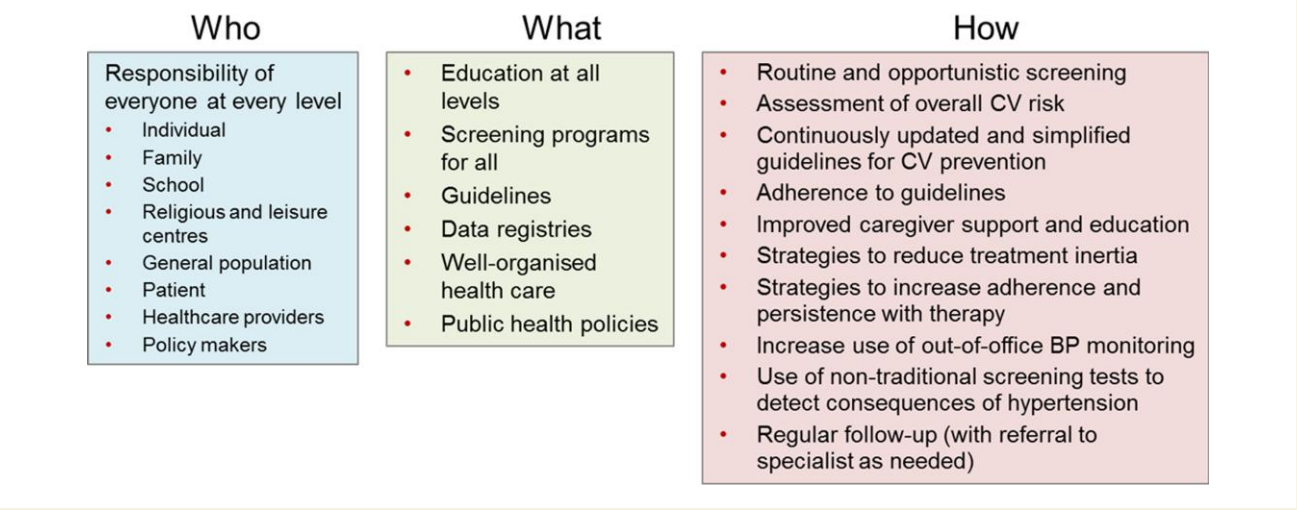


Figure 1 Strategies to prevent hypertension.[9]

Table 1 The changing risk factor landscape[10,11]

- Food habits
- Obesity
- Physical activity/inactivity
- Tobacco and recreational drug use
- Blood pressure trends (SBP vs. DBP)
- Educational systems, public health issues
- Care providing organisations

DBP, diastolic blood pressure; SBP, systolic blood pressure

populations as well. Primordial prevention includes population-based strategies to prevent the development of risk factors, such as governmental policies (laws, taxes, and subsidies), making neighbourhoods more walkable, promoting healthier food choices and more regular physical activity, media campaigns, and screening programmes. Primary prevention strategies include screening and managing BP, lipid, and glucose abnormalities. It essential that primordial and primary prevention initiatives be practical and realistic, particularly from early life. For example, young adults may prefer more flexible care such as telemedicine, increased use of social media and websites, and other digital health apps. Many good educational initiatives are available online. See the section on 'technology platforms' below for more information on these programmes.

Accurate screening and diagnosis in adults

Because hypertension is generally an asymptomatic condition, the 2018 European Society of Cardiology (ESC) and the European Society of Hypertension (ESH) joint guidelines recommend population-based screening programmes and opportunistic measurement of BP.[2,13] All adults should have their BP measured at regular intervals and should be aware of their measurements. Physician visits for other reasons can provide good opportunities to screen for hypertension.

Office BP measurement using sphygmomanometers has been the cornerstone of hypertension assessment for over 100 years.[14] It is inexpensive, widely available, and has a demonstrated impact on outcomes. However, office BP measurements are prone to measurement errors, and they may not reflect a patient's BP in their daily lives (e.g. white-coat hypertension, i.e. elevated office BP values and normal out-of-office BP, and masked hypertension, i.e. normal or high normal office BP values associated with elevated out-of-office BP), which occur in as many as 10–25% of patients.[15,16]

Because of these limitations, guidelines are increasingly recommending combined use of office and out-of-office BP monitoring [e.g. home BP monitoring (HBPM) and ambulatory BP monitoring (ABPM) over 24 h] to improve hypertension diagnosis.[2,13,17,18] *Table 2* summarizes some of the advantages and disadvantages of office, HBPM, and ABPM.[2,16–20]

HBPM, when combined with education, lifestyle counselling, mHealth tools, or telemonitoring is becoming increasingly important in improving hypertension control and thereby reducing organ damage and improving CV outcomes.[21–23] Studies have shown that patients are able to use HBPM to successfully titrate their antihypertensive medication, and this translates into improved BP control rates.[14] HBPM may also reduce physicians' therapeutic inertia; in a meta-analysis, physicians were more likely to change medications when HBPs were elevated.[24]

The increased availability of more affordable, automated electronic devices for HBPM makes this a viable strategy to improve BP control for many patients. Regardless of the type of device, accuracy is essential.[17,25] Standardized protocols are available to assess the clinical validation of electronic BP monitors. STRIDE BP is an international organization affiliated with the ESH, the International Society of Hypertension, and the World Hypertension League, which is dedicated to improving the accuracy of BP measurement and hypertension diagnosis. The STRIDE BP group conducted a systematic review of 419 validation studies, and of the 260 included devices, 83% were approved as accurate for OBP, ABPM, or HBPM.[25,26] Updated lists of validated BP monitors are available online from www.stridebp.org, as well as from scientific organizations

Table 2 Advantages and disadvantages of office blood pressure, ambulatory and home BP monitoring[2,16–20]

	Advantages	Disadvantages
OBP	• Readily available • Strong data link to CVD. Used in most hypertension outcome trials	• Poor standardization can lead to overestimation of BP • Inadequate reproducibility (single-visit OBP has low diagnostic accuracy) • Issues of WCH[a] and MH[b]
ABPM	• Identification of WCH[a] and MH[b] • Reproducible average 24-h, day and night-time values • Large number of readings in daily environment • Assessment of nocturnal BP • Useful to assess response to antihypertensive therapy (poor control or excessive BP lowering) • Good prognostic evidence (CV morbidity and mortality)	• Costly • Limited availability in primary care settings • May cause discomfort, particularly at night • Patients may be reluctant to use it
HBPM	• Generally Inexpensive; widely available • Identification of WCH[a] and MH[b] • Useful for long-term monitoring • Useful to assess response to antihypertensive therapy (poor control or excessive BP lowering) • Patient engagement may improve adherence • Can be used with telemonitoring	• Potential for measurement errors • Static BP readings only • No work-place readings • Limited evidence on new devices also yielding nocturnal measurements. • Possible patient 'obsessional' behaviour and anxiety • Possible unsupervised treatment changes • Potential for digital exclusion

ABPM, ambulatory BP monitoring; HBPM, home BP monitoring; MH, masked hypertension; OBP, office blood pressure; WCH, white-coat hypertension.
[a]WCH: elevated office BP values and normal out-of-office BP.
[b]MH: elevated out-of-office BP with normal office BP values

from many other countries.[17] Notably, of the estimated 4000 devices being marketed worldwide, fewer than 10% have been adequately validated.[17]

Progress in imaging technology to improve hypertension control

Progress in imaging technology has provided the means for earlier detection, and more accurate quantification, of the adverse consequences of hypertension. While identification of conventional risk factors is useful in CV risk assessment, the detection of preclinical disease may help identify those patients with hypertension who are likely to progress to functional disease and CV events.[27] It is possible to non-invasively detect preclinical disease in asymptomatic patients, including left ventricular hypertrophy, systemic atherosclerosis, large artery stiffness and renal dysfunction.[27] Arterial stiffness is an independent predictor of hypertension and CV risk in adults,[28] and in adolescents, arterial stiffness was associated with an elevated risk of hypertension and adiposity in adulthood.[29] These preclinical findings predict CV risk better than traditional risk factors and can improve risk stratification and outcomes.[27–31] In the SCOT-HEART (Scottish COmputed Tomography of the HEART Trial), detection of preclinical disease based on computed tomography (CT) angiography was shown to lead to changes in preventive treatment and subsequent improvements in outcomes.[32]

Beyond traditional basic screening, echocardiography, carotid ultrasound, pulse wave velocity, ankle-brachial index, cognitive function testing, measurements of arterial stiffness, and brain imaging can also be used to detect adverse consequences of hypertension.[2,13,28] For example, the severity of white matter hyperintensities, which are associated with cognitive decline, have been shown to progress with age and BP levels, even in patients aged younger than 50 years.[33] These findings suggest that early treatment of elevated BP may be warranted. However, while some tests identify target organ damage where treatment can modify prognosis, for other measures of hypertension damage it is not yet known whether treatment will modify the damage, as in the case of cognitive tests and brain imaging.

Optimal use of current treatments to improve hypertension control

Lifestyle modifications

Lifestyle interventions and antihypertensive drug therapy are well-established strategies to lower BP.[2,13,34] Lifestyle modifications have demonstrated efficacy for prevention and adjuvant treatment of hypertension, although adherence and long-term persistence is often poor.[2,34,35] Recommended lifestyle modifications include: increased physical exercise, body weight normalization and healthy eating habits (salt restriction; moderation of alcohol consumption; high consumption of vegetables and fruits).[2,13,34] Obesity prevention and treatment should be a priority to lower the burden of hypertension and related conditions.[34]

Antihypertensive agents

A large meta-analysis included data on 348 854 individuals from 48 clinical trials of antihypertensive medications over an average of 4 years follow-up.[36] Results showed that each 5 mm Hg reduction in systolic BP (SBP) obtained through this approach was associated with a 10% reduction in the relative risk of major CV events (including stroke, ischaemic heart disease, heart failure, and CV death). Neither the presence of prior CVD nor baseline BP modified the effect of treatment.

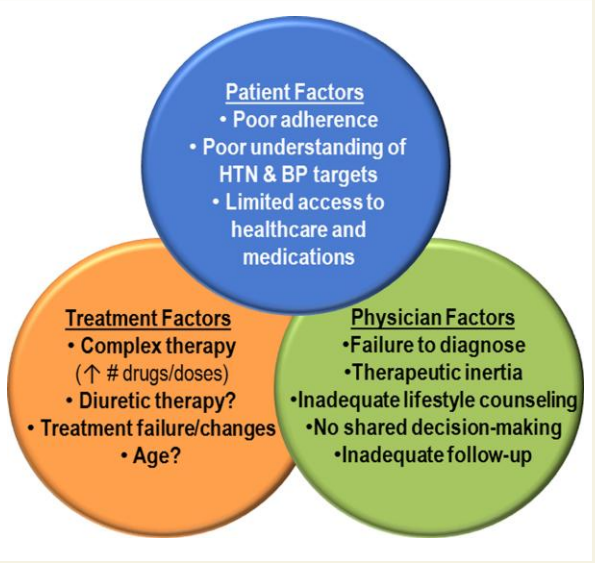


Figure 2 Barriers to BP control.[2,38–40]

The renin–angiotensinaldosterone system (RAAS) is an important target for antihypertensive treatments such as angiotensin converting enzyme inhibitors and angiotensin II Type 1 receptor blockers (ARBs). Novel agents targeting RAAS have recently been made available or are under investigation including atrial natriuretic peptide inhibitors, non-steroidal mineralocorticoid receptor antagonists, and angiotensin II Type 2 (AT2) agonists.[37]

Despite the well-proven efficacy of lifestyle and medication, uncontrolled BP remains a major problem worldwide. Three important barriers to BP control that can be targeted by current and new technologies are (i) poor patient adherence to management, (ii) physician inertia in monitoring BP and escalating therapy, and (iii) complexity of treatment (*Figure 2*).[2,13,38–40]

Device-based strategies

It is important to differentiate between uncontrolled BP due to non-adherence, and treatment-resistant hypertension. The latter is diagnosed if BP remains uncontrolled despite optimal therapy (with at least three antihypertensive drugs of different classes including a diuretic, all at maximally tolerated doses).[2,13] On the other hand, studies show that 23–66% of patients with apparent treatment-resistant hypertension are poorly adherent to drug treatment.[41,42]

Device-based therapies for patients with severe hypertension, including renal denervation, baroreflex activation therapy, and pacemaker-mediated hypertension treatment are actively under investigation.[2,43–45] The most studied of these approaches is renal sympathetic denervation.[44,46] Randomized, sham-controlled trials, making use of both office and ambulatory BP monitoring, have proven its BP-lowering efficacy in patients with and without concomitant antihypertensive medication.[44] However, most patients will continue to require drug therapy.[43]

Guidelines do not currently recommend routine use of device-based therapies outside of clinical trials.[2,47] However, European guidelines were written before the most recent evidence became available.[2] For this reason, a recent position paper from the ESH suggested that renal denervation may play a role in difficult-to-treat hypertensive patients who are selected based on BP values and current treatment, high lifetime CV risk, poor drug adherence, intolerance to multiple BP-lowering drugs, the underlying pathophysiology, and patient preferences where shared decision-making is essential.[48]

Strategies to improve hypertension control

Reducing complexity of therapy

Each additional antihypertensive drug has been associated with 2–3 times the risk of non-adherence.[38,49] A meta-analysis of 16 studies including 62 481 patients with hypertension found a 15% improvement in medication adherence with single-pill combination vs. free-equivalent combination therapies, and an almost doubling of the rate of persistence.[50] A single-pill combination can also significantly improve both systolic BP (mean difference, −3.99 mm Hg, $P = 0.05$) and diastolic BP (−1.54 mm Hg, $P = 0.0076$) at week 12.[51] International guidelines emphasize the importance of using single-pill combination therapy.[18] Diuretics have been associated with lower rates of adherence than other antihypertensive drugs.[38,49] This fact may be related to pharmacokinetics, pharmacodynamics, or side effects, as well as to their frequent use in free-equivalent combination regimens.[38] Simplified treatment regimens through single-pill combinations can improve patient adherence and may simplify therapy for physicians.

Improving patient adherence

Adherence with pharmacotherapy for hypertension one year after initiation is typically reported as up to 50%, however, an estimated 2/3 of patients take only some of their medication.[40,49] This emphasizes the need to engage with patients and assess their reasons for non-adherence.

Poor adherence can be intentional, related to disease or treatment misperceptions; or unintentional, related to forgetfulness or difficulty accessing healthcare and healthy food.[3] Contributing factors include complexity of therapy, patient beliefs about hypertension and antihypertensive drugs, and the physician–patient relationship (*Table 3*).[38,40,49] Approaches to address patient non-adherence to hypertension management are shown in *Table 3*.[18,40,49–58] However, the first step toward addressing patient non-adherence is to identify it; among the possible approaches, chemical adherence testing has become increasingly available and used, especially in apparently treatment-resistant patients. Physician–patient discussion of therapeutic drug monitoring results is a fundamental step towards improvement of patient adherence.[58]

Patient misconceptions about hypertension and antihypertensive treatments are important factors in intentional non-adherence, including beliefs and fears about stress, symptoms, and dependence on medication, as well as dislike of medications.[3] In a survey of 711 patients, adherent patients were more likely to believe that hypertension was a chronic condition, and that treatments are beneficial to reduce BP and for the prevention of CVD compared with non-adherent patients. They did not believe that doctors overuse drugs, but rather that the medications were necessary to maximize their health.[59]

Table 3 Common barriers to patient adherence and proposed strategies to overcome them

Barrier	Proposed strategies	Digital/technological solutions that can help
Complexity of therapy	• Use single-pill combinations[50,51] • Use simplified regimens and once-daily dosing[18] • Monitor adherence as warranted, provide patients with feedback on adherence[58] • Review all concomitant prescriptions, aim to reduce complexity of therapy[53]	• Reminder apps (cue-dosing) • Telemonitoring • Smart pills[40,52] • Smart dispensers, or caps • Educational websites and apps • Interactive Apps to increase patient engagement
Diuretic therapy	• Avoid diuretics when appropriate[38,49] • Consider closer monitoring, and dosage adjustments as needed	• Telemonitoring • Educational websites and apps
Patient beliefs/attitudes about hypertension and medication (health literacy)	• Acknowledge and address patient beliefs/fears about stress, symptoms[3,59] • Provide an accurate description of the benefits and adverse effects of treatment[3] • Use patient-centred approaches, particularly those that are nurse- or pharmacist-led[40,55,56] • Provide accessible information for schoolchildren and adults, (esp. diet, exercise from a young age) • Suggest easy to adopt lifestyle modification	• Devices that monitor BP with apps that provide feedback on risk levels, or provide results electronically to physicians • Educational websites and apps • Interactive apps to increase patient engagement • Interactive exercise and dietary modification apps
Age and gender	• Age and gender have not consistently been identified as risk factors for non-adherence, but strategies should address age or gender specific needs and concerns[49,54] • Younger: Tailor education to personal risk, beliefs, and attitudes.[55,57] • Older: Consider a review of cognitive abilities and digital literacy of patients, their family and caregivers, regular reminder systems, and easy-to-manage pill containers[53]	• Technology is a matter or patient preference and accessibility. Do not assume that age is a reason not to suggest websites or apps
Physician–patient relationship	• Cultivate a strong physician–patient relationship, customized to the patient's needs and lifestyle • Listen to patients and gain their trust • Use a collaborative communication style rather than an inquisition style[40,55] • Discuss patients' sociodemographic circumstances as well as their hypertension medications[56] • Engage patients in decisions and agree on tasks and goals[40]	• Telemonitoring • HBPM to monitor BP linked to apps that provide feedback on risk levels, or provide results electronically to physicians • Interactive apps to increase patient–physician interactions and patient engagement

Clinicians should acknowledge patients' concerns, and educational initiatives must directly target patients attitudes.[3] Patients engaged in decisions about their treatment are more adherent than patients who are not.[40] Interactions that include discussions of the patient's sociodemographic circumstances (living situation, relationship with partner), in addition to their medication can positively impact adherence.[56]

Digital tools such as websites can be useful, but it is important for physicians to be aware of trustworthy websites, and advocacy groups that they can direct their patients to. Digital tools such as smartphone reminder app, can also be useful when adherence is unintentional due to forgetfulness. See the section on 'technology platforms' below for more on these tools.

Reducing therapeutic (physician) inertia

Therapeutic inertia, or clinical inertia, defined as a failure of clinicians to initiate or intensify treatment in accordance with current guidelines[60] is a pervasive problem in hypertension management.[61] For example, although combination antihypertensive therapy has been shown to be associated with a lower risk of CV events, and better adherence than monotherapy,[2,13,47,62] a study found that up to 3/4 of patients were initiated on monotherapy and, among these, 2/3 remained on one drug during the 3-year follow-up.[62]

Provider factors that contribute to therapeutic inertia include lack of knowledge about appropriate therapeutic goals, high patient volume, and time constraints,[60,61] patients with multiple comorbidities (esp., psychiatric conditions or diabetes) and patient being 'near' or at

Table 4 Strategies to target therapeutic inertia[60]

Proposed strategies	Digital/technological solutions that can help
• Physician and patient reminders • ABPM • Physician and patient education • Physician peer visits • Task-sharing	• Risk calculators, and automated prompts for intensification integrated into EHR systems • Automatic uploads of HBPM and other patient-generated data into EHR • Websites for physician–patient interaction and personalization of treatment strategy

ABMP, ambulatory blood pressure monitoring, EHRs, electronic health records

'acceptable' targets.[60,61] Strategies to target physician inertia have been associated with increased rates of BP control (*Table 4*).[60] Patient education may also help improve therapeutic inertia, patient non-adherence and patient preference have been cited by physicians as a reason not to intensify therapy when warranted.[63]

Physicians and patients should be aware of the importance of treating hypertension in the context of CV risk. A large meta-analysis showed that reductions in BP were associated with reductions in the risk of major CV events regardless of prior diagnosis and even at normal or only mildly elevated BPs.[36] This can help when physicians are discussing with patients the need for antihypertensive treatment to reduce CV risk rather than focusing on BP alone.

Physician time constraints, exacerbated by complex patients, and high patient volume, can contribute to not intensifying therapy. Strategies that can help are 'task-sharing' interventions, remote monitoring programmes that integrate into current workflows, and adequate reimbursement. A meta-analysis including 31 studies found that task-sharing with nurses, pharmacists, dieticians, and community health workers led to significant decreases in BP.[64] An update, including 43 studies, found that sharing tasks including administrative, basic, or advanced clinical tasks resulted in improvements in SBP control.[65] When used as part of a multi-component strategy this approach has demonstrated efficacy and cost-effectiveness especially in low- and middle-income countries.[64,66]

The use of remote monitoring was rapidly accelerated by the COVID-19 pandemic.[67] The pandemic resulted in improved infrastructure (including video consultations, website portals for interactions), increased integration into electronic health records, and reimbursement for telemedicine in many countries.[68] Incorporating HBPM and other patient-generated health data into electronic health records has been shown to improve BP control rates when used by physicians and pharmacists to support clinical management.[69–71] The success of remote monitoring tools may be largely due to the improved link between the patient and the physician.[72] For clinicians, integrating digital solutions into practice can be a challenge.[69] In a survey of primary care providers there were concerns around how to use the HBPM data, the ability to individualize the frequency of patient measurements, the frequency of physician viewing of data, and the alert parameters.[69] Some of these tools are described in more detail in the section on technology platforms below.

Technology platforms to engage patients and improve BP control: digital health approaches

Digital health involves the use of information and communication technologies (ICT) to improve health.[73,74] It is sometimes divided in two categories, mHealth and telemedicine, but many programmes include both. mHealth strategies encompass smartphones and wearable technologies for health services, while telemedicine refers to delivery of remote care (patient data transmitted to physician, with telephone or website-based patient–physician interaction).[73,74]

Most digital tools aim to target behavioural changes such as adherence (dosing reminders) and lifestyle modifications (e.g. diet, exercise).[75,76] These generally provide feedback to patients, and some include educational information. Other tools are designed to monitor BP (and adherence), such as HBP telemonitoring, wearables, or smart pills linked to apps to capture information, transfer it to the healthcare team, and provide feedback to the patient. There is also increasing interest in the development of cuff-less BP measuring devices.[75,77]

Digital health solutions are based on hardware or software and should be classified as medical devices, which means they must undergo extensive development, validation, and approval processes.[68,75] This is particularly important for devices that measure BP. However, many health apps are not adequately tested for efficacy, usability, and acceptability but rather are labelled as 'wellness or fitness' products to avoid regulations.[68]

Of the 1000 s of mHealth apps, few have undergone regulatory approval.[76] This makes it difficult to identify apps that are trustworthy and have demonstrated clinical utility. In addition, standards for approval of apps varies widely from country to country.[76] Attempts to highlight trustworthy apps through assessment schemes have been implemented: for example, in the UK, the NHS has outlined digital technology assessment criteria (https://www.nhsx.nhs.uk/key-tools-and-info/digital-technology-assessment-criteria-dtac/).

Few digital tools have been studied with long enough follow-up to demonstrate reductions in CVD risk. Nevertheless, evidence to date suggests that mHealth strategies can improve patient health, empower patients to manage their personal health, and improve patient–physician shared decision-making (*Figure 3*).[73,75,76,78] In 2019, the ESC e-Cardiology Working Group published a position paper on the use of digital health in CV medicine.[73] They concluded that digital healthcare delivery has the potential to improve CV care.

mHealth (mobile apps and websites)

A European Heart Network review of mHealth or ICT for CV patients included over 40 studies assessing various web- or mobile phone-based tools, with or without HBPM and remote or telemonitoring.[74] The review concluded that smartphone mHealth apps have potential in remote monitoring and improving patient adherence, but there is insufficient evidence to confirm benefits over existing strategies.[74]

A scoping review published in 2021 assessed 15 studies (including 10 RCTs) of web-based dietary and physical activity intervention programmes for patients with hypertension that were published between 2011 and 2020.[78] Most web-based tools demonstrated

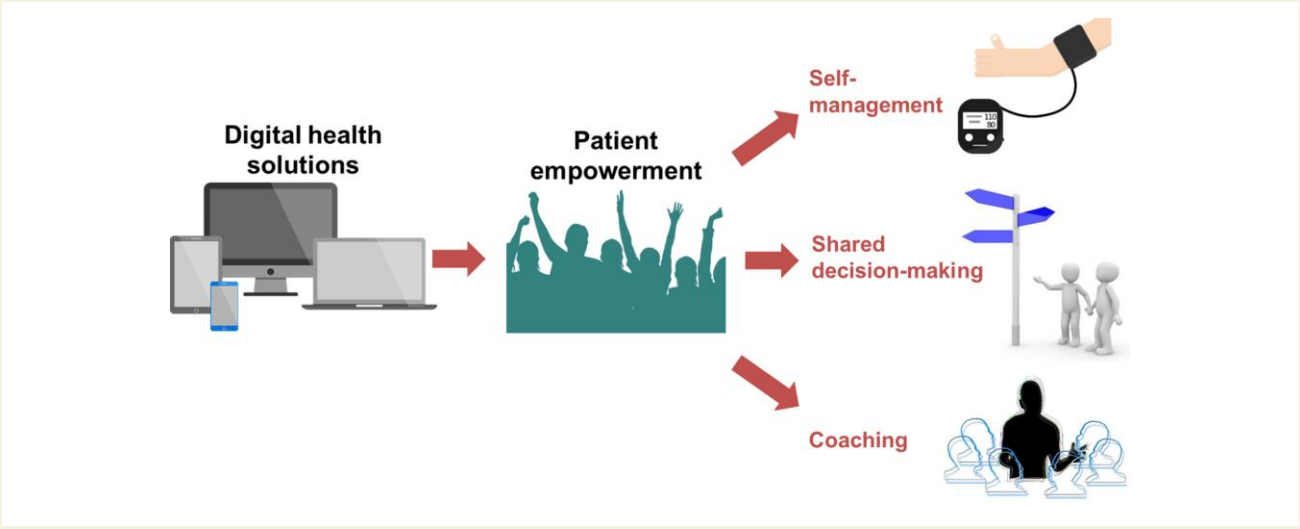


Figure 3 Role of technology in improving BP control.[73,75,76,78]

benefits, especially improved communication between clinicians and patients. Clinicians also reported some improvement in patient adherence to medication and appointment schedules. Patients showed improved health with use of the website in addition to their regular schedule, and were empowered to manage their personal health. Studies that have assessed acceptability and the suitability of websites report that they must be highly accessible, and must include many multimedia and interactive features.[78]

One example of a digital programme that has undertaken a rigorous approach to development and validation is the ESH CARE programem. ESH CARE is a BP management app that was developed by a scientific society, and has been adopted by the ESH.[72] ESH CARE is a multi-component tool that allows users to send stored BP readings to a dedicated website where they can be evaluated by the healthcare team, allowing more precise and continuous patient management. The app includes educational information and is designed to empower patients to actively participate in their BP management.[72] A pilot study found that a combination of HBPM, the ESH CARE app, and a dedicated website (a programme called POST, Patient Optimal Strategy of Treatment) improved BP control at the 6-month follow-up (72.3% vs. 40.0% in the usual care group).[79] Additional large, long-term studies are planned to further evaluate the POST-strategy, and its effects on BP control, as well as on CV morbidity and mortality.[72]

mHealth strategies that were more interactive, were more likely to demonstrate significant benefits, and were more likely to keep patients engaged for a longer period of time.[3,80] Interactive features can include interactive prompts, transmission of patient measurements, treatment plan/goals, and patient–physician communication.[80]

Telemedicine

BP telemonitoring combines a telemedicine strategy with patients' HBPM, with values being transmitted to the healthcare team, usually via the internet.[77] The COVID-19 pandemic increased the availability and use of telemedicine around the world.[68] Data show that patients can accurately measure their vital signs including systolic and diastolic BP, heart rate, peripheral oxygen saturation, body temperature, and respiratory rates. In one study, patients learned how to use the devices within 10 min, and measurements were rapidly available to physicians.[81] Importantly, home BP telemonitoring has been shown to result in greater reductions in both office and 24-h ambulatory BP as compared with usual care.[24,68,82–85] A meta-analysis of 11 RCTs found a mean reduction in BP of 3.9/2.2 mmHg after 12 months in studies using various combinations of HBPM with telephone calls, email, phone messages, or websites compared with usual care.[85]

A European Heart Network review concluded that telemonitoring may be effective, but studies are needed to demonstrate whether it will provide added benefit over HBPM alone, and whether it is cost-effective.[74] An international expert position paper on the use of BP telemonitoring in hypertension management found that a multi-component strategy is likely to be the best strategy (*Table 5*).[68]

Table 5 Elements of a successful telemedicine programme in hypertension management[68]

- Remote monitoring and transmission of vital signs (e.g. blood pressure)
- Telephone or website communication (with optional video consultation)
- Support for adherence to medication and other management strategies
- Education on lifestyle and risk factors
- Both an automated feedback strategy and a multidisciplinary supervisory team (physician, nurse, or pharmacist)

Wearables (e.g. wrist devices)

An increasing number of affordable, cuff-less BP devices, including smartphone, wearable, and 'tricorder' technologies, have become available. A review of some of the commercially available devices concluded that early data suggest promise but many lack proper

validation.[77] Use in practice of these technologies is limited by motion artefacts, a lack of adequate software and data transfer, difficulties in calibration, and a lack of reimbursement models.[77] Several watch-type wearables have demonstrated accuracy according to the standards used for cuff-type BP monitors,[86,87] but these devices should be validated using protocols customized for the specific sensors or other features of the wearable, including their ability to reliably track BP changes over time.[17]

As of December 2021, 53 wrist devices, based on the oscillometric BP measurement technology, have passed the STRIDE BP acceptable validation procedures (updated lists available at https://stridebp.org/bp-monitors); however, these devices may be less accurate in actual practice, in part due to issues related to incorrect use (wrist at heart level without flexion or extension).[17]

Notably, wristband wearables and other cuff-less devices, which are currently still based on immature BP measurement technologies, were not recommended for HBPM in the 2021 European Society of Hypertension guidelines for office and out-of-office BP measurements.[17]

Academic and industry partnerships to improve BP control

To improve the validity and utility of technological solutions, and reduce the global impact of hypertension, collaborations between industry and academic institutions is essential.[84] The digital health systems need more standardization, proof of accuracy and privacy, and evidence for long-term benefits on hard outcomes like CV events. Work should continue on developing unobtrusive, cuff-less, accurate and reliable self BPM-devices. Clinicians and patients, but also experts in behavioural medicine, should be involved from the beginning in the development of all tools to ensure they are truly useful for both patients and physicians.[84]

The ideal academic/industry co-development programme would focus on validating 2–3 multi-component tools, which would include education, a digital app, home self-care and monitoring, automatic transmission of data, and telemedicine. RCTs with longer-term follow-up should be conducted, and the tool itself should be designed to capture outcome metrics on an ongoing basis and to provide feedback to both patients and physicians. However, validation of such digital health tools can be difficult, as they are not constituted by a single 'ingredient', but rather implement a multi-dimensional approach, for which it could be difficult to define a 'placebo' for the control group. The use of new randomized controlled trial frameworks (Multiphase Optimization Strategy) to test simultaneously multiple interventions, or N-of-1 studies should be explored.[88] Both academic and industry members should advocate for regulatory and reimbursement standards. Finally, there should be plans in place to fund and integrate digital tools seamlessly into primary care physicians' clinical practice and a strategy to facilitate updating the programme as needed.

Strategies to improve the adoption and utility of digital health tools are shown in *Figure 4*.[68,73,74,76] From a patient perspective, governments should invest in infrastructure to increase access to digital tools for everyone, and in education to improve digital and health literacy from a young age. From the healthcare perspectives, tools should be designed from the outset to be fully integrated with existing organizational structure to ensure they decrease and not increase the workload. This would include a clear pathway for who will view patient data and how the information will be used. More large, long-term trials are need to provide definitive evidence for physicians, regulatory and reimbursement organization that a certain tool is effective and will improve patient outcomes. Like patients, many healthcare workers also require training in digital health, and this should be integrated into current teaching programmes. Both physicians and patients need reimbursement for the necessary hardware or software to use the tool, and healthcare professionals must also be reimbursed for their time. In addition, patient privacy must be ensured. Therefore, regulatory and reimbursement standards should be developed, and companies should be rewarded for pursuing the more rigorous development pathway.

Figure 4 Summary of strategies to improve quality and usability of digital health tools.[68,73,74,76]

Healthcare system approaches to risk factor management

Government and healthcare systems approaches are needed to counteract the negative impact of hypertension on a global scale, particularly in light of the fact that CVD mortality rates are often high in rural areas in low-income and middle-income countries where health systems may be weak.[66,89] Government policies can impact risk factor management including unhealthy diets (high salt, low fruit and vegetable intake), physical inactivity, tobacco and alcohol use, and obesity.[12] Hypertension programmes are often underfunded, especially in low- and middle-income countries, where hypertension funding does not rank in proportion to its resulting disease burden compared with other conditions.[90]

Improved BP control starts with awareness and education. The World Health Organization (WHO) has a detailed education

package (WHO HEARTS) that should be widely implemented on a global scale. Government policies should aim to promote healthy environments including salt, sugar, and alcohol reduction programmes, as well as obesity control including use of laws, taxes, and subsidies. For example, sodium reduction interventions, such as package labelling, and mass media campaigns can decrease intake at the population level and have been found to be highly cost-effective.[91,92] Obesity control should be a commitment at all ages through education, diet, and exercise. Physical activity can be promoted by providing safe environments and incentives for exercise. Collaborating with the food industry, educational and private institution can be used to help improve nutritional value and make healthy food available at homes, schools, and at work.

Routine BP screening should be performed at all healthcare encounters, and programmemes should be undertaken at pharmacies, markets, religious and social events, vaccinations, elections, and so on, which should be promoted through mass and social media awareness campaigns. Self BP programmes should be encouraged and regulations introduced to improve access to validated BP measurement devices.

Access to healthcare can be improved through task-sharing programmes, including increasing resources for community works, which can cost-effectively improve the diagnosis and treatment of hypertension.[66] Remote healthcare delivery through mHealth and telehealth programmes can also facilitate access. Hypertension medicines recommended by national guidelines should be on national essential medicines lists and be available free of charge or at affordable cost at all health facilities. Centralized volume buying can be used to help decrease the cost of medications.[93] Low cost single-pill treatments can improve control of BP.[51]

It should to be emphasized that these strategies apply also to hypertension management in low- and mid-income countries, in particular in Africa. As described in a 2022 World Hypertension League Call to Action to improve hypertension management in Africa, the hypertension epidemic is currently responsible for a dramatic increase in CV events and CV mortality, which emphasizes the need for urgent implementation of appropriate strategies for hypertension diagnosis, control, and prevention.[94]

Author contributions

All CRT members that were included as authors contributed to design of the CRT meeting and to selection of the topics; G.P. drafted the initial manuscript. All authors critically revised the manuscript, gave final approval, and agreed to be accountable for all aspects of work ensuring integrity and accuracy.

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Data availability

No new data were generated or analysed in support of this manuscript.

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