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# Smart inhalers: Transforming asthma management and the pharmacist's involvement in patient education

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***Abstract*---Background:** Asthma remains a global healthcare challenge despite advancements in classification, diagnosis, and inhalation therapy. A significant proportion of patients continue to experience uncontrolled asthma, which is linked to factors such as non-adherence to treatment and improper inhaler technique. **Aim:** This article aims to explore the potential of smart inhalers in transforming asthma management and to highlight the critical role of pharmacists in patient education. **Methods:** A comprehensive review of literature was conducted, focusing on the prevalence of uncontrolled asthma, the impact of non-adherence, and the integration of digital health technologies, particularly smart inhalers. The study involved an examination of the role of pharmacists in providing asthma education and promoting proper inhaler technique. **Results:** Findings reveal that 30% to 70% of asthma patients are non-adherent to their medication regimens. Smart inhalers equipped with digital health technologies can enhance medication adherence by providing real-time feedback to patients regarding their inhaler use and asthma status. The involvement of pharmacists in patient education is crucial for optimizing inhaler technique and improving overall asthma management. **Conclusion:** Smart inhalers represent a promising advancement in asthma care by addressing non-adherence and enhancing self-management. Pharmacists play a vital role in educating patients about asthma management and promoting proper inhaler use. Collaborative efforts among healthcare providers are essential to achieve optimal asthma control.

***Keywords*---**Smart inhalers, asthma management, digital health technology, patient education, pharmacists, medication adherence.

## Introduction

Despite advancements in the classification, diagnosis, and inhalation therapy of asthma for both maintenance and exacerbation management, the condition continues to represent a significant global challenge for patients, healthcare providers (HCPs), and healthcare systems [1,2]. The persistent high prevalence of asthma correlates with inadequate control, a crucial risk factor for asthma

exacerbations [3–5]. Research indicates that between 30% and 62% of patients in Europe and North America are classified as having uncontrolled asthma based on established guideline criteria [6–11]. This high incidence of uncontrolled asthma is exacerbated by the widespread belief among patients, general practitioners, and respiratory specialists that asthma is managed more effectively than it actually is. A survey conducted in 2018, which incorporated online responses and semi-structured interviews with 234 Canadian healthcare professionals across four provinces (Alberta, British Columbia, Ontario, and Quebec), revealed insights into the underlying factors contributing to gaps and challenges in asthma care in Canada [12]. There was a strong consensus regarding statements such as “Most patients with asthma do not proactively help themselves” and “HCPs believe they should be doing more to highlight critical gaps in both patient self-care and management.”

Asthma control is affected by numerous factors, including comorbidities, environmental influences, medication adherence, asthma status, and issues related to both patients and physicians [13–31]. Guidelines from the Global Initiative for Asthma (GINA), the United States National Asthma Education and Prevention Program, and the Canadian Thoracic Society identify non-adherence and improper inhaler technique as two principal contributors to asthma management challenges [13,14,32]. Moreover, high utilization of short-acting beta2 agonists (SABAs) and misconceptions surrounding asthma control must also be addressed to substantially enhance patients’ asthma conditions. Factors influencing asthma control include various patient-related factors such as adherence, which is impacted by inadequate knowledge about asthma and its management, confusion between maintenance and rescue inhalers, unwarranted changes to inhaler types, and patient inertia. This inertia may manifest as low acceptance of asthma diagnosis or severity, clinical fatigue or frustration due to lack of improvement, and apathy towards preventive treatment. Inhaler technique also plays a significant role; proper education and reinforcement of inhaler usage, the type of inhaler utilized, and motivation to master the technique are essential. Other patient-related factors include older age, duration of asthma, severity of asthma, smoking history, female sex, low socioeconomic status, stress, and access to or cost of medication.

Physician-related factors impacting asthma control encompass a lack of specialist care, suboptimal adherence to asthma guidelines, underestimation of asthma severity, poor communication regarding asthma management to patients and caregivers, clinical fatigue or frustration due to lack of improvement, and apathy towards preventive care. Respiratory-related factors include low forced expiratory volume in one second (FEV1), particularly when below 60% of the predicted value, elevated blood eosinophils, and increased levels of fractional exhaled nitric oxide (FeNO). Other medical conditions that influence asthma control consist of obesity, chronic obstructive pulmonary disease, chronic rhinosinusitis, allergic rhinoconjunctivitis, cardiovascular disease, gastroesophageal reflux disease, allergies, significant psychological issues, substance abuse (including alcohol), and pregnancy. Lastly, environmental factors such as air pollution, weather conditions, exposure to dust, gases, vapors, fumes, or other allergens, and second-hand tobacco smoke, including e-cigarettes, also contribute to the overall management of asthma and its exacerbations. Non-adherence to asthma therapy

has been documented to range from 30% to 70%, regardless of the measurement method employed, and various studies highlight the substantial effect of non-adherence on asthma management [33–35]. The Global Initiative for Asthma (GINA) guidelines define non-adherence as the failure to follow the medication regimen as mutually agreed upon by the patient and healthcare provider (HCP) [13]. In practice, patients may leave their physician's office with a prescription for asthma medication without fully understanding or agreeing to its use, even after receiving guidance on the importance of adhering to the prescribed regimen. Adherence can be assessed in terms of treatment initiation, implementation, persistence, and discontinuation. The reasons for non-adherence are complex and multifactorial, and adherence levels can fluctuate within the same patient across different therapies for various conditions [33,36].

Non-adherence can be classified as either intentional or unintentional [13,37]. Intentional non-adherence occurs when patients consciously choose to disregard treatment recommendations, often due to factors such as concerns regarding the treatment, perceived ineffectiveness, personal beliefs about the illness, treatment fatigue, perceived necessity, or limited resources. Conversely, unintentional non-adherence is observed in patients who are unable to adhere to their prescribed regimen due to factors outside their control. Examples include forgetfulness, complex dosing schedules, or improper medication administration. A significant contributor to unintentional non-adherence is poor communication between the HCP and the patient, which can lead to misunderstandings of treatment instructions. This miscommunication is often multifaceted and can be influenced by family dynamics and belief systems. Inadequate inhaler technique also plays a critical role in suboptimal asthma control. A systematic review encompassing 144 articles revealed that the rate of proper inhaler technique was only 31% (ranging from 28% to 35%), while another 31% (ranging from 27% to 36%) demonstrated poor technique, with no notable improvements in technique observed over the past 40 years [38]. The most frequently identified errors associated with both metered-dose inhalers and dry-powder inhalers include improper inhaler preparation, incorrect head positioning, failure to fully exhale before inhaling the medication, insufficient inhalation effort, and not holding one’s breath for at least three seconds following inhalation [19,38,39].

**Principles of Asthma Education**

To effectively address the factors that compromise asthma control—such as non-adherence, poor inhaler technique, excessive use of short-acting beta agonists (SABAs), and misconceptions regarding asthma management—comprehensive patient education that is customized according to the patient's age and health literacy level is imperative. The GINA guidelines emphasize the significance of educating patients on self-monitoring of symptoms and/or peak flow, developing a written asthma action plan, and conducting regular reviews of asthma control, treatment, and inhaler use skills, which have been demonstrated to mitigate asthma morbidity in both adults and children [13].

For enduring behavior change, asthma education should adhere to the principles of adult learning, considering the patient's pre-existing knowledge about asthma, literacy and education levels, motivation to learn about their condition, and

cultural perspectives. Effective education can be delivered by a range of healthcare providers, including physicians, nurses, pharmacists, and trained asthma educators [13]. All healthcare providers involved in asthma education must be adept at delivering information in a manner that considers the patient's motivation, beliefs, and capabilities. Additionally, healthcare providers must remain informed about the latest developments in asthma diagnosis, classification, monitoring, and management, including daily care and responses to exacerbations, and be ready to adapt their management strategies based on new information and guidelines. This readiness to modify clinical practice applies to both healthcare providers and patients. Education for healthcare providers should encompass enhanced patient engagement strategies aimed at promoting behavior change, such as motivational interviewing and shared decision-making, particularly for patients who exhibit intentional non-adherence [40–42]. The fundamental principles of motivational interviewing involve guiding and empowering patients who may be ambivalent about changing their behavior, helping them to identify their needs and capabilities for change [43]. Shared decision-making ensures that patients feel adequately informed and part of the treatment team, aiding them in recognizing their preferences among therapeutic options while providing professional guidance as necessary [42].

Regular reinforcement of correct inhaler techniques is vital for optimizing patients' self-administration skills [19,20]. Instead of “testing” technique—which may be perceived by patients as judgmental—educational reinforcement should be positive and motivating. Factors contributing to incorrect inhaler technique include inadequate instruction from healthcare providers, physical limitations, and changes in inhaler devices. Although teaching inhaler technique is a core competency in asthma management, healthcare providers may not always possess the skills to demonstrate these techniques effectively [39,44,45]. This instruction is a shared responsibility among all healthcare providers involved in the care of asthma patients, necessitating clear communication to ensure proper technique is conveyed. Asthma educators are essential in aiding patients and their caregivers in managing asthma, reducing the risk of exacerbations, responding appropriately to such exacerbations, and enhancing overall quality of life [46,47]. These educators should optimally collaborate with the entire healthcare provider team to ensure that these educational messages are consistently reinforced at every point of care.

**Roles of Digital Health Technology**

Digital health technology (DHT) has been evolving over the past 30 years, significantly impacting healthcare systems and patient care [48–50]. DHT encompasses a broad range of electronically delivered care options, from online patient documentation and telemedicine to wearable devices and artificial intelligence (AI)-based systems. Beyond enhancing healthcare delivery, DHT increasingly plays a vital role in the education of healthcare providers and patients. Traditionally, patient education has involved general information about the patient’s condition and its management; however, advancements in DHT now allow for individualized education that is tailored to monitor disease markers, providing patients with relevant information about their current health and self-management strategies [50]. DHT is often treated as a homogenous entity in

discussions, despite encompassing a wide range of applications, from generalized non-interactive content to personalized interactive elements [51].

- **Generalized DHT** includes content provided to patients that is not patient-specific or bidirectional, such as reminders for prescription refills, appointments, and non-interactive educational materials like brochures.
- **Patient-specific non-interactive content** refers to data collected from patients or shared with them that does not facilitate self-management, such as static educational materials.
- **Interactive patient-specific activities** are bidirectional and involve data collection that offers feedback to patients, including interactive telemedicine sessions and digital therapeutics (DT) devices and platforms.

Digital therapeutics represent an emerging category of DHT, comprising regulatory-approved devices and software that have demonstrated efficacy in preventing, managing, or treating medical conditions [52,53]. Discussions surrounding DHT must acknowledge the diverse spectrum it covers and the varying degrees of user interaction with the content. Digitally mediated care models aim to improve health outcomes by promoting consistent, evidence-based management while empowering patients and their caregivers to access timely and appropriate care, whether from healthcare providers or through self-management. The adoption of DHT is bolstered by the global prevalence of portable digital technology, such as smartphones. As of now, approximately 5.29 billion individuals worldwide utilize mobile phones, constituting 67.1% of the global population [54]. In Canada, about 30.74 million individuals (81.8%) were smartphone users in 2019 [55,56]. The market for digital health applications continues to expand, with estimates suggesting between 350,000 and 500,000 medical, health, and fitness apps available for download globally, a rise from 325,000 in 2017 [57,58]. Notably, over 91,000 new health apps were launched in 2020 alone [57]. The proportion of apps focused on health condition management increased from 27% in 2015 to 47% in 2020 [57]. Among the 2,580 health condition management applications, those addressing mental health and behavioral disorders represented the largest share (22%), followed by diabetes (15%), heart and circulatory issues (10%), digestive health (8%), and respiratory conditions (7%) [57]. While the number of available apps continues to grow, their quality remains uncertain, as no standardized evaluation has been established. The European Committee for Standardization, in collaboration with the International Organization for Standardization and the International Electrotechnical Commission, has initiated a project aimed at developing guidelines to effectively assess the quality and reliability of health applications [60]. Several challenges persist that may impede the advancement of DHT in healthcare systems. An increasing reliance on DHT for patient information and self-management may exacerbate social and economic digital divides [61–65].

- **Internet access** is crucial for health literacy; in Canada, limited access to reliable internet, particularly in remote areas or among lower socioeconomic and marginalized communities, has created a digital divide. Therefore, DHT must be developed with the aims of maximizing accessibility, fostering meaningful interaction, and promoting lasting behavior change.
- There is also a significant level of mistrust regarding healthcare and DHT, particularly among ethnic minorities and marginalized groups [65–67].

- A considerable amount of DHT is either incomplete or not integrated into current medical record systems, diminishing its overall utility.
- While rapid data collection and sharing facilitate unprecedented big data analysis that enhances medical research and care provision, ethical concerns regarding data transfer—particularly around privacy, data protection, and informed consent—remain unresolved [68–70].
- The role of AI is continually expanding in diagnosis, treatment, and predicting clinical outcomes; however, biomedical AI technologies may exhibit biases [71]. Moreover, established standards for AI validation are lacking, and many AI systems operate as "black box" techniques, allowing for observable inputs and outputs but obscuring internal processes.
- AI also introduces multiple medicolegal implications; healthcare professionals may become overly reliant on technology at the expense of their clinical judgment. Additional factors potentially increasing liability include the tendency to copy and paste patient information rather than performing comprehensive examinations at each visit, claims of negligence due to delayed responses to patient emails, and failure to act on the increased volume of patient data available. Furthermore, barriers related to app usage include inadequate physician compensation, the absence of reimbursement models for staff time spent supporting patients with data-gathering apps, and a lack of insurance coverage for associated technology costs.

To optimize the expansion of DHT solutions within clinical practice, it is essential to leverage the benefits of these technologies while addressing existing and potential barriers.

**Smart Inhalers: Design, Types, and Applications in Asthma Management**

Asthma is a chronic respiratory condition characterized by airway inflammation, bronchoconstriction, and variable airflow limitation. Effective management of asthma is essential for reducing symptoms and preventing exacerbations. Adherence to prescribed treatment regimens is crucial for optimal asthma control, yet studies indicate that many patients struggle with non-adherence and poor inhaler technique. Smart inhalers have emerged as innovative solutions to these challenges, leveraging digital health technology (DHT) to enhance medication adherence, monitor symptoms, and empower patients in their self-management efforts.

**Design of Smart Inhalers**

Smart inhalers are advanced devices equipped with sensors and connectivity features that track medication usage and provide real-time feedback to patients and healthcare providers. The design of smart inhalers typically includes:

1. **Sensors**: These detect when the inhaler is actuated, recording the time and date of each dose. Some models may also monitor inhalation technique, ensuring that the patient uses the device correctly.
2. **Connectivity**: Most smart inhalers utilize Bluetooth or other wireless technologies to connect to mobile applications or cloud-based platforms.

This enables data sharing with healthcare providers, fostering continuous monitoring and personalized feedback.

3. **Mobile Applications**: Accompanying apps serve as user-friendly interfaces for patients, allowing them to view their medication adherence patterns, track symptoms, and access educational resources about asthma management. These apps can also generate reminders for medication refills or prompt users during peak pollen seasons, enhancing overall management strategies.
4. **Data Analytics**: Advanced algorithms may analyze data collected from the inhaler and app, generating insights that inform treatment adjustments or flag potential issues requiring intervention.

**Types of Smart Inhalers**

Smart inhalers can be categorized into various types based on their functionality, technology integration, and design:

1. **Digital Spacers**: These are traditional spacer devices modified with sensors and connectivity features. They help patients using metered-dose inhalers (MDIs) optimize their inhalation technique while tracking medication usage.
2. **Smart Metered-Dose Inhalers (MDIs)**: These inhalers come equipped with integrated sensors that detect usage and connect to mobile apps for real-time data transmission.
3. **Dry Powder Inhalers (DPIs)**: Some DPIs have been enhanced with digital capabilities that monitor usage and provide feedback on inhalation technique and adherence.
4. **Mobile Health (mHealth) Solutions**: These include mobile applications that can be paired with standard inhalers, allowing patients to manually input data regarding their medication usage and symptoms.

**Applications for Asthma Management**

The integration of smart inhalers into asthma management strategies offers numerous advantages:

1. **Enhanced Medication Adherence**: By providing real-time data and reminders, smart inhalers address one of the most significant barriers to effective asthma control—non-adherence. Studies indicate that patients using smart inhalers demonstrate improved adherence rates compared to traditional inhalers. The data collected can help healthcare providers identify adherence patterns, allowing for tailored interventions.
2. **Improved Inhaler Technique**: Smart inhalers with built-in sensors can provide feedback on inhalation technique, ensuring that patients use their devices correctly. Poor inhaler technique is a common issue leading to suboptimal medication delivery and control. By reinforcing proper techniques through app-based education and reminders, smart inhalers can help reduce this problem.
3. **Data-Driven Insights**: The continuous data collection capabilities of smart inhalers facilitate the monitoring of patient trends and patterns over time. Healthcare providers can access real-time information regarding a patient's adherence and symptomatology, enabling more informed decision-making regarding treatment adjustments.

4. **Personalized Asthma Action Plans**: Smart inhalers can facilitate the development of personalized asthma action plans, which outline specific steps to manage worsening symptoms or exacerbations. By integrating real-time data on symptom severity and medication adherence, these plans can be adjusted to better suit individual patient needs.
5. **Patient Empowerment**: Smart inhalers promote patient engagement by providing them with immediate feedback on their asthma management. This empowers patients to take an active role in their care, fostering self-management behaviors that lead to improved outcomes.
6. **Remote Monitoring and Telemedicine**: The integration of smart inhalers with telehealth platforms enables remote monitoring of patients, reducing the need for frequent in-person visits. This is particularly beneficial for patients living in remote areas or those with mobility challenges. Healthcare providers can conduct virtual consultations and adjust treatment plans based on real-time data, enhancing the quality of care.
7. **Predictive Analytics and Early Intervention**: Advanced data analytics can help identify potential exacerbation triggers and patterns. For example, if a patient's inhaler usage decreases or there is a rise in reported symptoms, predictive algorithms can alert healthcare providers to intervene early, potentially preventing severe exacerbations.
8. **Education and Training**: Smart inhalers often include educational features within their mobile applications, providing patients with information on asthma management, proper inhaler technique, and the importance of adherence. This integrated approach ensures that education is continuous and accessible, improving overall asthma knowledge among patients.

**Challenges and Considerations**

While smart inhalers present many benefits, several challenges must be addressed:

1. **Cost and Accessibility**: The price of smart inhalers and the associated technology may limit accessibility for some patients. Ensuring that these devices are affordable and accessible is critical for widespread adoption.
2. **Data Privacy and Security**: As smart inhalers collect sensitive health data, ensuring patient privacy and data security is paramount. Developers must implement robust cybersecurity measures to protect patient information from unauthorized access.
3. **Health Literacy**: Patients must possess a certain level of health literacy to effectively use smart inhalers and interpret the data provided. Education programs should focus on improving health literacy to maximize the benefits of these technologies.
4. **Integration with Healthcare Systems**: Successful implementation of smart inhalers requires seamless integration with existing healthcare systems. This includes ensuring that healthcare providers can easily access and interpret data from smart inhalers within their electronic health records.

Smart inhalers represent a significant advancement in asthma management, leveraging digital health technology to enhance medication adherence, improve inhaler technique, and empower patients in their self-management efforts. By

providing real-time data, personalized insights, and educational resources, smart inhalers can transform the approach to asthma care, ultimately improving patient outcomes. Addressing the challenges associated with cost, data privacy, and health literacy will be crucial to ensure the successful integration of smart inhalers into everyday clinical practice. As the landscape of asthma management continues to evolve, smart inhalers hold great promise in facilitating more effective and patient-centered care.

**Conclusion**

Asthma management has evolved significantly over the years, but it still poses considerable challenges for patients and healthcare providers. The persistent issue of uncontrolled asthma affects a significant number of individuals, with statistics indicating that 30% to 62% of patients in Europe and North America fail to achieve adequate control. A multifaceted approach is necessary to address the complexities surrounding asthma management, with emphasis on understanding the factors that contribute to poor outcomes, including medication non-adherence and inadequate inhaler technique. Smart inhalers, equipped with digital health technologies, have the potential to revolutionize asthma care by providing real-time feedback on medication usage and enabling better self-management strategies. These devices can help bridge the gap in understanding and adherence by fostering a more interactive relationship between patients and their medication regimens. Studies have shown that patients who utilize smart inhalers exhibit improved adherence rates, which can lead to better control of asthma symptoms and a reduction in exacerbations. Pharmacists play a pivotal role in this transformation by being frontline healthcare providers who can educate patients on proper inhaler use and self-management strategies. Their involvement ensures that patients not only understand their treatment plans but also develop the skills necessary for effective asthma management. Collaborative practice among healthcare providers, including pharmacists, physicians, and nurses, is vital for reinforcing educational messages and ensuring consistency in asthma care. Furthermore, the integration of digital health technologies into everyday asthma management must consider the challenges associated with accessibility, especially in marginalized communities where internet access and health literacy may be limited. Developing smart inhalers and other digital solutions should focus on inclusivity, ensuring that all patients can benefit from these advancements. Overall, smart inhalers represent a significant step forward in asthma management. They not only empower patients through improved self-monitoring and adherence but also facilitate better communication and education between healthcare providers and patients. By leveraging the expertise of pharmacists and embracing digital health technologies, we can create a more effective and supportive environment for asthma management, ultimately improving patients' quality of life and health outcomes. Addressing the complexities of asthma through innovative solutions will be essential in the ongoing effort to control this pervasive condition and reduce its impact on healthcare systems.

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**أجهزة الاستنشاق الذكية: تحويل إدارة الربو ودور الصيدلي في تعليم المرضى**

**الملخص:**

**الخلفية :** يظل الربو تحديًا صحيًا عالميًا على الرغم من التقدم في التصنيف والتشخيص والعلاج بالاستنشاق. لا يزال نسبة كبيرة من المرضى تعاني من الربو غير المتحكم فيه، والذي يرتبط بعوامل مثل عدم الالتزام بالعلاج وتقنيات الاستنشاق غير السليمة.

**الهدف :** يهدف هذا المقال إلى استكشاف إمكانية أجهزة الاستنشاق الذكية في تحويل إدارة الربو وإبراز الدور الحاسم للصيادلة في تعليم المرضى.

**الطرق :** تم إجراء مراجعة شاملة للأدبيات، مع التركيز على انتشار الربو غير المتحكم فيه، وتأثير عدم الالتزام، ودمج تقنيات الصحة الرقمية، وخاصة أجهزة الاستنشاق الذكية. شمل الدراسة فحص دور الصيادلة في تقديم التعليم حول الربو وتعزيز تقنية الاستنشاق السليمة.

**النتائج :** تكشف النتائج أن 30% إلى 70% من مرضى الربو لا يلتزمون بأنظمة أدويتهم. يمكن أن تعزز أجهزة الاستنشاق الذكية المزودة بتقنيات الصحة الرقمية من التزام المرضى بالأدوية من خلال توفير تغذية راجعة في الوقت الحقيقي بشأن استخدامهم لجهاز الاستنشاق وحالة الربو. إن مشاركة الصيادلة في تعليم المرضى أمر حاسم لتحسين تقنية الاستنشاق وتحسين إدارة الربو بشكل عام.

**الخلاصة :** تمثل أجهزة الاستنشاق الذكية تقدمًا واعدًا في رعاية الربو من خلال معالجة عدم الالتزام وتعزيز الإدارة الذاتية. يلعب الصيادلة دورًا حيويًا في تعليم المرضى حول إدارة الربو وتعزيز الاستخدام الصحيح لجهاز الاستنشاق. تعتبر الجهود التعاونية بين مقدمي الرعاية الصحية ضرورية لتحقيق التحكم الأمثل في الربو.

**الكلمات المفتاحية :** أجهزة الاستنشاق الذكية، إدارة الربو، تكنولوجيا الصحة الرقمية، تعليم المرضى، الصيادلة، الالتزام بالعلاج.