



Asthma Management in the Era of Smart-Medicine: Devices, Gadgets, Apps and Telemedicine

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Abstract

Asthma is the most common chronic pediatric condition. Effective asthma management requires a proactive and inclusive approach that controls the patient's symptoms and prevents recurrence of exacerbations. Clinicians should encourage patients to become involved in their management since self-management approaches have proven to be an effective means for chronic illness treatment. Novel forms of self-monitoring and management are technological interventions. In the last decade, novel technology has been developed and used to improve asthma control since it is a powerful agent that addresses a variety of challenges in chronic disease management such as education, communication and adherence. A myriad of technology-based strategies are available although many of these are not evidence based and further studies are needed to evaluate their efficacy in specific asthma-control endpoints. Herein, authors present a review of current and future technology-based options for asthma management and a comparison between them.

Keywords Asthma management · Wearable devices · Telemedicine · Developing technology

Introduction

Asthma is a very common disease; it affects over 300 million patients and is the most common chronic pediatric disease [1].

The management of asthma now-a-days is facilitated by excellent medications and guidelines. Despite these means, there has been no change in adherence to medication and morbidity. Annually, there are 670,000 emergency department visits for asthma exacerbations in children [2].

These exacerbations are closely related to non-adherence; up to 60% of asthma-related hospitalizations and [3] and common reasons for lack of compliance include treatment complexity and poor recall [4]. To achieve asthma control, patients should also monitor their symptoms, avoid exacerbation triggers and have good adherence to their treatment plan [5].

Technological interventions can help in enhancing treatment adherence; allow long term longitudinal data collection on symptoms and drug intake; and aid in self-management

programs [6]. Self-management approaches have long been recognized for chronic illnesses [7, 8] and have proved to be effective in improving lung function, reducing activity limitations and emergency department visits [9].

In this review, authors examine current and future strategies to improve pediatric asthma control focusing on electronic devices and developing technology.

Electronic Monitoring Devices (EMDs)

EMDs are now considered the gold standard to monitor medication since they provide objective data and are not biased by patient self-report [10].

Chan et al. conducted a randomized study in school-aged children with asthma exacerbation presenting to the emergency department. Patients were randomized to EMD (Smart-Track) with audiovisual reminders or EMD alone. Median percentage adherence was 84% in the intervention group compared to 30% in the control group. Asthma control test (ACT) score improved more than three points in the intervention group. Despite these improvements, there was no difference between the two groups regarding missed school days, lung function or emergency department visits [11].

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In a real-world study by Merchant et al. patients were randomized to EMD (Propeller Health) with or without feedback on SABA (Short acting bronchodilator) use. After 52 wk of follow up there was no significant difference in ACT scores between groups although in patients with initially poorly controlled asthma ACT scores improved and the proportion of subjects with adequate control was also higher [12].

Both studies demonstrated the benefit of EMD use in enhancing adherence and providing feedback to patient and physician. Potential limitations of EMD use are the cost and time of implementation in clinic and the potential lack of benefit in medication delivery technique.

Mobile Phone-Based Technologies (Apps)

Mobile phone applications, “apps” have had a rapid development and are used in many fields including healthcare and medicine. Despite the wide variety of medical apps available, only a limited number of apps have been tested in a clinical setting with objective measures of improvement (Table 1). To the authors knowledge, all these applications are developed by the respective investigators and have not been made available to the public. Most of these interventions proved to be effective in the primary measured outcome.

By contrast, a randomized clinical trial by Ryan et al. that included adolescents, the use of an app based intervention had no difference in asthma control when comparing it to classical diary symptom recording [18].

Regarding the apps available for two popular smartphone brands (iPhone and Android); a review published by Wu et al. found 209 asthma-related apps. From these, 52% provided teaching information for patients, 22% helped with symptom and medication tracking and 18% were medical provider-directed apps (Table 2). The utility of these commercially available apps has not been validated in the clinical setting and health care professionals should be careful when recommending its use.

A potential advantage of apps over other technological interventions is the fact that people carry their smartphones all the time and it would not require purchasing another device or gadget. This represents a huge advantage in terms of implementation as 92% of teenagers use internet on a daily basis and 73% have access to a smartphone [19].

Gadgets and Wearable Devices

Medical devices such as wearable body sensors are tools that can help in providing medical monitoring, medical data access and communication in emergency situations [20, 21]. The

goal of these sensing systems is to detect and quantify respiratory wheezing while transmitting the signal to a smartphone.

Acoustic monitoring devices have been used for several clinical studies. Boner et al. measured the nocturnal wheeze in asthmatic children using acoustic respiratory monitoring and found that among the patients with apparently well controlled asthma 57% had considerable amounts of night wheezing that was unrelated to conventional measures of lung function [22].

Wearable systems can also correlate an individual’s environmental exposure with physiologic and subsequent adverse health responses.

Current continual monitoring systems for asthma include heart and respiratory rate monitoring [23], use of GPS to track exposure to polluted areas [24] and combined measures of environmental (ozone concentration, temperature and relative humidity) and physiologic features [25]. There has been research focusing on the development of wireless sensor devices, integrated into fabrics (smart shirts) or other wearable devices [20].

The use of these continual monitoring systems is still a developing field that needs further study on the clinical impact.

Telemedicine

Telemedicine facilitates the diagnosis and treatment of patients in remote locations by using a wide variety of telecommunication options, such as internet and telephone media. The American Telemedicine Association (ATA) defines it as the remote delivery of health care services and clinical information using telecommunication technology [26].

Telemedicine options include: internet monitoring [27–30], online patient reminder [31], text messages [32], e-mail reminders [33].

Evidence from studies so far has not clearly shown whether asthma telemonitoring with feedback from a healthcare professional is effective in decreasing the onset of exacerbations, visit to emergency department or hospital stay [34].

In the US rural areas, for every 100,000 patients there are only 30 specialists available compared to the 263 specialists available for each 100,000 patients in urban areas [35].

Telemedicine management options might be cost-effective in underserved communities; while in communicated areas, these interventions could potentially increase the health care cost since patients would be using the telemedicine resources in addition to going to clinic. Telemedicine is a US\$ 17.8 billion industry and is expected to grow 18.4% annually from 2015 to 2020 [36]. In underserved communities, it would offer better access to specialized health care.

Table 1 Applications that have been studied in clinical scenarios

App	Description	Main features	Measure of improvement	Evidence	Available to public	Additional comments	Author
Mobile Adolescents' Disease Empowerment and Persistence Technology (M-ADEPT)	Electronic medication monitor fitted to patient's ISC (Inhaled Corticosteroid) that loads information to smartphone application	App delivers visual reminders twice daily. Provides positive text messages and rewards within app	ICS adherence Asthma control per ACT	From baseline to week 8, ICS adherence increased >50% and ACT score increased from 18 to 23.	Not available at app store. Investigator developed (NIH EIR #0577703-13-0020)	Evidence on clinical improvement	Mosnaim [13]
AsthmaCare (mHealth app)	App with daily reminders	Daily reminders of medication use, trigger avoidance and appointment notification	Acceptance of the app by the user	High user preference over written methods	Investigator developed	No clinical outcome measure or adherence assessment	Farooqui [14]
Health app	App with daily reminders and data entering	Data entry on peak flow and symptoms with recommendations based on data. Medication reminder. Weekly educational reminders	Asthma Control Test	In patients with uncontrolled asthma, ACT improved from 16 to 18. Asthma attack prevention domain improved from 34 to 36	Investigator developed	ACT improved only in patients with underlying uncontrolled asthma	Burbank [15]
Nursing Health app	App to facilitate nurse-patient	App allowed to share information, health assessments, personalized health plans	Patient-nurse communication	Adolescents perceived more rapid response, improved access and quick response times to asthma related questions	Investigator developed	No clinical outcome measure	Haze and Lynaugh [16]
Ecological momentary assessment (EMA)	App integrated with Bluetooth enabled sensors for asthma inhalers	Inhaler use is detected when phone receives signal from Bluetooth sensor. App prompts survey on stress, energy and fatigue at the moment	Patient satisfaction and ease of use	95% of patients reported easy to use app	Investigator developed	No clinical data	Dzubar [17]
t + Asthma application	App for data entry and communication with health professional	The app recorded symptoms, drug use and peak flow and transmitting data to healthcare professional.	Asthma control questionnaire (ACQ)	No significant difference in change in asthma control, number of acute exacerbations, steroid courses and unscheduled visits.		Tested on adolescents and adults. Randomized clinical trial comparing app versus paper based monitoring	Ryan et al. [18]

Table 2 Number of applications available for iOS and android devices

Category	No. of apps available
Teaching/General information	24
Teaching/Treatment information	18
Tracking/Symptoms	22
Tracking/Medication use	18
Medical provider-directed apps (references, calculators, <i>etc.</i>)	37

Challenges for Technology

The technological interventions available have several advantages and limitations and the development of an inclusive and validated tool for asthma management is a potential area of research protocol (Table 3).

The development of innovative methods for monitoring and controlling asthma faces several challenges; one of them being the customization by age. Children aged 0–4 y have a higher prevalence of uncontrolled asthma (47.3%) than those between 12 and 17 y (34.8%) [38]. This proves the different needs of pediatric groups and the importance of adjusting the intervention by age.

Another challenge will be to overcome the burden of socioeconomic status when implementing any of the options described. This has particular importance in developing countries where the availability and affordability of inhaled therapy is the first obstacle faced [39]. Low socioeconomic status is closely related to poor asthma outcomes as evidenced in a

South African study in which asthma mortality was higher on the weekend due to barriers in health service access [37].

The cost-efficacy of technological strategies also needs to be considered. In a multicenter randomized clinical trial, the implementation of mobile technology did not appear to improve objectively the management of patients [18]. The use of mobile phone technology needs to improve clinical outcomes when compared with standard clinical care in the context of asthma management compliant with the current guidelines.

Future research needs to address all these concerns as well as identify subgroups of patients more likely to benefit from close monitoring (*e.g.*, Those who have frequent asthma attacks).

Conclusions

Ideally, technological interventions should remind the patient about taking the medications and provide real-time data with feedback between the patient and clinician. These interventions should be cost-effective and easily incorporable into clinical practice and daily life; be compliant with treatment guidelines; provide reliable communication and ensure data integrity.

The usefulness of the electronic options available so far for asthma managing and monitoring is still debatable. The studies published so far for a personalized asthma management highlight the concern of security and cost-effectiveness of these tools. The advantages of new technologies should be compared to their potential disadvantages or limitations.

Table 3 Main advantages and limitations of technological interventions available

Intervention	Advantages	Limitations [37]
Applications (apps)	• Support self-monitoring • Provide written and multimedia educational information • Reminders for medication taking • Space for patients to log symptoms • Accessibility perceived convenience • People carry their phone all the time	• Require further study on clinical efficacy • Risk of loss of privacy of health information • Limited access to phone during school hours
Electronic monitoring devices	• Objective report on medication adherence • Provide feedback to patient and physician	• Treatment adherence does not ensure adequate technique of medication administration • Cost and time of implementation
Gadgets	• Early detection of emergency conditions • Objectively assess efficacy of treatment	• Sensor nodes are prone to failure • Size and capacity of the battery limit portability
Telemedicine	• Improved timeliness of care • Real-time urgent care consultations • Eliminates transportation expenses for routine check-ups • Expedited transmission of imaging and laboratory testing for second opinion	• Technical training and equipment • Reimbursement policies and privacy protection rules need to be clarified • Uneven distribution of telecommunication networks in underserved areas

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Compliance with Ethical Standards

Conflict of Interest None.

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