Clinic Rev Allerg Immunol (2019) 56:161–173
DOI 10.1007/s12016-016-8542-y

Allergy and Asthma Care in the Mobile Phone Era

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Published online: 21 May 2016

Abstract Strategies to improve patients' adherence to treatment are essential to reduce the great health and economic burden of allergic rhinitis and asthma. Mobile phone applications (apps) for a better management of allergic diseases are growing in number, but their usefulness for doctors and patients is still debated. Controlled trials have investigated the feasibility, cost-effectiveness, security, and perspectives of the use of tele-medicine in the self-management of asthma. These studies focused on different tools or devices, such as SMS, telephone calls, automatic voice response system, mobile applications, speech recognition system, or cloud-computing systems. While some trials concluded that m-Health can improve asthma control and the patient's quality of life, others did not show any advantage in relation to usual care. The only controlled study on allergic rhinitis showed an improvement of adherence to treatment among tele-monitored patients compared to those managed with usual care. Most studies have also highlighted a few shortcomings and limitations of telemedicine, mainly concerning security and cost-efficiency. The use of smartphones and apps for a personalized asthma and allergy care needs to be further evaluated and optimized before conclusions on its usefulness can be drawn.

Keywords Allergy · Mobile health technology · Mobile applications · Mobile phone · Asthma · Allergic rhinitis

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Introduction

Allergic Rhinitis and Asthma: Poor Adherence to Treatment

Allergic rhinitis and asthma are very common diseases, estimated to affect over 300 million individuals, and they are the most common chronic disease among children. Asthma is a public health problem for high-, middle-, or low-income countries [1]. Over 80 % of asthma deaths occur in low- and lower-middle-income countries. Asthma is under-diagnosed and under-treated, creating a substantial burden to individuals and families and possibly restricting individuals' activities for a lifetime [1]. Most asthmatics have allergic rhinitis [2], a common chronic disease having a significant negative impact on the quality of life (QOL). The level of allergic rhinitis (AR) control remains inadequate for many patients [3].

The patients with asthma and/or AR can take drugs such for example inhaled corticosteroids (ICS) to reduce inflammation and beta-2 agonists or antihistamines to release their symptoms, but they suffer from the disease recurrently when they stop using these drugs. Many patients need ICS for a long time, but they often forget to take them until the symptoms appear again. Poor adherence to medication leads to worse treatment outcomes, higher hospitalization rates, and increased health care costs [4]. Therefore, the patients with asthma and/or AR need education programs to achieve adequate adherence to medication [5].

To control asthma and AR, patients should also monitor their symptoms, avoid triggers, and follow their treatment plan [6]. Successful asthma treatment can be largely attributed to education, not only to medication. The education of patients and health professionals on the proper use of inhalers is one of the mainstays for the treatment of asthma in the pediatric population [7]. The traditional education is face to face between

patient and general practitioner, nurse or professional doctors. Every patient should be directly seen by a doctor, although some patients with minor disorders undergo self-medication, independently whether this is correct or not. Nevertheless, many patients with chronic diseases have a poor adherence to their prescribed medicine after their face-to-face visits [8–10]. Strategies to improve the patient's adherence to prescription are therefore essential in the management of chronic disease and asthma.

The Expanding World of Mobile Phone Technology

Mobile technology allowed since 1980s not only real-time bilateral voice communication but also real-time bilateral transmission of written messages. In recent years, smart phone incorporated also media players, camera and flash (flashlight), video cameras and GPS navigation, NFC (near field communication), gravity sensor level meter, and other features, making it a feature-rich device. Today, high-resolution touch screen and web browser can display also standard web pages and mobile-optimized website. Through Wi-Fi and mobile broadband, smart phones can achieve high-speed data access and cloud access and email handling, connect with other electric devices with Bluetooth or Wi-Fi, and transfer data each other. Mobile applications "apps" extend more intelligent functions and are used in many fields. The mobile application market had a rapid development in the areas of mobile commerce, game industry, social real-time communication networks, and so on. Consequently, smart phone sales volume is worldwide huge (over 1200 million units in 2014). Mobile phones are a part of people's everyday lives and enable activated requests for data wherever they are [11]. This world of mobile technology is rapidly expanding, and it is changing many aspects of our daily life.

Mobile Health, Asthma, and AR

The use of smart phones has rapidly expanded also to healthcare and medicine. Mobile health (m-health) comprises the concept of utilizing mobile devices to carry out the task of viewing electronic medical records, reserving medical appointments with a patient's medical provider, and electronically refilling prescriptions. The term is most commonly used in reference to using mobile communication devices, such as mobile phones, tablet computers, and PDAs, for health services and information [12]. There are approximately 5 billion mobile phone users, and by 2017, there will be "more mobile phones than people" on the planet. Then, the mobile phone with health applications will be soon the most popular mobile health device in the world [13].

A seminal study published in 2004 suggested that collection of asthma diary data through a mobile phone and the use of short message service (SMS) as alert system is a feasible way to support the self-management of asthma in motivated and self-efficacious patients. In 2015, a worldwide consortium, leaded by Jean Bousquet, proposed an integrated plan for the use of the mobile health technology in the management of allergic rhinitis (MASK, MACVIA-ARIA Sentinel NetworK for allergic rhinitis) [14].

This thematic review aims to summarize the impact of m-health technology on asthma and AR and to discuss some of the issues related the mobile phones and applications, including their feasibility, cost-effectiveness, acceptability, security, and perspectives.

Methods

We used the following key words for our research strategy in Medline: "allergy," "mobile health technology," "mobile phone," and "mobile application." The restriction was "clinical trial" in "humans" in the last 6 years (from 2010 to 2015). Outcomes measured included the following: feasibility, quality of life, self-management, costs, adherence to medical therapy, exacerbations, hospitalization rates, symptoms and their severity, office visitor rates, emergency visit rates, unscheduled visits, absence from school, or work. Studies were included if they (1) were clinical trial; (2) addressed the impact of mobile technology, using SMS, MMS, and mobile applications; and (3) focused on allergy diseases (asthma, allergic rhinitis or hay fever, food allergy, atopic dermatitis). We also examined a few publications resulting from our own experience but not fitting the selection criteria. Last, we retrieved a list of applications after searching the key word "allergy" in "Google Play" and "Apple App store."

Results

Literature Search

We retrieved all the abstracts using the search terms and the restriction, and 22 articles were selected for full text review. Some of them were excluded because they were used some special mobile devices but not the mobile phone. Included studies came from ten countries: Germany ($n=1$), Singapore ($n=1$), Taiwan ($n=1$), Portugal ($n=1$), Canada ($n=1$), Italy ($n=2$), Sweden ($n=2$), China ($n=2$), United Kingdom ($n=2$), and United States of America ($n=9$). The final set of 22 studies included 10 randomized control trials (RCTs) and 11 controlled trials, another one was a case report with a letter, and all the studies included 3411 participants. These studies focused on asthma ($n=16$), allergic rhinitis ($n=5$), and asthma and rhinitis ($n=1$). All the studies found that the mobile technology was a useful tool except one. These studies were published in 2010 ($n=1$), 2011 ($n=3$), 2012 ($n=7$), 2013

($n = 4$), 2014 ($n = 5$), and 2015 ($n = 2$). All the retrieved studies focus on the therapy or/and prevention, but no one focused on diagnosis (Table 1). No study focused on food allergy, drug allergy, dust mite allergy or eczema, etc.

Clinical Relevance of m-Health, by Technology Used

Different m-health features were used in different studies. SMS was the most common examined feature, being used in 9 out of the 22 retrieved studies [15–23]. Seven studies investigated a smartphone application [6, 29–34], five telephone [24–28]; one cloud-computing systems [35] was examined by only one study (Table 1).

SMS

The studies that used SMS or email got as alert systems to improve adherence to medication had all a positive result. Five of these eight studies adopted a randomized controlled design [15–19]. In a population of 115 Singaporean patients with asthma, aged 21 years or above, Prabhakaran et al. found that SMS was accepted by most patients and could improve the asthma control test (ACT) score and the adherence to treatment. The authors concluded that an SMS might be more effective than conventional nurse telephone call management [15]. Among 71 Chinese patients with asthma, aged older than 18 years, SMS improved the perceived control of asthma, follow-up rate, and asthma-specific quality of life (QOL) [16]. Among 370 Canadian patients with asthma, aged 14 years or older, De Vera et al. are running a study empowering pharmacists in asthma management through interactive SMS (EmPhAsIS); while the study is in progress, the authors suggest that this tool had a tremendous potential to reduce the burden of asthma by improving adherence to treatment. Objective conclusions would be soon drawn when the trial is completed [18]. Pizzulli et al. found that internet-based telemonitoring improves adherence to NCS treatment and disease knowledge among children and adolescents with seasonal allergic rhinoconjunctivitis [19]. Wang et al. demonstrated that a daily SMS reminder might be an effective intervention to improve adherence to medication and treatment outcomes in AR patients [17]. Similarly, our group could demonstrate a higher adherence to ICS (mometasone) treatment among 30 German children with seasonal allergic rhinitis, compared to 31 controls receiving usual care, as they could record their symptoms and medication on a e-health platform (electronic diary (e-diary)) and received SMS alerts [33].

Out of the another four trials [20–23], two used the control test with comparing to paper records [20], Facebook, Twitter, MySpace, email, and internet [21], the third one discussed the time-based SMS (messages were generated by Compliance for Life™ technology at specified times) and event-based SMS (messages whenever patients took asthma medications or experienced asthma symptoms) [22], and the last one was a nonrandomized pilot feasibility trial [23]. Among 53 Swedish patients with allergic rhinitis, aged 8–18 years, Aberg et al. found that the use of SMS reminders and e-diaries was excellent logistics tools that could produce a significant reduction of all symptoms and specifically runny nose. The patient's symptoms from the nose, eyes, and lower airways were lower in the group using SMS reminders and e-diaries, when compared to controls following usual care [20]. In a population of 145 USA patients with asthma, aged 12–40 years, Baptist et al. observed that patients with asthma consider email or SMS and social media websites as very useful tools to communicate with medical staff [21]. In a population of 16 USA patients with asthma, aged 18–25 years, MacDonell et al. found that SMS can usefully provide personalized feedback on medication adherence and could be used to tailor an intervention to each participant's specific need, personal barriers to medication adherence, and patterns of medication use [22]. In 19 USA teenagers with asthma, SMS well supported disease self-management [23].

Telephone Voice Live and Automatic Recognition and Response Systems

In a population of 950 USA patients with persistent asthma, aged 3-12 years, Garbutt et al. found that the coaching intervention may improve asthma control and disease-related quality of life and reduce urgent care events for asthma care [25]. Among 83 USA patients with asthma, aged 19 years or above, Young HN et al. found that telephone consultation intervention was feasible and showed indicators of effectiveness, suggesting the design was well suited for a robust study to evaluate its impact in uncontrolled asthma patients. Pharmacists helping patients manage asthma through telecommunications may resolve access barriers and improve care [26].

In a group of 48 USA patients with asthma, Raju et al. found that asthma management using the Asthma Control Score (ACS) and the Asthma Action Plan (AAP) actively administered during telephone calls with an operator was a feasible and accepted strategy for the patients to improve their asthma control without the need for an office visit [24]. Among 53 USA adolescents with asthma, Mulvaney et al. also used a voice response system (Telesage) to assess asthma symptoms and adherence. Telesage system was administered through the adolescents' mobile phones and gave a quantitative and qualitative assessment of asthma symptoms and adherence conduction with daily calls to patient's mobile phones for 1 month. The result was that mobile phones provided a feasible method to assess asthma symptoms and adherence in adolescents. And results provided valuable insights regarding the context of adherence decision making that could be used clinically for problem solving or as feedback to adolescents in a mobile- or web-based support system [27]. Furthermore, a

Table 1 Details of the included studies

Author [ref] (year), country	Disease	Study design (No. of patients trial duration)	Technology Frequency; Period	Outcomes and/or conclusion
SMS alert systems				
Randomized controlled trials				
Prabhakaran [15] 2010; Singapore	Asthma	RCT 115; 12 weeks.	SMS 1/day; 2 weeks 1/week; 10 weeks	• improved asthma control score • service was accepted by most patients and maybe more effective usual care
Lv [16] 2012; China	Asthma	RCT 71; 12 weeks.	SMS 2/day	• the QoL PCAQ-6 score improved more in the SMS group than in controls ($p < 0.05$) • SMS group had the highest AQLQ(S)score and follow-up rate after 12 weeks
Wang [17] 2014; China	AR	RCT 50; 30 days	SMS	• self-reported adherence to medication was significantly higher in the SMS vs control group • the clinic attendance rate was higher in the SMS vs controls (72 vs 40 %, $p = 0.02$) • VAS score improvement was significantly bigger in SMS group than that in the control group • authors' conclusions: a daily SMS reminder may improve adherence to medication
De Vera [18] 2014; Canada	Asthma	RCT 370; 12 months.	SMS	• study in progress (2014) • this is the first study of an intervention based on mobile communication technology involving community pharmacists in asthma management • considering the non-adherence problem in asthma, and the availability of effective treatments, there is a tremendous potential to reduce the burden of asthma through improving adherence
Pizzulli [19] 2014; Germany	AR	RCT; 63; 1 month.	SMS + app	• objective adherence to medication was significantly higher in the SMS group vs controls • disease knowledge improvement was significantly higher in the SMS vs control group • Authors' conclusions: (AllergyMonitor™) improves adherence to NCS treatment and disease knowledge among children and adolescents with pollen allergy
Not-randomized controlled trials				
Aberg [20] 2011; Sweden	AR	CT 53; 4 weeks	SMS 3/day	• a significant reduction in total symptom scores and specifically for runny nose • all symptoms were lower in the active group • the best effect was seen after days with low or moderate pollen counts • no clinically significant adverse effects were seen. SMS communication on mobile phone for reminders and recording symptom scores was an excellent logistics tool
Baptist [21] 2011; USA	Asthma	CT 145;	SMS, email, Facebook	• text messaging, email, and Facebook were used at least weekly by a majority of respondents • Email was clearly the most preferred method to receive asthma information and to communicate with a physician • there was some interest in using Facebook or text messaging, whereas Myspace and Twitter had minimal interest • on logistic regression analysis, female and Black or Hispanic participants were more likely to have an interest in the use of electronic media for asthma care • frequent users (>1×/week) of each electronic media type had greater enthusiasm for their incorporation into asthma care free text entries revealed that many participants felt social media sites were for connecting with friends rather than for health care, and privacy concerns were also raised
MacDonell [22] 2012; USA	Asthma	CT 16; 14 days	SMS	• event-based messages were relatively low • time-based messages were very high • All participants expressed positive feedback about the program • though 40.0 % reported confusion with event-based messages and most preferred time-based messages • low medication adherence rates and reasons for missing medication consistent with previous research with youth with asthma
Britto [23] 2012; USA	Asthma	CT 19; 3 months	SMS	• no teen made changes to their original text messages or delivery schedule on their own • they gave high ratings on the usefulness, acceptability, ease of use of the text messaging system • allowing teens to control the timing and content of reminder text messages may support self-management of chronic disease

Table 1 (continued)

Author [ref] (year), country	Disease	Study design (No. of patients trial duration)	Technology Frequency; Period	Outcomes and/or conclusion
Telephon coaching and consultation, recognition and response systems				
Raju [24] 2012; USA	Asthma	CT 48; 5 months	Telephone call 1/day	• asthma controlled proportion improved from 69 to 78 % • asthma management using the phone is a feasible strategy • phone calls are accepted by patients and improve asthma control without an office visit
Garbutt [25] 2012; USA	Asthma	RCT 950; 12 months.	Telephone-coaching	• the coaching intervention may improve asthma control and disease-related QoL and reduce urgent care events for asthma care
Young [26] 2012; USA	Asthma	CT 83; 3 months	Telephone-coaching 1/month.	• this telepharmacy intervention is feasible and showed effectiveness; the design is well suited for a robust study to evaluate its impact in uncontrolled asthma patients • pharmacists helping patients manage asthma through telecommunications may resolve access barriers and improve care
Mulvaney [27] 2013; USA	Asthma	RCT 53; 30 days	Voice Response System (VRS) 1/day	• VRS can assess asthma symptoms and adherence in adolescents • VRS maybe more expensive than traditional retrospective self-report • possible bias in missing data
Bender [28] 2015; USA	Asthma	RCT 899; 24 months	Speech recognition (SR)	• inhaled corticosteroid adherence was higher in the intervention group than that in the usual care group (44.5 vs 35.5 %; $P < 0.001$) • asthma-related urgent care events did not differ between the two groups • strong potential for low-cost SR adherence programs integrated with an e-health record • SR may reduce health care use in a population with less-controlled asthma
Web-platforms and mobile applications				
Asthma self-management				
Liu [29] 2011; Taiwan	Asthma	RCT, 89; 6 months	App PEFR 1/day	• PEFR and FEV1 significantly increased in mobile telephone group vs controls • QoL was significantly higher in mobile telephone group vs controls • fewer exacerbation and unscheduled visits in mobile telephone group vs controls • daily dose of systemic or inhaled corticosteroids in mobile telephone group vs controls
Ryan [30] 2012; United Kingdom	Asthma	RCT 288; 6 months	App 2/day	• no significant difference in the change in asthma control or self-efficacy between patients monitored with an app (e-diary) and those using a traditional diary • exacerbations, steroid courses, and unscheduled consultations similar in both groups • mobile phone service was not cost-effective
Licskai [31] 2013; United Kingdom	Asthma	CT 22; 3 months	App	• mean asthma QoL questionnaire score improved from 4.3 to 4.8 ($p = 0.047$) • app can support knowledge translation at the patient and provider levels
Burnay [6] 2013; Portugal	AR and asth-ma	CT 8; 4 months	App	• app can receive information and news about disease, define medication and tasks notifications, and synchronize all records at network with an online database • may contribute to patient enablement
Assisted care				
Haze [32] 2013; USA	Asthma	CT 20; 2 months.	App + SMS communication	• can improve nurse-patient relationship • teenagers could ask more questions and quicker response times • RN care coordinators perceived improved ability to contact teenagers and improved accuracy of assessment data
Tripodi [33] 2014; Italy	AR	Historical comparison 27; 9 months	App + SMS	• can improve adherence to sublingual immunotherapy • facilitate direct communications between doctors and patients through a chat messaging system
Costa C [34] 2014; Italy	AR	Pilot study 21; 91 days	App	• can predict the presence or absence of symptoms up to 4 days before the event • predictive performance tended to improve when the degree of individual allergic susceptibility was also taken into account
Lucas [35] 2015; Sweden	Asthma	Case report 1; 3 months	Cloud-computing smartphones	• discover sensitive environmental triggers of asthma for individual • proactively improve asthma control, management, and quality of life • pollen and air quality data collection networks need improvement • cloud-computing smart phones may be crucial in personalized health care

AR allergic rhinitis, *ACT* asthma control test, *CT* controlled trial, *EMA* ecological momentary assessment, *RCT* randomized controlled trials, *App* mobile phone application, *PEFR* peak expiratory flow rate, *QoL* quality of life, *SMS* short message service, *SP*A smart phone application, *SR* speech recognition, *VAS* visual analogic scale

speech recognition system was used by Bruce G. Bender et al., in a study of 3- to 12-year-old patients with a persistent asthma diagnosis in USA. Speech recognition telephone calls were directed to the parents in the intervention arm when an inhaled corticosteroid refill was due or overdue. Calls were automatically tailored thanks to information obtained from the electronic health record and from the answers of the parents themselves to questions on refills, parents' desire to learn more about asthma control, or speak with an asthma nurse or pharmacy staff member. The study found that inhaled corticosteroid adherence was higher in the intervention group than in the usual care group, showing that the speech recognition system had a strong potential for the implementation of low-cost self-report adherence programs integrated with an electronic health record. According to the authors, the interventions might reduce health care utilization when applied in a population with less-controlled asthma [28].

Applications

Mobile applications (apps) are the third and the most interesting technology recently investigated in patients with asthma and allergies. Studies can be divided in two categories respectively focusing on (a) "self-management" of asthma [6, 29–31], and (b) doctor- or nurse-driven management of asthma and/or allergic rhinitis [32–34].

Apps for Asthma "Self-Management" Many apps provide tools for daily self-monitoring of symptoms and consequent adjustment of the therapy for a better asthma control. However, only a few studies have investigated whether this approach is useful or not.

- In 2011, a prospective, randomized, controlled study investigated the impact of an application supporting self-management in 89 Taiwanese patients with moderate-to-severe persistent asthma [29]. Half of the patients were controls following usual care methods, and the other half were assisted by an electronic diary (e-diary) to record patient's daily asthma symptom score. This app daily measured the level of asthma control and immediately displayed the consequent clinical advices based on the international guidelines for asthma management (GINA). The patients in the "mobile telephone" group had better quality of life after 3 months, less asthma exacerbations, and unscheduled visits than the control group. The authors concluded that the mobile telephone-based interactive self-care system provides a convenient and practical self-monitoring and self-management and improves asthma control [29].
- A prospective, single-center, not-randomized, pre-post intervention study also used an app consisting in an asthma action plan. Adult Canadian patients with asthma ($n = 22$) registered daily their symptoms and peak flow data and automatically received from the system control assessment, advice about treatment, and environmental alerts (e.g., air quality). Most patients reported that the app was easy to use, clarity, and timeliness and asked to continue using the app after the study; both, asthma control and asthma-related quality of life, improved during the study. The authors concluded that the app could successfully integrate the asthma action plan and support knowledge translation at the patient and provider levels [31].
- By contrast, a large randomized, controlled trial, involving 288 adolescent and adult British patients with poorly controlled asthma, reached opposite conclusions [29]. In this study, patients had been randomized to recording symptoms, drug use, and peak flow either on a classical diary or through an e-diary. Both diaries provided the patients with immediate feedback for action, when necessary. No difference in asthma control or self-efficacy between the two groups was observed, and the authors concluded that mobile technology was not cost-effective [30].
- Last, a small but instructive pilot study in eight Portuguese patients with asthma and allergic rhinitis showed that the app called "m-CARAT" might usefully contribute to patient enablement [6]. This app allows patients to answer a questionnaire on their disease, record daily symptoms and medication, record an attack and the respective trigger, alert about medication, and monitor drug intake. The authors announced further prospective studies and developments of this app [6].

Doctor- or Nurse-Driven Management of Asthma and Allergic Rhinitis Some apps have been recently designed to facilitate the communication between the doctor (or the nurse) and the patient with asthma.

- In the USA, a pilot study investigated the clinical impact of an app on 25 teenager patients with asthma. The app addressed four functions: (1) health assessment, (2) personalized health plan, (3) disease-specific education, and (4) communication for follow-up evaluation. Accordingly, the patient could (1) complete a questionnaire assessing asthma control in which most recent answers were displayed on the dashboard, (2) view a personalized asthma action plan, (3) select short education modules (i.e., segments of education already used in the existing asthma management program) of either a slide or a video clip on a selected asthma topic, and (4) send a text message using short message service. From the dashboard side of the secure web site, the registered nurse (RN) care coordinator could (1) enroll the patient; (2) input patient-specific information; (3) view any patient use of the application; and (4) text message the patient, including asking the patient to complete a control questionnaire or education module within the application. Most patients indicated a positive impact of the app on their

interaction with the nurse and appreciated the chance of asking more questions and receive quick answers. The nurse noted an improved quality of the communication and of the data assessed by the teenagers. The authors found that the app improve the nurse-patient relationship [32].

- We recently completed a randomized controlled study on the use of an e-health platform (AllergyMonitor©) aimed at improving the interaction between patients with allergic rhinitis and their doctor [19]. The study population consisted of 63 patients aged 5–18 years with moderate-to-severe SAR to grass pollen requiring daily administration of nasal corticosteroid (NCS) (mometasone) during the pollen season. The patients were assisted in a specialized care unit in Berlin, and they were randomized to tele-monitoring or usual care. In a 6-week-long monitoring period, the patients in the tele-monitoring group had a better adherence to NCS treatment and achieved a better disease knowledge than those in the usual care group [19]. The same app might improve adherence to sublingual immunotherapy (SLIT) [33] and may be useful in predicting symptoms exacerbations in polysensitized patients with pollen allergy [34].

Other Allergy and Asthma Apps Available on the Market

Many more asthma and allergy apps are available on the market but have never been tested in clinical studies. Statistics from an application data tracking company (AppFigures) statistics showed that in 2014, the total android applications in Google Play reached 1.43 million, while the total iOS App Store application was 1.21 million. On 8 December 2015, we searched the key word "allergy," "asthma," "hay fever," and "rhinitis," on Google Play, iTunes, and we retrieved 136 applications [Table 2; the first and second part]. Food allergy ($n = 68$) is the most targeted area of interest, followed by pollen allergy (15), allergic rhinitis (6), asthma (5), allergic rhinitis and asthma (4), drug allergy (3), and mite allergy (2). A heterogeneous group of 33 applications targeted allergic diseases in general. Most applications provide information for patient's education or prevention. A few are directed to treatment, some are more complex electronic diaries, and most of those focusing on pollen provide local bulletin with updated information on pollen counts. There is an enormous heterogeneity in the diffusion of these applications, with a few downloaded more than 100,000 times, and many downloaded less than 100 times. A detailed classification and analysis of all these apps is beyond the scope of this review.

i-Cloud

Cloud technology is the most advanced of all the features linked to m-health. The only study so far published and based on this technology has involved a Swedish patient seeking care in an allergy clinic because of his asthmatic symptoms. The study highlighted the potential of cloud-computing and smartphones to improve the management of asthma. In particular, cloud-computing initial results suggested that strong associations exist between asthma exacerbations and environmental factors [35]. The system actively acquired daily information on the environmental exposures and the patient's condition, processed them automatically, and provided the patient with systematic and timely advice about its asthma condition and the corresponding management. The authors also suggested that more advanced smartphone application and cloud-computing functionalities can be used to capture geospatially and temporally relevant environmental data and help health care professionals to better understand some of the environmental stimuli that trigger their personal exacerbations [35].

Shortcomings and Limitations

The enormous advantages of new technologies should be matched always against their potential or real disadvantages and limitations.

- A telephone will never substitute the power of a direct human contact between patient and medical worker [31]. Common sense says that clinicians and patients must be face to face in many occasions, or the doctors would get a mistake diagnosis. Doctors need inspection, palpation, percussion, auscultation, and comprehensive analysis before diagnosis. Therefore, we thought this may be an important limitation to mobile phone in health.
- The SMS did not reduce the number of emergency department (ED) visits or hospital admissions during a short-term study lasting [15].
- Many older patients did not have mobile phones, or if they had one, most of them did not know how to use the SMS or were non-English speaking [15].
- The SMS procedure was assumed to be too complicated and time-consuming for the children [20].
- Some patients reported confusion with event-based SMS [22].
- Chinese academics found no significant differences in the changes of FEV1% and sputum eosinophil counts and neutrophil counts after using SMS technology in asthma patients [16].
- Ryan et al. found that app mobile phone-based monitoring did not offer any advantages over and above paper-based care when guideline standard clinical support services were provided; mobile technology group was not cost-effective [30].
- In some public school, many students were not able to use their mobile phone at school [27].

Table 2 Allergy apps on the market (2015)

	Target	Apps name	Android	iOS	Main keyword	Costs €	User star	Comment number	Download times
First part									
Asthma	Edu	AASC	●	○	pollen	0	–	–	10–50
	Edu	50Eduallergy & asthma associates of SCA	○	●	relief, California	0	–	–	–
	Edu	asthmaMD	○	●	journal, diary, trigger	0	–	–	–
	Edu	KEMILEX	●	○	Denmark	0	3.3	3.3	1–5K
	Pre	The allergy, Asthma and Sinus Center	○	●	pollen count, location	0	–	–	–
Allergic rhinitis and asthma	DI	Allergy Diary by MACVIA ARIA	●	○	allergic rhinitis, asthma, symptoms	0	–	1	10–50
	Edu	Allergy Control	●	○	respiratory, allergy	0	4.2	25	1–5K
	Pre	Allergy Track	●	○	translates, religious, dietary	0	3.1	36	5–10K
	Tre	allergy ke upchar-remedies of allergy	○	●	solution, skin allergy	0	–	–	–
Allergic rhinitis	DI	Hay Fever Diary Lite	●	○	track, symptom, pollen	0	4	391	10–50K
	DI	Hay Fever Diary Pro	●	○	hay fever	2.49	4.3	54	0.5–1K
	Pre	Allergic Rhinitis	●	○	allergic rhinitis	0	2.5	2	100–500
	Pre	Allergy Alarm	●	○	allergic rhinitis, treatment, prevention	0	–	8	100–500
	Pre	Hay Fever Allergy	●	○	hay fever	0	–	–	10–50
	Tre	spring allergy remedies	●	○	remedies	0	–	1	50–100
Pollen-related disease	DI	AllergyMonitor	●	●	monitor	0	4.6	74	1–5K
	Edu	Allergy Pollen Count	●	○	pollen, count	0	4.4	102	5–10K
	PB	Pollen	●	○	Austria, Germany, Sweden	0	3.6	743	100–500K
	PB	Pollen allergy warning Sweden	●	○	Sweden	0	3.1	95	5–10K
	PB	Pollen-News	●	○	Switzerland, forecasts	0	3.6	142	10–50K
	PB	Pollen-Radar	●	○	Germany, forecast	0	3.6	266	50–100K
	Pre	air quality and pollution	○	●	air, quality	0.99	–	–	–
	Pre	AlertaPolen	●	○	pollen, Spanish	0	3.1	317	10–50K
	Pre	AllergiePass	●	○	digital form	0	5	6	0.5–1K
	Pre	Austin Allergy	●	●	forecast, Texas, pollen, mold, forecast	0	3.9	146	10–50K
	Pre	Hooks - Alerts for Everything	●	○	alert	0	3.9	2232	100–500K
	Pre	Husteblume	●	○	Vienna	0	2.9	117	10–50K
	Pre	Livocab® direkt - Pollen-Alarm	●	○	alert, forecast	0	3.8	360	5–10K
	Pre	pollen allergy	○	●	grass, tree, spores, weed	0	–	–	–
	Pre	skin and allergy news	○	●	news, dermatology, skin	0	–	–	–
Mite allergy	Pre	Allergy Expert	●	○	doctor, medical personnel	0	–	–	10–50
	Pre	MilbenCheck	●	○	personal allergen, mites	0	2.4	14	1–5K
Food allergy	DI	Allergy Diary	●	○	recording, graphical statistics	0	3.7	22	1–5K
	DI	Food Diary	●	○	food, track, symptom	2.49	4.2	181	100–500
	Edu	Allergies Advise	●	○	food	0	–	–	5–10
	Edu	allergy ally	○	●	create and edit, caregiver	0	–	–	–
	Edu	Allergy Analyzer	●	○	relationships, symptoms, food	0	3.1	19	1–5K
	Edu	Allergy Analyzer Tab	●	○	relationships, symptoms, food	0	3.1	10	0.5–1K
	Edu	Allergy Andy	●	○	food	0	–	5	50–100
	Edu	allergy FT: allergy food translator	○	●	egg, fish, milk, peanut, shellfish	2.99	–	–	–
	Edu	allergy guard lite	○	●	food, ingredients	0	–	–	–
	Edu	Allergy Tracker (Ad Free)	●	○	food	1.63	–	–	1–5
	Edu	Allergy Traveler Language Pack	●	○	food	1.5	–	3	100–500
	Edu	Bugabees-Friends w Allergies	●	○	food	3.75	–	–	10–50
	Edu	dairy allergy	○	●	Food, Translate	0	–	–	–
	Edu	iAvoid Food allergy	○	●	eight, food allergies	0	–	–	–
	Edu	I have a nut allergy international translation HD	○	●	translate, 56 languages	0	–	–	–
	Edu	Medrills: Allergic Reactions	●	○	3 days reactions, causes, treatments	3.02	–	2	10–50
	Edu	My Allergy Menus	●	○	filters, restaurant menus, ingredient, GPS	0	–	1	10–50
	Edu	seafood allergy EMBE	○	●	seafood	0	–	–	–
	Edu	Shellfish Allergy	●	○	shellfish	0	–	1	10–50
	Edu	Sjekk matvaren for allergier	●	○	scanner, bar code	5	3.9	38	1–5K
	Edu	User's Guide to Allergies	●	○	education	1.63	–	–	–

Table 2 (continued)

	Target	Apps name	Android	iOS	Main keyword	Costs €	User star	Comment number	Download times
Second part									
Food allergy	Edu	WITS? Healthy Food Ingredients	●	○	scan, ingredient	0	2.8	38	5–10K
	Pre	Allergy Alert	●	○	allergy recall news	0	–	2	1–5K
	Pre	Allergy Dictionary	●	○	food	0	–	–	10–50
	Pre	Allergy Free	●	○	food	0	–	7	100–500
	Pre	allergy journal	○	●	journal, food, allergy	0.99	–	–	–
	Pre	Allergy Scan	●	●	wheat, gluten, soy, shellfish, tree, nut	0	–	3	100–500
	Pre	Allergy Traveler	●	○	translates, religious dietary	0	3.1	14	1–5K
	Pre	allergy watch	○	●	food, cosmetics, drugs, mold, pets, bee	0	–	–	–
	Pre	AllerTrack-Meal Log IBS/ Celiac	●	○	IBS, celiac disease, lactose	0	–	5	0.5–1K
	Pre	Asian Food Allergy	●	○	Asian	0	–	1	10–50
	Pre	AYRTEC ALLERGYCAST	○	●	baby, food, track	0	–	–	–
	Pre	baby food allergy tracker	○	●	baby, food	0.99	–	–	–
	Pre	Biomed Allergy Translator	●	○	food	0	–	4	0.5–1K
	Pre	BiteAppy: Allergy Diet Eating	●	○	search, restaurant	0	4	40	1–5K
	Pre	cook it allergy free	○	●	cooking, gluten	0	–	–	–
	Pre	Dia's Allergens	●	○	popular foods, drink	0	2.6	13	1–5K
	Pre	Egg Allergy Disease & Symptoms	●	○	egg gluten, wheat, egg, milk, nut, peanut, soy, shellfish	0	–	–	10–50
	Pre	fast food & restaurants gluten & allergy free	○	●	fast food	0	–	–	–
	Pre	Fast Food Allergies	●	○	menus, restaurant, USA, Canada, UK	0.77	3.7	14	100–500
	Pre	food allergy menus	○	●	food, safety	0	–	–	–
	Pre	Food Allergy Safety	●	○	track	5.25	–	–	1–5
	Pre	Food Allergy Tracker Free	●	○	translate, dietary, abroad	0	3.9	61	1–5K
	Pre	Food Allergy Translate	●	●	food, translate	1.47	–	2	50–100
	Pre	Food Allergy Translate Free	●	○	lactose, histamine, sorbitol, personal threshold	0	2.2	10	1–5K
	Pre	Food and Symptoms Diary	●	○	celiac disease, lactose	2.88	4.5	18	1–5K
	Pre	food diary (free)	●	○	scans, supermarket, labels	0	2.9	181	10–50K
	Pre	Food Thumb	●	○	track, statistically, analyze, habits	0	–	9	100–500
	Pre	Food. Symptoms & Allergy Diary	●	○	food, beverage, ingredient	0	3.6	11	1–5K
	Pre	healthy diet & gluten	○	●	restaurant, dietary	0	–	–	–
	Pre	Interactive Food Allergy Menus	●	○	restaurant, dietary	0	2.9	38	1–5K
	Pre	Intolerance Food Diary	●	○	monitor, isolate	0	3.8	170	10–50K
	Pre	Kafoodle	●	○	suit, allergy, intolerance	0	–	6	100–500
	Pre	Latex Allergy Information	●	○	latex	0	–	3	50–100
	Pre	Milk Allergy	●	○	milk	0	–	1	100–500
	Pre	Milk Allergy Information	●	○	milk	0	–	–	100–500
	Pre	my allergy menus	○	●	restaurant, dietary, real-time	0	–	–	–
	Pre	My Food Allergies	●	○	narrow, intake	0.74	–	1	50–100
	Pre	My Gluten Free Me	●	○	ingredients, gluten	0	2.8	29	5–10K
	Pre	My Gluten Free Me	●	○	national institutes of health	0	3.6	11	5–10K
	Pre	Peanut Allergy	●	○	peanut	1.97	–	–	5–10
	Pre	peanut allergy EBME	○	●	peanut, symptoms, label synonyms, hidden sources	0	–	–	–
	Pre	Peanut Allergy Information	●	○	peanut	0	–	–	50–100
	Pre	Recipes by Ingredients	●	○	recipes	0	3.6	2371	100–500K
	Pre	Seafood Allergy	●	○	seafood	1.97	–	–	1–5
	Pre	Shellfish Allergy Information	●	○	shellfish	0	–	1	10–50
	Pre	Wheat Allergy Information	●	○	wheat	0	–	–	100–500
	Tre	Allergy Relief Handbook	●	○	food	0	–	–	1–5
Drug allergy	Pre	Drug Allergy Information	●	○	drug, information	0	–	1	100–500
	Pre	Drugs.com Medication Guide	●	○	search, drug, information	0	4.2	9402	0.5–1M
	Pre	Penicillin Allergy Information	●	○	penicillin	0	–	–	100–500

Table 2 (continued)

	Target	Apps name	Android	iOS	Main keyword	Costs €	User star	Comment number	Download times
All kinds of allergy	DI	Allergy Pal	●	○	allergies, translate, English, French, Spanish, German	0	3.4	15	1–5K
	Edu	Allergies 101 by GoLearningBu	●	●	rhinitis, skin, food, mold	0	3	2	100–500
	Edu	Allergies Disease & Symptoms	●	○	symptoms, causes, tests, diagnosis, treatments, home, rem	0	–	3	100–500
	Edu	Allergies Tips Guide	●	○	dust mites, pet dander, mold	0	–	–	100–500
	Edu	allergy academy	○	●	deliver, course	0	–	–	–
	Edu	Allergy Glossary	●	○	reference, guide	1.27	–	–	1–5
	Edu	Allergy Journal	●	○	scientific journal	0.74	3	14	100–500
	Edu	Allergy Risk	●	○	allergy information, child	0	–	1	10–50
	Edu	allergy track	○	●	symptom, monitor, manage, track, doctor	0	–	–	–
	Edu	allergy track	○	●	journal, track, Google Health	0	–	–	–
	Edu	Audiobook - Allergies	●	○	audio book	0	3.7	64	10–50K
	Edu	Common Allergy Myths	●	○	allergy, myths	0	–	–	100–500
	Edu	e-symptoms	●	○	electronic log	0	3.4	17	5–10K
	Edu	Mount Sinai Guides: Allergy	●	○	diagnosis, management	26.97	–	–	1–5
	Edu	pediatric allergy and immunology	○	●	journal, children, immunity	0	–	–	–
	Edu	Simple Allergies	●	○	symptoms, common, allergies	0	–	–	1–5
	Edu	Smart Allergy Taming	●	○	allergic rhinitis, sublingual, immunotherapy	0	–	–	50–100
	Edu	Tell the Doctor: Allergy	●	○	record, automatically, doctor	0	–	–	5–10
	Edu	Angioedema Allergy	●	○	information, signs, symptoms, diagnosis, management	0	–	–	10–50
	Pre	Allergies	●	○	allergy, at hand	1.77	–	5	1–5
	Pre	allergy free dessert	○	●	recipe, collection, milk, egg, soy, peanut	1.99	–	–	–
	Pre	AllerKey	●	○	NFC tag	0	–	2	10–50
	Pre	AllerKey	●	○	worldwide, diagnoses, medications	0	–	2	10–50
	Pre	CosmEthics	●	○	scan, bar code	0	3.9	81	1–5K
	Pre	CosmEthics	●	○	eye	0	3.8	17	1–5K
	Pre	Sun Allergy Disease & Symptoms	●	○	sun	0	–	–	10–50
	Pre	TreeID	●	○	trees	1.45	1.9	34	1–5K
	Tre	ALLERGY Acupressure Treatment Free	●	○	acupressure, relieve	0	4.1	44	5–10K
	Tre	ALLERGY Acupressure Treatment Pay	●	○	acupressure, relieve	2.19	–	–	10–50
	Tre	Allergy Release Hypnosis	●	○	audio, hypnotherapy	0.87	–	–	10–50
	Tre, Edu	Allergy Release Hypnosis	○	●	Acupressure, Relieve	0	–	–	–
	Tre, Edu	no allergy - instant acupressure self-treatment	○	●	Acupressure, Relieve	0	–	–	–
	Tre, Edu	告别过敏症	○	●	Chinese medicine	0	–	–	–

DI diary, *PB* pollen bulletin, *Edu* education, *Pre* prevention, *Tre* treatment; (*K* 1000, *M* 1000,000)

- Medical staff has not much time to accept calls or to reply SMS [32].
- Mobile technologies cannot be easily integrated in the existing hospital informatics systems. If the two systems are isolated, it will have big problems of security and significantly increase the workload of medical workers [32].
- The last, but not the least, in all the 22 studies, only 4 used apps that could provide environment data in real-time [19, 33–35].

Security and Costs

Security means—in this area—data safety collection. After all, mobile technology is a program that needs to transform clinical symptom or sign into data and a computer language, and then the data can be used. Relevant clinical phenomena must be accurately converted to machine language, and we have to ensure that the data remain completely protected and reliable from the phone to the server during their transmission.

Licskai et al. used the smartphone application (SPA) that applied standard 3DES encryption and secure socket layer network transmission security protocols in an IBM Domino enterprise application server architecture, with an integrated lightweight directory access protocol for authentication according to user name and encrypted passwords [31].

Ryan et al. concluded that the use of their app had produced no clinical advantages but increased the care costs, because of the expenses linked to tele-monitoring. In their study, the use of m-health (compared to the use of a traditional clinical diary on paper) has not been cost-effective [30]. Similarly, Mulvaney et al. considered a voice response system more expensive than traditional retrospective self-report; however, they also concluded that this m-health technology should be investigated for its added value in clinical practice and integrated with tailored mobile intervention techniques to improve adherence [27].

Discussion

Notwithstanding the great number of asthma and allergy apps available in the market, we found only 22 studies examining their impact on the management of allergic diseases. Moreover, most studies focus on asthma, a few on allergic rhinitis, and almost none of them on food allergies. We also observed that most, if not all studies, focus on monitoring patients after the diagnosis and prescription of therapy. We can therefore draw conclusions around the role of m-health in awareness, education, and adherence to treatment in patients with asthma. M-health technology seems to play a role in educational reminding, guiding role of medication, and enhancing patients' adherence to treatment. M-health may therefore play a crucial role in asthma management, especially of adolescents and young adults, who tend to discontinue the medication as their symptoms improve [20, 27, 32]. These patients tend to undergo more emergency or unscheduled visit, exacerbations, hospitalizations. The regular use of SMS (including MMS), voice reminders, and apps supporting self-management has improved patients' understanding of the disease and their adherence to medication [6, 15–18, 20–22, 24, 27–29, 31, 32, 35].

Most of the studies performed so far concluded that m-health is useful in the management of allergic diseases. Nevertheless, one of the best trials so far published has reached three negative conclusions. In this trial, m-health (1) did not improve asthma control or self-efficacy; (2) did not reduce acute exacerbations, steroid courses, and unscheduled consultation; and (3) was more expensive than the use of a traditional diary [30]. One may explain this conclusion with a low recruitment rate or with the interference of chronic obstructive pulmonary disease (COPD) on symptoms severity. Interestingly, controls were also monitored on a daily basis with a classical clinical diary using a paper support, instead of a modern electronic diary using a mobile phone app. Then, this study demonstrated that "the diary" itself, and not the way it is realized (on paper or electronic, traditional, or innovative), is essential for a treatment success. The point is that in our fast society, in the real life, and outside clinical trials, the patients do not normally dedicate time to fill regularly a paper-based diary, and above all, doctors have no time to read them, draw complex curves, and calculate outcomes. In real life, both the traditional and the electronic diaries are "useful" but only the electronic diaries are feasible, and "usual care" does not contemplate a clinical diary. Studies comparing an e-diary against usual care (unfortunately not including a diary) would be very informative and useful to understand the impact of m-health in real-life clinical practice.

Our review also highlights the lack of studies investigating the impact of medical devices connected to a mobile phone. Nowadays, wearable medical devices have been invented that can monitoring heart rate, pulse, temperature, blood pressure, blood sugar, patient's location, etc. [36]. Many devices are being developed that can change the way we can monitor respiratory allergies. These include peak expiratory flow (PEF) or peak nasal inspiratory flow (PNIF), respiration parameters, breathing sounds and remote auscultation, image exchange, and so on. These devices can exchange data with smartphone apps via Bluetooth, and the apps can exchange data with the corresponding server through the internet. Then, through cloud-computing technology and exchanging data between servers, the cloud could integrate and analyze data real-time and dynamically, then pushed information through servers to the patient and his/her doctors. Servers or the doctors can elaborate the signal and give to the patient a personalized feedback or recommendation through the phone itself or by voice, or its wearable device (Fig. 1). There is a huge expansion in this area that will increase the impact of m-health on allergies but that it still not the object of clinical trials and related publications.

Apart from the beautiful study from Ryan et al. [30], none of the other studies examined in this review made a direct cost-benefit evaluation. Therefore, we would be tempted to predict or to suggest that cost-benefit studies prospectively investigate whether m-health could cost-effectiveness of asthma and allergies treatment in public health care settings. Information is needed to ascertain whether m-health can:

1. reduce episodes of asthma exacerbation and unscheduled visits [29]

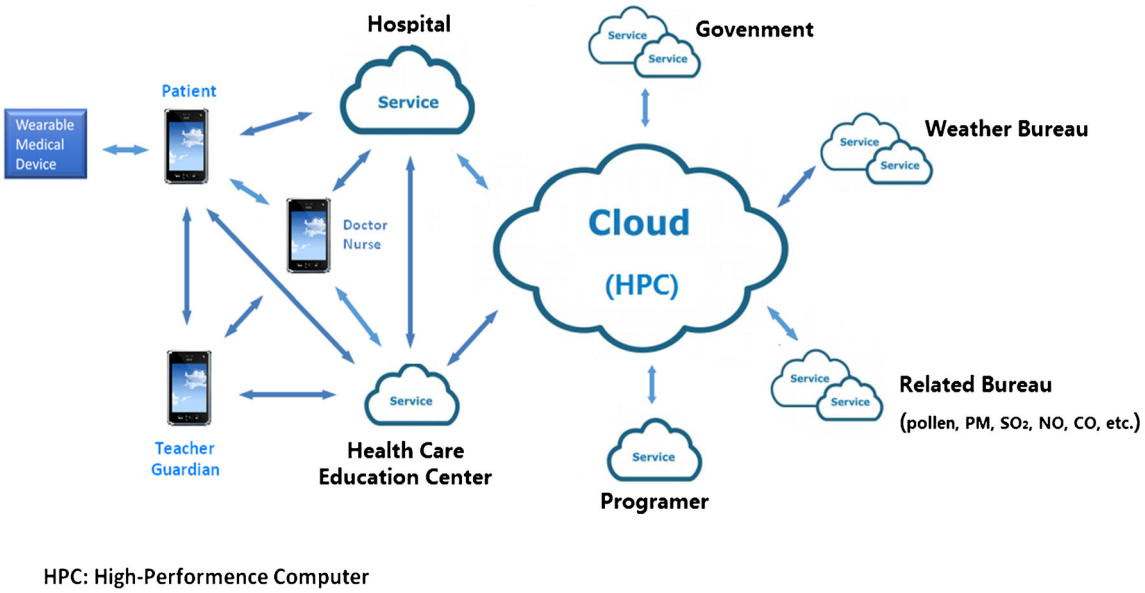

Fig. 1 Cloud-computing technology, mobile phone and mobile health applications

2. improve asthma control by reducing the need for an office visit [24]
3. reduce the number of atopic dermatitis patient referrals to specialists [37]
4. better support self-management of chronic disease [23]
5. improve self-reported adherence to medication [17]
6. improve adherence and reduce the burden of asthma [18, 28]
7. promote personalized health care [35]

As Lucas RW et al. have noted, m-health may proactively improve the patient's asthma control, management, and quality of life when the patients know their level of exposure to triggers and how to avoid them [29]. Emphasis and resources should therefore be allocated to the improvement and support of data collection networks. It is essential to made available to any individual patient, through his/her smart phone, pollen, and air quality information. The implementation of cloud-computing and smartphone technologies had the potential to become a game-changing advance in the provision of personalized health care, but needed to be evaluated on a larger scale [35].

We look forward in the future to have more applied research on cloud-computing technology in the medical field and more ability to effectively integrate all the relevant departments, to integrate all of the public health resources and real-time, and dynamically push message to the patient's phone. Cloud-computing technology could automatically push message to the patient disease information (images, sound, video, and other forms of multimedia)-related education. So it could improve patient awareness of the disease and treatment compliance. Patient could visually see the relevant information on the phone screen and feedback in a variety of ways, such as inputting text message, recording voice, taking photos, recording video, and uploading. Then, it formed a good interaction in the patient and the medical workers and the system. These were feasible by using cloud-computing technology and mobile applications. We hope the early arrival of this wisdom medical health system.

Conclusion

The studies on the impact of m-health in asthma and allergies are still very few. The mobile health technology has an enormous potential and may be in the future a feasible, cost-effective, useful tool for not only allergic disease, but also for many other diseases. It has some questions about personality and security. We need integrate the public health departments and use cloud-computing technology to overcome all the shortcomings. Patients with asthma and allergies will obtain all the relevant information of their disease, and this information were dynamically updated in real time. Government's funding, adequate coordination, and clinical studies are required to use the best and sustainable use for all the patients of the fantastic progress of mobile phone technologies.

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