

Connected asthma:

how technology will transform care



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Foreword

Two years ago, the National Review of Asthma Deaths delivered a damning assessment of current routine practice in asthma care, and concluded that two-thirds of deaths were preventable.

People with asthma know there is nothing as frightening as being unable to breathe, and yet the review found that the simple elements of basic care that prevent asthma attacks were not being delivered.

We know that good care stops asthma attacks, but there are still too many tragic examples where this isn't happening – from information on repeat asthma attacks not being relayed to the right healthcare professional, to patients not having the basic care of an asthma action plan. Last year Tamara Mills, a 13-year-old from Newcastle, died despite attending primary and secondary care 47 times in four years. The Coroner's report concluded there had been 'no appreciation that each episode was a deteriorating step in her overall respiratory well-being'. Each visit instead sought to address the immediate presentation as an isolated event. Now we are in an era in which technology and data-sharing should have flagged Tamara as a high risk patient as routine. This was tragic and unacceptable. Data literally can save lives, but only if used to change care.

Every day we spend increasing amounts of time being digitally engaged and yet personal asthma action plans, which make someone four times less likely to be admitted to hospital, are still delivered in paper form. Basic questions for asthma reviews are still being collected during the precious minutes of a face-to-face asthma review with no standardised coding. This makes sharing difficult and creates significant inefficiencies in already hard-pressed general practice. This clunky system might be why many people with asthma simply do not show up for their review and why the vast majority support the development of technologies to help them manage their own asthma.

Progress is being made more rapidly in other health areas, such as diabetes and mental health with new digital tools to improve management and therefore outcomes for those people. There have been some promising developments in asthma, as you will see in this report, but for now they remain piecemeal and have failed to reduce the complexities and guesswork from managing an episodic condition with multiple triggers and complex treatment. Asthma has the best evidence that self-management works, but with 5.4 million people in the UK with asthma we can only be able to deliver at scale cost effectively by industrialising technology solutions.

The kinds of tools we see in the report – from helping to make treatments more effective, to evidence-based algorithms that predict risk of an attack – will be vital.

Asthma is an almost unique condition in that people are likely to always carry two devices with them – their inhaler and mobile phone – increasing opportunities to innovate. However, many of these innovations are happening in isolation and without sufficient regard for the end user experience.

We believe the UK is in an advantageous position to collaborate and use a multidisciplinary approach involving academics, patients and industry to provide industrialised management solutions. The UK has a proud history of research, is an established pharmaceutical powerhouse, has a thriving tech sector, and has the talent and reach of the NHS to get innovations to people with asthma efficiently and effectively. With global prevalence set to rise from 300 to 400 million by 2025, the UK – especially through collaborating with the wider EU – can lead the way in providing solutions for this large, complex and growing global health challenge for other countries; which could provide significant economic benefit.

'the vast majority support the development of technologies to help them manage their own asthma...'

To do this we need a greater focus on asthma mHealth, by those researching asthma and other disciplines. We need the system basics in place urgently – paper-free action plans, basic risk stratification and data sharing can be done right now. We also need some serious effort and investment to develop disruptive technologies for asthma management, and harness the insights from ever-increasing data sets and people with asthma to develop the algorithms and user-centred devices that will be at the heart of new solutions.

At Asthma UK we are determined to stop asthma attacks. Outcomes have plateaued in recent years and this must be changed. Our last major breakthrough was the inhaler and we are hugely excited by the prospect of smart inhalers coupled with mobile devices. We believe mHealth solutions are the future for asthma care and the key to reducing highly preventable deaths.

Kay Boycott Chief Executive

Executive summary

Asthma is a large, complex and growing global health challenge. 5.4 million people in the UK have asthma, an episodic condition where severity and risk of a potentially life-threatening attack can vary day by day, season by season and across someone's lifetime.

Asthma medication also needs to be delivered variably to manage an individual's asthma 'pattern'. The sheer variety of inhalers, with their own dosage and technique, mean that just getting the right treatment delivered at the right time is difficult.

With developments in technology beginning to modernise how we approach long-term conditions, and opportunities to harness these innovations starting to emerge within the NHS, new ways to tackle persistent challenges for asthma are coming into focus.

Who is this report for?

This report will be of interest to key decision-makers within government, the NHS, and both the life science and technology industries. It highlights some of the current technologies developing globally that are aimed at enabling care for asthma.

These novel innovations demonstrate the emerging potential for technology to address the challenges facing the management and self-management of asthma today.

What are the challenges?

Issues around variation in care were identified in the Royal College of Physicians' National Review of Asthma Deaths (NRAD). Much of the NRAD report is still to be implemented, and technology can provide a means to achieve this – for example, the recommendation to enable systems to support asthma self-management including increasing use of agreed personal asthma action plans.

However, these innovations need to be intuitive for people with asthma to use, particularly given the motivational barriers that can already serve as hurdles to self-management.

Research suggests the majority of people in the UK would welcome an mHealth solution to help manage their long-term condition – this is mirrored with strong support from people with asthma and healthcare professionals managing asthma patients.

Investing more in user-centred design will help to ensure that these are used effectively, and validated testing will help to ensure effective applications are industrialised.

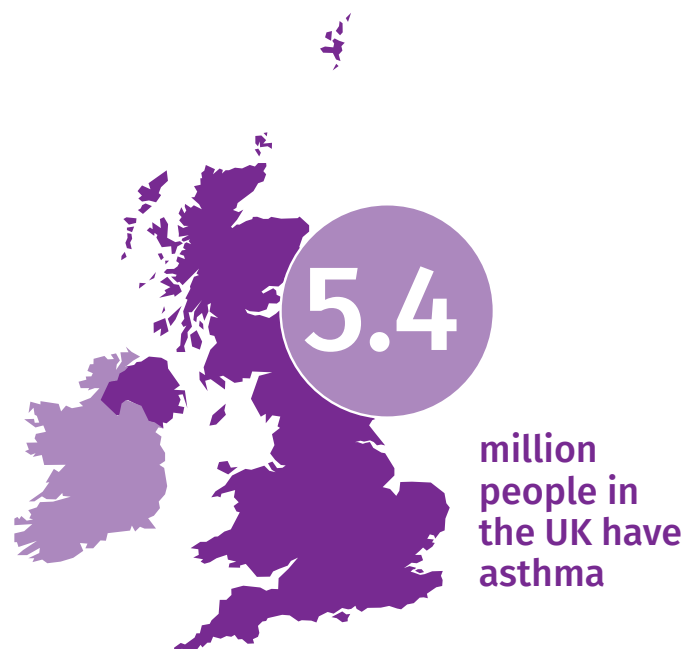
What difference could tech have?

This could transform how asthma care is delivered and how people manage their asthma in the future, as highlighted by asthma experts within the European Asthma Research and Innovation Partnership. They have placed mHealth solutions among the highest priorities for research to optimise asthma management and prevent asthma attacks, which highlights the potential benefits from investment in this field.

Some of the technologies to achieve this already exist or are in the later stages of development. Others require a focus on addressing longstanding system interoperability and data linkage issues before success can be achieved. Together, these changes could be transformational for people with asthma.

Why asthma?

Given the size and nature of the asthma population, the unmet need, and in particular the strength of the evidence for asthma self-management, there is a compelling argument to make asthma a focus and an exemplar for investment in technology-enabled self-management and clinician-led management in primary care.



Key applications of technology in asthma

Technologies have been developed aimed at tackling some of the key challenges in asthma:

- increasing adherence to medicines
- helping people self-manage dynamically to reduce their risk of an asthma attack with solutions personalised to an individual's triggers, and
- equipping healthcare professionals with the tools to identify those people at higher risk of an attack.

Digital technology delivered via smartphones (mHealth) in particular has the potential to help people self-manage their asthma at scale through improved understanding of their condition, how to recognise and avoid their condition worsening, and how they should respond if their condition worsens. This self-learning opportunity could also help to combat the complacency around the condition among some people with asthma.

- mHealth solutions could contain the information held within the current paper-based asthma action plan to enable quicker, accurate and more simplified self-management at scale.

Smart inhalers for adherence monitoring

Good adherence to treatment is vital to control symptoms and prevent asthma attacks, yet adherence is generally poor.

- Inhalers that connect to a smartphone in combination with mobile apps show promise to improve adherence.
- These need further testing in real world settings within the NHS to demonstrate proof of concept.

Health apps to track treatment use and avoid triggers

People can take preventative action to avoid environmental asthma triggers, which differ between individuals, and smartphones offer a perfect route for this information to be personalised.

- Health apps that accurately relay environmental information to someone at imminent risk of exposure and enable behavioural change could help prevent a life-threatening asthma attack.

Remote monitoring to support asthma management

Some studies indicate that some worsening symptoms suggest an asthma attack can occur days or weeks in advance, during which preventive action could potentially be taken.

- Technologies such as remote monitoring could help people recognise worsening control.
- Predictive algorithms could provide people with environmental alerts, enabling them to take action to reduce their risk of an attack.

Using innovative systems and data

GP software providers of electronic health records can provide a digital version of the asthma action plan, as demonstrated by one major software provider so far.

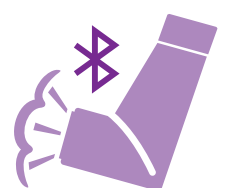
Risk stratification tools help identify asthma patients most at risk of an attack and who require urgent help to prevent a life-threatening event.

- These could be used to help create a risk-based approach to asthma management and benefit primary care asthma management, which currently allocates resources on the basis that everyone with asthma is at the same degree of risk.

Electronic prescribing alerts highlight where people with asthma have been prescribed excessive quantities of reliever inhalers, or too few preventer inhalers.

Internet-based management tools using personalised algorithms could also help people with severe asthma to reduce use of oral corticosteroids, which have adverse side-effects.

Designing systems to alert GPs when their asthma patients attend an emergency department or out-of-hours service for an attack would help them intervene earlier and more systematically, and help prevent future attacks.



Key recommendations

Technology offers much promise but we are still at the early stages. We are already seeing proliferation of data formats, operating systems and apps. To ensure tech-enabled asthma management can be distributed and used at scale, existing technology-based solutions need to be implemented alongside the development of future innovations and the mechanisms by which these are assessed.

Deploying existing technology

As soon as local interoperability and data linkage allows, NHS bodies across the UK should over the short term:

- use provider power to incentivise the rapid increase across all GP software providers of standardised digital personal asthma action plans, which detail patients' own triggers and current treatment, and specify how to prevent relapse and when and how to seek help in an emergency. This should become a core requirement in future GP software agreements
- ensure full deployment of electronic surveillance of prescribing in primary care to alert clinicians with precise data on where patients are being prescribed excessive quantities of short-acting reliever inhalers, or too few preventer inhalers, and
- in recognition of the 5.4 million people with the condition, promote the use of e-prescribing tools to people with asthma in partnership with patient organisations.

In the medium term, NHS bodies should:

- prioritise the full introduction of electronic alerts to enable every attendance at an emergency department or out-of-hours service for an asthma attack to be followed-up by the patient's GP, and
- ensure digital asthma action plans are incorporated within core Electronic Health Record systems to allow seamless sharing between clinicians and patients.

Designing new user-centred technologies

Governments and administrations in the UK and the EU should:

- invest greater funding in collaborative asthma research aimed at developing innovative technology to facilitate the management and self-management of asthma, bringing together life sciences and tech companies in collaborations with multi-disciplinary academics and patients
 - these should build on existing innovations and focus on developing user-centred intuitive design for people with asthma and designed to be interoperable across NHS systems and with clinician records

- collaborations should seek to match existing expertise within the asthma field with developers of innovation and people with asthma.

Research funders should:

- convene mHealth experts to build consensus on what constitutes good user experience for people managing their long-term condition to ensure ongoing use of technology
- prioritise research into a full range of clinically- and consumer-tested predictive analytical algorithms for use in asthma management
- through the National Institute for Health Research, determine and recommend a set of research methodologies that include user-acceptance measures to aid in trial design of mHealth solutions.

Integrating the next generation of technologies into the NHS

In order to ensure that future innovations for tech-enabled asthma management are able to be rapidly adopted in the UK:

- the UK Government should consider the long-term implications of current regulation of and guidance on mHealth solutions and ensure that these are proportionate to risk while encouraging innovation and rapid deployment, and
- there needs to be clarity on the process through which mHealth solutions need to be validated to become widely adopted in the NHS.

NHS bodies should:

- establish a testing programme for smart inhalers via current test beds and innovation schemes aimed at improving adherence to asthma medications.



**Every 10 seconds
someone in the UK
has an asthma attack**

Introduction

The growth of digital health in the UK

The data-driven 'Internet of Things' has begun to ignite innovation across a broad range of sectors, increasingly bringing every object, consumer and activity into the digital realm.

Historically, the NHS has been a world leader in healthcare innovation. However, diffusing innovation across the NHS at pace and scale has been challenging.^{1,2} As a result, the UK is lagging behind other countries such as Sweden, Denmark and the USA on digital health, with innovations like e-prescriptions and integrated communications readily available to patients in these countries.³

Thought leadership on the development of the NHS has technology firmly at its core, whether it's the National Information Board's current initiatives towards 2020, or Nesta's vision further into the future.^{4,5} This approach would have benefits to the UK's overall health and wealth. Technology will meet people's health needs more effectively, while potential improvements in healthcare productivity would also generate wider benefits for the UK economy.

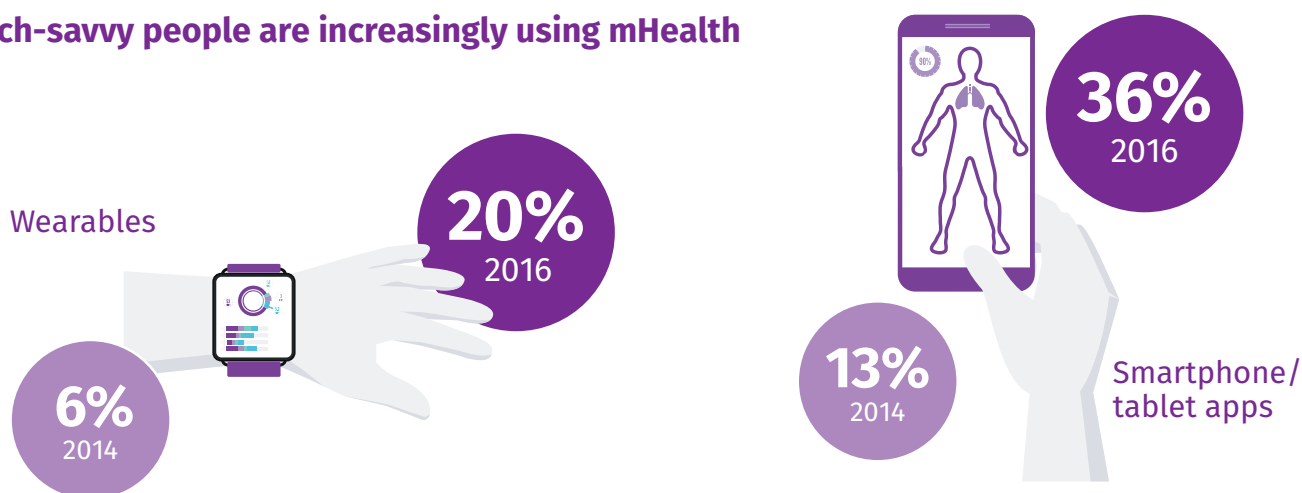
As smartphone technology has developed, so too have the capabilities of tracking apps and associated connected technologies like wearables. Flexible patches now exist that can detect body temperature, heart rate, respiration rate and hydration level and transmit the data to a smartphone. Technology is already developing to make wearable innovations more inconspicuous and ubiquitous by incorporating this into everyday applications – such as smart jewellery or smart clothing.⁶

New areas of technology are emerging, from smart pills that can transmit data on adherence, to machine learning where artificial intelligence is being used to optimise treatment.⁷ Within diabetes, the *Philips HealthSuite* digital platform seeks to manage the care of people with type 1 diabetes by combining information from electronic records, wireless devices and patient-reported data. IBM's *Watson Health* is also crunching the data from Medtronic's digital diabetes technology together with its pool of anonymous medical records and fitness information, with potential to prevent severe events in patients.⁸

These developments are occurring alongside a change in how patients will use the NHS. As patient access to Electronic Health Records (EHRs) becomes available, the practice of sporadic interactions between a patient and healthcare professional fixed to a healthcare location will inevitably evolve into a more regular exchange of information between the two – with patient data managed at healthcare professional level being complemented by an individual's self-collected data. Scotland, Wales and Northern Ireland have all made substantial progress towards developing EHRs.⁹

Though historically EHRs have been difficult to implement in the NHS in England, the Department of Health in England is aiming to provide all patients with access to EHRs – including information from a patient's full health and care interactions by 2018.¹⁰ The information gathered could lead to a more efficient and effective approach, where people at high risk are more readily identified.

Tech-savvy people are increasingly using mHealth



Source: Accenture, Digital Consumer Health Engagement 2016 – Global Report (2016). Unweighted sample of 1,013 adults in 2014 (466 adults in 2016) that identified as managing their health with tech - figures England only.

Please note: the innovations highlighted throughout this report should be taken as illustrative of the technologies being currently developed, rather than endorsement by Asthma UK.

Connected asthma: how technology will transform care

Global picture



of people globally would be willing to share mHealth data with their doctor



of people globally would like to access their medical records in full online

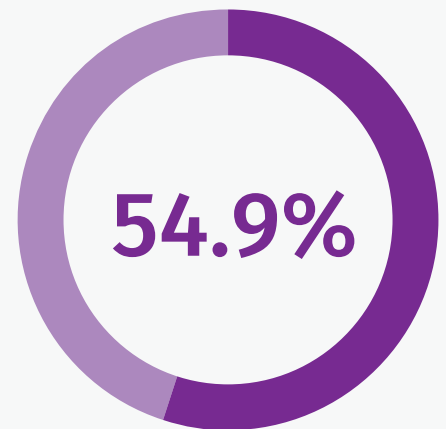
Source: Accenture, Digital Consumer Health Engagement 2016 – Global Report (2016). Weighted sample of 7,840 adults across 7 countries.

Global revenues

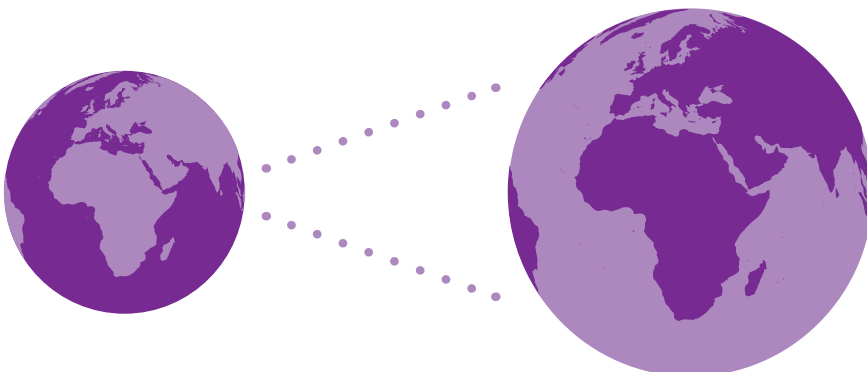
2013 mHealth valued at **\$2.4 billion**

2018 forecast to reach **\$21.5 billion**

Growth per year of



Source: BCC Research, Mobile technologies and global markets (2014)



300 million people have asthma globally today

This is set to rise to **400 million** by 2025

Source: Global Initiative for Asthma Program, The global burden of asthma (2004)

Opportunities to address the unmet need in asthma

Asthma is a large, complex and growing global health challenge. 5.4 million people in the UK have asthma, with around 250,000 people estimated to have asthma that does not respond to current treatments. It is an episodic condition where severity and risk of a potentially life-threatening attack can vary day by day, season by season and across someone's lifetime. Inhalers along with oral steroids are the main treatments, with over 50 inhalers currently on the market. Each inhaler has its own dosage and technique, meaning that just getting the right treatment delivered at the right time is difficult. Globally, 300 million people have asthma – a number that is set to grow to 400 million by 2025.

Addressing the unmet need for asthma could result in more effective use of resources in the NHS. The costs associated with asthma are increasing globally.¹¹ The UK spends in excess of £1 billion in direct healthcare expenditure on asthma.¹² 85% of asthma patients are managed exclusively in primary care, with asthma estimated to account for around 2–3% of GP consultations.¹³ Asthma is estimated to cost around £52m in GP consultations.¹⁴ As highlighted by the recent *General Practice Forward View*, this comes at a time when the significant pressure GPs are under is affecting patients and impacting on the wider NHS.^{15,16}

We still do not understand all the factors that cause asthma, but we do have a well-established evidence base of how to help control asthma and prevent attacks using interventions that focus on maintaining control and reducing risk of an attack. An annual asthma review, for example, allows clinicians to assess current risk and control for those on the Asthma Register. Checking someone is taking their medicines as prescribed on an annual basis is a key part of controlling symptoms, while the review is also often the opportunity to assess overall asthma risk.

But this annual interaction with healthcare professionals can mean that the full asthma picture is not captured. For example, at an annual review people may forget to mention occasions when their condition worsened during the preceding year. The information used to assess an individual's asthma control is therefore generally limited to the period around that review, which is a fraction of the time they are living with the condition.

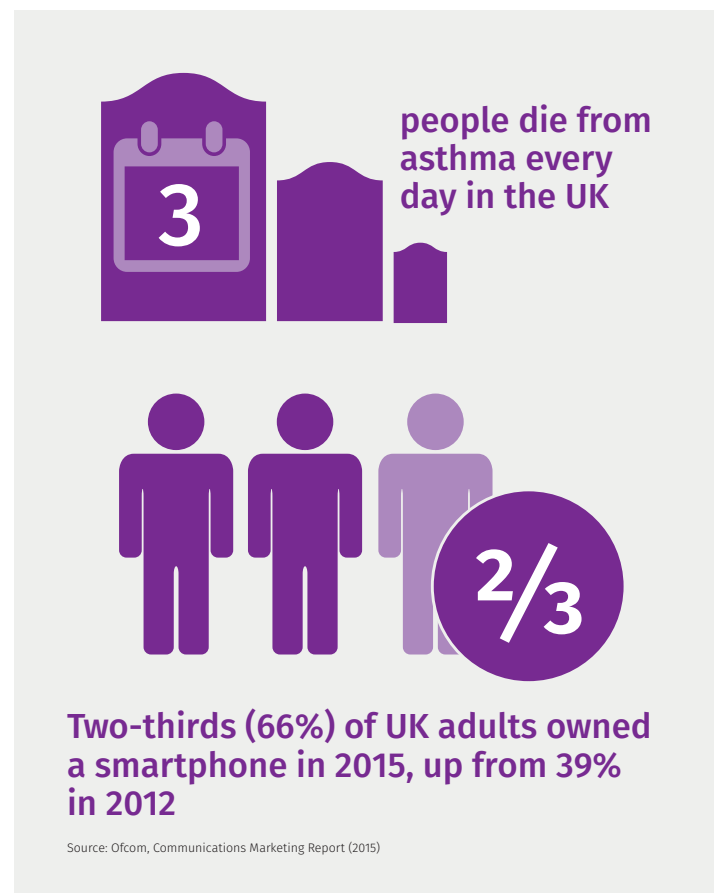
Healthcare professionals aim to deliver the best care and motivate good asthma self-management, but this can be complex and time-consuming and so often is not possible in the allotted time. They currently do not have many of the systems in place to support them effectively, leading to variation in care. Seven out of ten people receive care that fails to meet basic quality standards,¹⁷

while the poor use of and limited adherence to medication, and errors in the prescription of medicines amount to a significant waste of resources.^{18,19} Self-management of asthma is also a complex, multistep process. It involves identifying and avoiding triggers, altering the environment, remembering both preventer and reliever medications, recognising worsening symptoms, adjusting treatment, and determining when to contact a doctor.

This presents a key challenge for healthcare professionals in preventing asthma attacks, as levels of control can deteriorate outside of their annual review and people can become complacent that they are not in danger of a potentially life-threatening attack.

'The evidence in favour of supported self-management for asthma is overwhelming'

– Prof Hilary Pinnock, University of Edinburgh



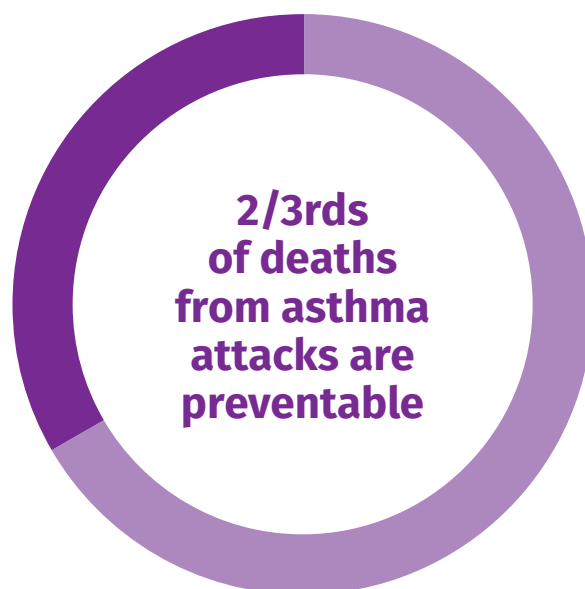
Opportunities to address this variation in care were identified in the National Review of Asthma Deaths (NRAD).²⁰ These included:

- improving risk stratification to distinguish between those with asthma requiring minimal healthcare professional support through an annual review, and those who require closer monitoring throughout the year
- ensuring safer prescribing to highlight where people with asthma have been prescribed excessive quantities of short-acting reliever inhalers, or too few preventer inhalers
- improving systems to ensure follow-up arrangements are made after every attendance at an emergency department or out-of-hours service for an asthma attack
- raising the quality of medical records, in particular addressing a lack of detailed recording of asthma reviews, and
- enabling systems to support asthma self-management including increasing use of agreed personal asthma action plans.

These opportunities to improve outcomes focus on how asthma is managed – both at healthcare professional level, and at individual patient level. The current model of care for asthma has the annual review at its core (see below), but given that asthma symptoms can change throughout a year, supported self-management represents a key opportunity for people to maintain good control. Asthma has one of the strongest evidence bases for self-management, with numerous studies showing that this can improve asthma control, reduce exacerbations and admissions, and improve quality of life when supported by regular professional review.^{21,22}

‘Technology to enable this will transform outcomes for people with asthma, and result in greater efficiency and efficacy of NHS resources...’

With a greater understanding of healthcare professionals’ management of asthma, a raft of potential solutions and strong evidence for self-management, it is clear what needs to be done to improve outcomes. New approaches are needed to help ensure that healthcare professionals prescribe more effectively, people with asthma are more involved in their care, risks of attacks are recognised and exposure to triggers is avoided. Technology to enable this will transform outcomes for people with asthma, and result in greater efficiency and efficacy of NHS resources.



The Asthma Review

Each year, an asthma patient should be invited by their GP surgery to attend a structured annual review of their asthma, during which a number of common issues are considered.

The review should bring together numerous components that, individually, have been proven to improve control and reduce asthma attacks – such as inhaler technique²³ and a written asthma action plan.²⁴ Other components of a structured review include:

- assessment of symptomatic asthma control using a recognised tool (such as the Royal College of Physicians 3 questions)
- measurement of lung function, assessed by spirometry or by peak expiratory flow
- review of exacerbations, oral corticosteroid use and time off work or study since last assessment
- assessing adherence
- adjustment of treatment
- assessment of comorbidities
- review of diagnosis.

Some estimates suggest that as many as two-thirds of people do not attend their annual asthma review.²⁵

People with asthma are generally recalled on the basis of being on a practice’s asthma register. In reality, the asthma register is often inaccurate and out of date.²⁶ This is despite evidence that keeping an accurate asthma register can lead to improved patient care.²⁷ The register allows for no distinction on the basis of risk or control between the 4.1 million people who are recalled. There is therefore a key need to help make the review more valued and effective for all people with asthma.

Technology-enabled asthma management

Asthma has historically been a good example of how innovative technology can improve health outcomes. The innovation of pressurised metered-dose inhalers, for example, led to a rapid improvement in patient outcomes.²⁸

However, since then there have been no examples in asthma of significantly disruptive innovation that has transformed the way care is delivered. For the vast majority of people with asthma, new approaches are necessary to improve their asthma control and prevent asthma attacks.

The evidence base for using technology to enhance care is relatively recent but continuing to grow.²⁹ A number of innovations have been developed, and are in development, to tackle a variety of conditions – offering ways to facilitate self-management, provide support from healthcare professionals, and enable monitoring to prevent the condition worsening.

As highlighted above and below, we know what needs to be addressed to improve both management by healthcare professionals and self-management in asthma, though the means to do this at scale have been previously lacking. This is where technology has the potential to solve many of the current challenges for asthma.

What do patients and healthcare professionals want from asthma technology?

In 2015 Asthma UK asked patients and healthcare professionals for their views on what they would like from an mHealth system.³⁰

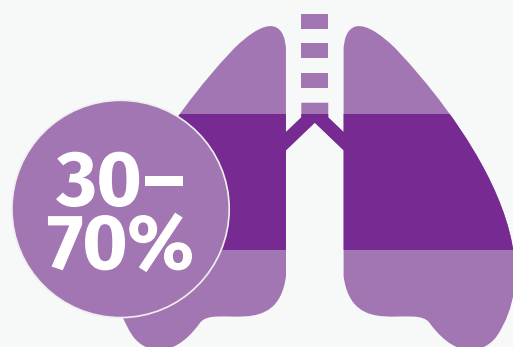
Nearly three-quarters of patients wanted to see an mHealth device that would help them monitor their asthma. In addition, nearly half suggested they would value a system which could be used as part of their asthma action plan and tell them if changes to asthma medication have improved their asthma and when to seek medical attention.

Over three-quarters of healthcare professionals said they would value an mHealth system that would monitor patients' asthma symptoms over time and provide patients with an asthma action plan.



85%
of asthma patients are treated in primary care, costing an estimated £52m each year

Source: Mukherjee, Stoddart, Gupta et al (2015)



30–70%
Between 30–70% of adults and children with asthma do not take their asthma medication as prescribed by their doctor

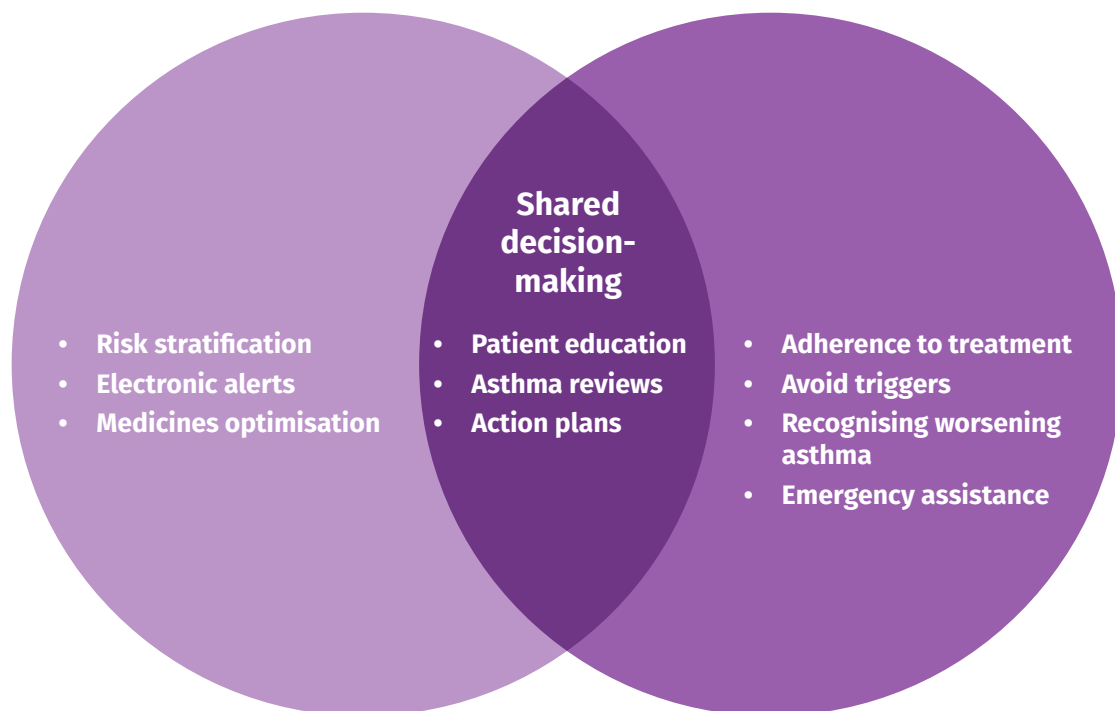
Source: Lindsay & Heaney (2013) and Elliott (2006)

Tech-enabled asthma management

Healthcare professional-led management



Patient-supported self-management



Technology-enabled asthma management applies a tech-enabled care approach specifically to asthma, where the introduction of innovative technology:

- enables enhanced, effective and informed healthcare professional-led management of asthma
- activates and motivates people with asthma to self-manage their condition,
- provides asthma education in small tailored amounts with the opportunity to gamify to make learning fun for young people, and
- facilitates shared decision-making between healthcare professionals and patients.

‘When you turn up to see a consultant every three months, it’s quite difficult to think back over that period and see how your asthma changed over time’

– Participant in myAirCoach focus group





Prioritising tech approaches to prevent asthma attacks







The European Asthma Research and Innovation Partnership (EARIP) is a pan-European project, co-ordinated by Asthma UK.

EARIP performed a review of the evidence for current and emerging asthma self-management tools and systems. Over 40 European asthma experts including health professionals, researchers, people with asthma and industry representatives were part of the exercise, which was followed by an expert workshop.

Through careful review and consensus-building among experts, EARIP has identified evidence-based tools and systems most likely to optimise asthma self-management. The emergence of mobile and electronic health applications and the drive to integrate national and regional data and health systems were rated among the highest priorities for research to optimise asthma management and prevent asthma attacks.

The European Union has a number of activities focused on improving health using eHealth tools. The *Digital Single Market Strategy for Europe* includes telemedicine and eHealth, aiming to promote interoperability and common standards of these digital technologies in the EU.

Aid to help stop asthma attacks	Opportunity	Type of tech solution	Barriers
Patient-supported self-management			
Adherence to treatment 	<p>Adherence to asthma treatments is generally poor with significant levels of complacency on the condition.^{31,32} Non-adherence is estimated to range between 30–70% in both adults and children.^{33,34}</p> <p>Increasing adherence to prescribed treatments combined with improving inhaler technique will help people with asthma to control their symptoms and reduce the risk of a potentially life-threatening attack.</p>	mHealth; telehealth	Patient behaviour; data linkage; lack of available technology
Avoiding asthma triggers 	<p>Location-specific alerts on adverse environmental conditions (such as pollen, air pollution etc.) or key meteorological changes (such as cold air alerts as used in the past for COPD patients³⁵) would help inform the decisions of people with asthma to make a necessary change to their self-management behaviours.</p> <p>With better information on triggers for asthma, people can take steps to reduce their risk – resulting in fewer healthcare professional consultations.</p>	mHealth; telehealth; wearables	Variety of triggers specific to individuals
Symptom trackers for recognising worsening asthma 	<p>Some studies indicate worsening symptoms suggesting an asthma attack can occur days, perhaps weeks, in advance, during which preventive action could potentially be taken.³⁶</p> <p>New tools tailored to a person's asthma and able to help people recognise worsening control could be potentially life-saving and reduce the number of emergency admissions.</p>	Telehealth; remote monitoring; mHealth	Lack of technology to drive patient behaviour change; complexity of triggers
Emergency assistance 	<p>In the event of an asthma attack people may need emergency advice on what to do. Some people can also experience difficulty in talking, making it hard to contact others for assistance.</p> <p>Ensuring timely advice is easily available when it is needed, and giving a voice to those in an emergency situation, could help to support people experiencing an asthma attack.</p>	mHealth	Current tools insufficient

Aid to help stop asthma attacks	Opportunity	Type of tech solution	Barriers
Healthcare professional-led asthma management			
Risk stratification of people with asthma 	<p>Better risk stratification tools would help to identify asthma patients most at risk and who need further healthcare professional intervention.</p> <p>Action could result in reduction in asthma attacks and more effective allocation of NHS resources.</p>	Digital health IT; predictive algorithmic analytics	Data linkage; Current tools insufficient
Electronic alerts for asthma prescribing 	<p>Electronic surveillance could highlight where people with asthma have been prescribed excessive quantities of short-acting reliever inhalers, or too few preventer inhalers.</p>	Digital health IT	Funding; data linkage
Medicines optimisation 	<p>Algorithms could also help to reduce use of oral corticosteroids, which have significant irreversible side-effects, especially at high doses.</p> <p>This would not only improve safety but also help to inform risk stratification and more efficient use of treatments.</p>	Personalised prescription algorithms	Data linkage
Electronic alerts following emergency admissions 	<p>Ensuring arrangements are made after every attendance at an emergency department or out-of-hours service for an asthma attack could help healthcare professionals to intervene and help prevent future attacks.</p>	Digital health IT; remote monitoring	Data linkage
Shared decision-making			
Improving asthma review efficiency 	<p>As many as two-thirds of people may not attend their annual asthma review, despite a significant minority being symptomatic and needing treatment change.^{37,38}</p> <p>New ways to deliver routine appointments remotely could reduce the numbers that do not attend.</p>	Telehealth; Digital health IT	Funding for IT; NHS culture
Personal asthma action plans 	<p>Asthma action plans make someone four times less likely to be admitted to hospital, but only 30% of people with asthma have a written plan, with nearly all provided in paper format.³⁹</p> <p>Delivering asthma action plans in a digital format, linked to a person's health record, could ensure these are more readily delivered to and used by people with asthma.</p>	mHealth	Linkage with EHRs

Smart inhalers for adherence monitoring

Using a smartphone's Bluetooth connection, smart inhalers are designed to collect and send data from sensors monitoring medication use. They aim to help track the daily inhaler use of a person with asthma, usually via a linked health app on the user's smartphone, and send alert reminders to use the inhaler.

Importantly, many of these are also being designed to become part of broader remote monitoring platforms, enabling healthcare professionals to determine when a change in treatment may be needed or to be alerted if a patient's condition significantly worsens and requires intervention. These real-time data could also be easily shared with healthcare professionals and reviewed together during consultations.

Propeller Health

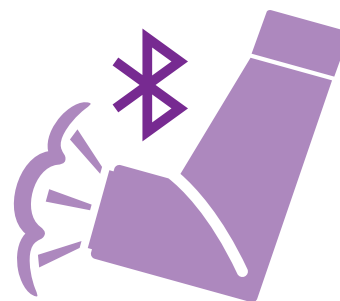
The *Propeller Health* sensor is a small device that attaches to the top of an existing inhaler. It can be used with both reliever and preventer medications for tracking symptoms and adherence respectively, with a record of the time and place an inhaler has been used. Patients or their family members can also receive a text, push notification or email reminder if they miss a scheduled dose.

A randomised controlled trial of 495 patients assessing the Propeller Health Asthma Platform for reliever inhaler monitoring has shown that over a 12-month period reliever use was reduced, reliever-free days were increased, and asthma control was improved.⁴⁰

Adherium

The *Adherium* smart inhalers clip onto a standard inhaler and track every time the preventer and reliever medications are taken. Data are transmitted to a dedicated website when the devices comes within range of a smart phone or wireless hub. This information is then available to a patient via an online Personal Health Record. A range of these devices are also touch-screen enabled.

These sensors have been found to be accurate in recording and retaining electronic data on inhaler actuations.⁴¹ A randomised controlled trial of 220 patients has also shown that Adherium's smart inhalers that included an audio-visual reminder led to significant improvements in adherence to preventer medication in school-aged children with asthma.⁴²



CareTRx

Gecko Health Innovations' *CareTRx* sensor fits on metered dose inhalers, with an LED display allowing programmable medication reminders. Multiple pressure sensors analyse actuation accuracy. The accompanying app and dashboard allows patients and healthcare professionals to access real-time data stored securely on the cloud.

Cohero Health

Cohero Health's inhaler sensors track adherence for both daily reliever and preventer medication, with linked apps tailored to both adults and children. These are designed to link together with data from Cohero's wireless mobile spirometer in order to produce a broad picture of a person's asthma.

CapMedic

CapMedic sensors record how an inhaler is being used, helping people to understand their inhaler technique and provide suggestions for improvements when needed. Audio messages, discreet vibrations, or visual feedback can help provide people with information and reminders on how and when to take their medication, with data connected to a smartphone app.

Promising technology: smart inhalers

Challenges:

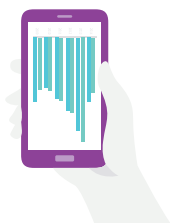
- Short-term costs to establish large scale use
- Current designs do not appear to assess the quality of inhalation
- Interoperability with NHS systems.

Immediate priority:

- Real-world testing needed within the NHS

Health apps to track treatment use and avoid triggers

There has been an explosion of health apps in recent years – 100,000 apps are listed in the mHealth sections of Apple and Android.⁴³ An estimated 1.7 billion people will be downloading health apps by 2017.⁴⁴ However, the quality of health apps for asthma is highly variable.⁴⁵



In addition to the connected health apps designed to link to specific smart inhaler devices, other apps have been developed with the aim of helping to track treatment use and avoid triggers for an attack, encouraging behaviour change based on the data presented.

Asthma Coach

Asthma Coach, developed by the Asthma Society of Ireland in consultation with healthcare professionals and asthma patients, the free app allows users to create reminders for medical appointments, medications, vaccinations, peak flow recording and asthma control tests.

The diary section gives users a digital space to record asthma attacks, manually input information to store their action plan, see charts and statistics of their medication use and email reports to themselves or their healthcare professional. A live pollen feed also allows users to monitor allergens like pollen and spores. Detailed asthma information and instructional videos provided through the app help users understand their asthma.

Asthma Health

The *Asthma Health* app was created through Apple's ResearchKit, an open source framework that allows researchers and developers to create powerful apps for medical research and is the vehicle of the Asthma Mobile Health Study run by the Icahn School of Medicine at Mount Sinai in New York.

The app enables a user to track their asthma symptoms and review trends, giving them feedback on their progress, and provides personalised reminders to take their prescribed medications. All of the information collected on the app can be shared with healthcare professionals, and the app's developers are planning to link the data with Electronic Health Records and genetic data provided through 23andMe.^{46,47} The study was extended to include users in the UK in 2016, and the data collected could help to provide new insights into asthma research.

Plume Air Report

The *Plume Air Report* app, developed by Plume Labs and part-funded by the French government, uses data collected from examining pollutant sources like nitrogen dioxide, ozone and carbon monoxide at 11,000 stations in

30 countries. Analysing the data, the app rates the risk to health using a colour-coded system. The advice is then tailored to the needs of cyclists, runners, parents and children, with a separate colour-coded system explaining how safe each area is.

Similar apps are also available such as *London Air*, developed by King's College London, which draws information from over 100 monitoring sites across London to measure air pollution levels, allowing people to take preventative action to reduce risk. Deloitte Health has also highlighted how a system linking air quality monitoring with the health system *could look in practice*.

Promising technology: health apps

Challenges:

- Reviews looking at quality of asthma information, consistency with the evidence base for asthma self-management and adherence to best practice principles for trustworthy content, suggest variable quality of asthma apps in the UK
- Uncertainty on regulation of health apps leading to risk-averse approaches
- Lack of certification/endorsement framework which would help ensure information security and technical resilience of asthma apps
- Asthma apps in UK do not yet link to Electronic Health Records
- High-powered information on triggers yet to be included to highly localised level within asthma apps.

Priorities:

- Short term – high quality mHealth solution needed with user-centred design informed by patients and healthcare professionals, which brings together the action plan, adherence tech, patient and symptom information into one central point
- Medium term – mHealth solutions need to link to Electronic Health Records.

Remote monitoring to support asthma management

A small number of studies have suggested that a ‘window of opportunity’ exists between the worsening symptoms and onset of an asthma attack, during which preventive action could be taken.⁴⁸

Given the importance of symptom control for asthma, innovations aimed at monitoring symptoms may help to encourage behaviour change if appropriately targeted.

If a person with asthma can gather real-time, up-to-date information, and share it with healthcare professionals (or have it rapidly analysed by automated algorithms), they can adjust their medications, alter their activity level, make a change to the surrounding environment – even make a decision to seek medical help.

Automated Device for Asthma Monitoring and Management (ADAMM)

New York-based tech company Health Care Originals are developing a *wearable sensor* in the form of a patch that connects to a smartphone, is designed to count coughs and measure respiration and wheeze, using predetermined algorithms of symptom sounds. It is intended to simultaneously monitor activity using the smartphone’s accelerometer, which allows people to view their symptoms in relation to their level of activity.

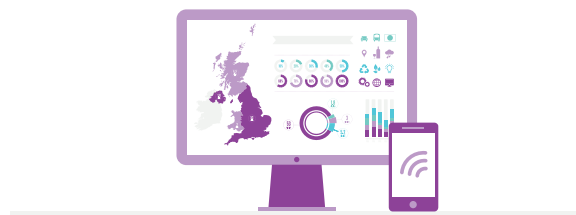
The company demonstrated an early prototype of the 3D-printed patch at the 2016 Consumer Electronics Show.⁴⁹ It aims to also feature inhaler detection, alerts and alert forwarding, symptom tracking and trending, and treatment plans. An adhesive would attach the wearable patch to the torso, and would be able to continue monitoring while charged overnight.

A very small study involving 84 teenagers suggested an early prototype of ADAMM could be a valid symptom-monitoring device.⁵⁰

The Inhaler Compliance Assessment (INCA) device

The *INCA device* is being developed by the Trinity Centre for Bioengineering in Dublin together with medical device company Vitalograph. It is designed to provide integrated acoustic analysis measuring correct inhaler technique and dosing that can be reported back to healthcare professionals.

This has been trialled on a diskus inhaler, with recording initiated by opening the inhaler and finished when the inhaler is closed. An electronic real-time clock marks the time the recording is made and this is stored as part



of the file’s metadata. The audio is analysed through an automated processing acoustic algorithm. Results from a very small 2014 study of 30 patients suggested that INCA may present a novel method to objectively assess how errors in both time and technique of inhaler use could impact clinical outcomes.⁵¹

Further research is underway to test the INCA device’s success in improving adherence and inhaler technique, and ultimately outcomes for people with asthma.

myAirCoach

The European Commission through its Horizon 2020 programme is funding *myAirCoach*, a pioneering research project worth €4.6m. The project aims to develop a holistic, personalised asthma monitoring system, which will help patients to self-manage and increase their awareness of their clinical and environmental state. It will also create a new and more comprehensive dataset of the biological state of people’s asthma on a day-to-day basis. This can then be examined by researchers who are aiming to discover whether asthma exacerbations can be predicted (and treated) at an earlier stage.

The project began in January 2015 and will run through to December 2017. Asthma UK is supporting this project by making sure the views and needs of people with asthma are driving the development of the system.

Promising technology: remote monitoring

Challenges:

- Technology to accurately predict attacks still in development
- Current prototypes require being attached to the torso, rather than utilising existing tech or clothing.

Immediate priority:

- More research needed to refine the technology before real-world trialling.

Using innovative systems and data to improve asthma management

Ensuring arrangements are made after every attendance at an emergency department or out-of-hours service for an asthma attack could help healthcare professionals to intervene and take action to help prevent attacks in the future. Innovations in system design to manage asthma are already being developed in other areas of the world, with opportunities to apply these to the UK.

Personalised computer decision support to support clinician-led care

A custom-developed *asthma decision support system* was built within an integrated EHR system, MOXXI, in Quebec, Canada. In the cluster-randomised trial, 81 primary care clinicians covering 4,447 asthma patients were followed for 3–33 months following their first visit.

The computer-assisted system provided systematic monitoring of asthma control status, follow-up of patients with out-of-control asthma, and evidence-based, patient-specific treatment recommendations according to clinical guidelines.

The study found that the asthma decision support system increased the quality of asthma management and reduced the rate of out-of-control asthma episodes for patients with poorly controlled asthma at study entry.⁵²

Alerts for emergency asthma admissions

Cincinnati Children's Hospital Medical Center (CCHMC) operates four primary care paediatric practices and has a long-standing focus on improving outcomes for children with asthma. In 2012, CCHMC began to receive emergency admission alerts through via their new health IT system, *HealthBridge*, to add to the technology used within the practice for high-risk asthma patients.

These alerts notify CCHMC when one of their primary care patients has an emergency or hospital admission at any of the 21 participating hospitals in the community. This enables healthcare professionals in primary care to have real-time data available on their asthma patients, enabling them to invite them in for assessment if alerted. Despite the extra time and effort to implement the system, practices placed high value on having the alerts.⁵³

Personalised electronic prescribing for asthma treatments

Research by the University of Amsterdam has shown how *electronic prescribing* could enable severe asthma patients to safely reduce their oral corticosteroid treatments. One clinical trial in the Netherlands involving 95 patients demonstrated this could be achieved without



a loss in asthma control.⁵⁴ This involved the use of an internet-based management tool which included the home monitoring of symptoms, lung function and exhaled nitric oxide (FeNO) testing.

Patients had daily information about their asthma provided on the web page and received weekly personalised instructions for stepwise corticosteroid dose adjustments according to a built-in algorithm. The results found that the tool was superior to conventional treatment in reducing total corticosteroid use without compromising asthma control or quality of life.

Predictive analytics to enable pre-emptive asthma care

Dell acquired analytics company StatSoft in 2014, and is now seeking to use its expertise within digital health through *Dell Statistica*. Their innovative approach to asthma management aims to integrate and correlate EHRs with other data sources including air quality, weather information, and pollen counts, which is then aggregated and virtualised. Statistica then runs very complex and advanced predictive analytical algorithms to quickly identify those people with asthma most at risk of a serious exacerbation in their condition based on the variables they have identified.

The system is designed to react to the data and deliver SMS alerts to patients about impending asthma events. Dashboards within the system enable healthcare professionals to be alerted to the status of asthma patients under their care, while patients are engaged and provided with information to aid their own self-management.

Use of video for training inhaler technique

Poor asthma inhaler device use is associated with reduced asthma control and more frequent emergency admissions.⁵⁵ Research conducted by Asthma UK suggests that 21% of people with asthma are not having their inhaler technique assessed at their asthma review with a healthcare professional – one of the key measures of routine asthma care.⁵⁶

At the University of North Carolina, a randomised controlled trial of 91 children found that a brief video intervention offered during paediatric clinic visits can lead to immediate improvements in children’s inhaler technique.⁵⁷ If video training is shown to be as an effective training tool for inhaler technique in people with asthma, this would increase the possibility of remote consultations with healthcare professionals for asthma in the future.

Developing risk tool algorithms

Better risk stratification of those people with asthma would potentially reduce the number of people who need to be seen regularly by a GP or nurse. Currently, everyone on the asthma register is invited to attend an annual asthma review. Using technology to stratify risk would help to identify those people with well-controlled mild asthma who may not need to see a healthcare professional in person.

For example, people could be enabled via an online portal or app to remotely complete a brief risk assessment to provide patient-reported data on their recent symptom management, reviewed against previous history and co-morbidities. This in turn could help identify which people with asthma to review in person, and which could potentially be assessed via a video consultation. This would need to be an ongoing process through the healthcare professional as asthma control may change over time. Risk stratification would also enable those in primary care to focus resources on those at greatest risk.

Promising technologies for healthcare professional-led asthma management

	Challenge	Short-term priority	Medium-term priority
Linked Electronic Health Records	Interoperability with broader NHS system and patient access to records	Ensuring interoperability and patient access	Linking to other asthma tech
Electronic prescribing alerts	Poor progress in adopting UK-wide	Ensure UK-wide adoption	
Personalised e-prescribing	Research to date limited	More research needed	Developing and testing algorithms
Predictive analytics	Requires fully linked data from a number of sources	Ensuring primary and secondary patient data linkage	Adoption of predictive analytics for asthma across NHS
Use of video for inhaler training	Ensuring confidence for use of video as a training tool	Further research needed to compare video vs current training methods	Equipping GP practices for e-consultations for asthma reviews
Risk stratification tools	Requires further robust risk tool development	Further research needed to trial effective tools for the NHS	Adoption of validated risk stratification tools for asthma across NHS

Policy recommendations

The innovations highlighted in this report demonstrate the emerging potential for technology to address the challenges facing asthma management and self-management and ultimately help stop asthma attacks.

Asthma UK is co-designing solutions identifying unmet needs that mHealth could deliver, and helping to facilitate engagement involving people with asthma. But to help transform asthma care through technology, activity is required that goes beyond the voluntary sector and commercial organisations working in isolation.

Overall, more investment in developing intuitive user-centred design is needed for people with asthma to become fully engaged in their care. Validated testing is equally needed to mainstream some of these applications. Ensuring this occurs could lead to new technologies becoming available that improve how asthma care is delivered and how people manage their asthma.

‘Many promising technologies are already starting to come through, and could be transformational if they are embedded within a connected environment for asthma care...’

Many promising technologies are already starting to come through, and could be transformational if they are embedded within a connected environment for asthma care. To achieve this, ongoing efforts aimed at tackling longstanding issues such as linking data across all care settings in the NHS need to be resolved, as does ensuring barriers around interoperability in the NHS are removed. Addressing these issues is vital to ensure the NHS as a whole is able to fully respond to the opportunities open to it through the potential of technology-enabled care.

This report has highlighted the size and nature of the asthma population, the unmet need, and in particular the strength of the evidence for asthma self-management. As the NHS starts to realise the potential of technology-enabled care for long-term conditions, there is a compelling argument for asthma to play a prominent role. By making asthma a focus and an exemplar for technology-enabled self-management and clinician-led management in primary care, this model could be then applied to other long-term conditions.

Technology offers much promise but we are still at the early stages for asthma.^{58,59} We are already seeing proliferation of data formats, operating systems and apps. To ensure tech-enabled asthma management can be distributed and used at scale, careful attention needs to be paid to managing this innovation in a systematic way.

Deploying existing technology across the NHS to address clinical gaps

Healthcare professionals need to be supported so that they can ensure that all people with asthma are provided with effective care.

There is already clinical consensus on what needs to happen at healthcare professional level with regards to the organisation of NHS services for asthma and the changes needed, as highlighted through the recommendations of the Royal College of Physicians’ National Review of Asthma Deaths. However, despite technology already existing that would help to meet a number of these recommendations, progress to deploy this technology has so far been lacking. Action is needed to deploy technology to meet these recommendations.

Digital asthma action plans

Of the major GP software providers of electronic health records, EMIS Health is currently the only one to provide a digital version of the asthma action plan.⁶⁰ With less than a third of people with asthma currently receiving an action plan in the UK, enabling people to access their plan online could be a highly effective way to drive up these numbers.

The NHS needs to take immediate action towards ensuring that every person with asthma has an agreed asthma action plan available to them digitally. This should involve encouraging all GP practices that currently use EMIS to ensure digital asthma action plans are provided for all asthma patients under their care, and incentivising other providers to include this.

This will ensure wider distribution of action plans addressing a key current gap in use. In the future, these need to be active tools within Electronic Health Records that can help facilitate engagement between people with asthma and their GP.

NHS bodies should:

- in the short-term, use provider power to incentivise the rapid increase across all GP software providers of standardised digital personal asthma action plans
- in the medium term, ensure digital asthma action plans are incorporated within core EHR systems to allow seamless sharing between clinicians and patients.

System alerts to improve patient safety

Developing interoperability across NHS settings to help link patient data remains a key challenge. However, some areas in the UK are progressing this more rapidly than others. Data can save lives by helping to recognise where declines in asthma control occur and relaying this information to ensure preventative interventions can happen.

NHS bodies should:

- in the short term, ensure full deployment of electronic surveillance of prescribing in primary care to alert clinicians with precise data on where patients are being prescribed excessive quantities of short-acting reliever inhalers, or too few preventer inhalers
- in the medium term, prioritise the full introduction of electronic alerts to enable every attendance at an emergency department or out-of-hours service for an asthma attack to be followed-up by the patient's GP.

Increasing electronic prescribing

In the future, e-prescribing using personalised algorithms may be used for people with asthma. Today, e-prescribing could help to increase adherence to asthma treatments by helping people to receive their regular medication in a more convenient way. Around a quarter of the population are so far using e-prescribing, with benefits including a reduction in GP workload.⁶¹ Given the size of the asthma population and their need for regular prescriptions, further inroads could be made in this area through a targeted focus on increasing take-up for people with asthma.

NHS bodies should:

- promote the use of e-prescribing tools to people with asthma in partnership with patient organisations.

Designing new user-centred technologies

The existing promise within asthma technology needs to be built upon and considered as part of a holistic asthma management solution. This requires a multidisciplinary approach – bringing together patients, clinicians, academic researchers, and both pharmaceutical and tech industries.

Patients and healthcare professionals need to be at the heart of developing these technologies to ensure that these meet their needs and are intuitive in how they are used. In this way, technologies can be designed to better support people to make adherence simpler and easier, avoid triggers, and prevent asthma attacks.

Funding further asthma research

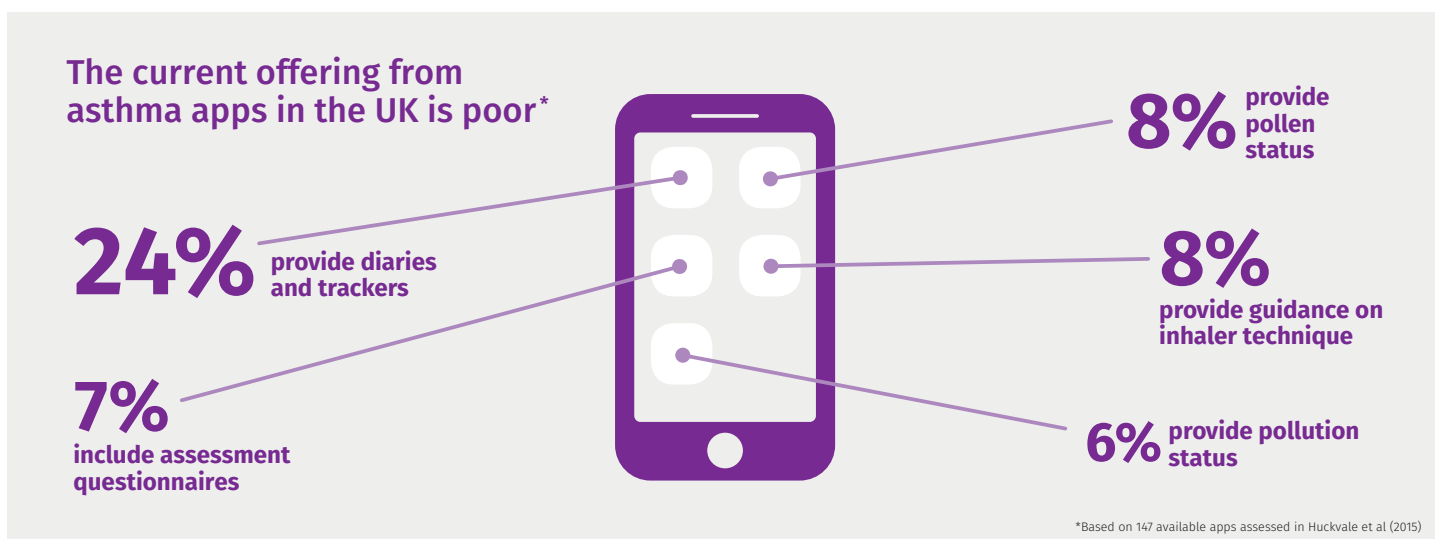
The overall proportion of funding into respiratory conditions is lower than their comparative disease burden,⁶² and expert analysis by asthma researchers across Europe has highlighted technology-enabled asthma management tools as one of the highest priorities for research.

Governments and administrations in the UK and the EU should:

- invest greater funding in collaborative asthma research aimed at developing innovative technology to facilitate the management and self-management of asthma, bringing together life sciences and tech companies in collaborations with multi-disciplinary academics and patients

Research funders should:

- prioritise research into a full range of clinically- and consumer-tested predictive analytical algorithms for use in asthma management.



Ensuring user-acceptance of new asthma technologies

Despite the promise of mHealth, evidence suggests low acceptance and adoption of mHealth solutions when individuals do not feel that their use is compatible with their health goals.⁶³

In addition, the development of robust methodologies to validate the impact, effectiveness and mechanisms of action of digital health technologies lag far behind the development of the technologies themselves. A review of published mHealth evidence found only 13% of the available evidence used research methods sufficiently robust enough for formal technology appraisal mechanisms.⁶⁴

Research funders should:

- convene mHealth experts to build consensus on what constitutes good user experience for people managing their long-term condition to ensure ongoing use of technology
- through the National Institute for Health Research, determine and recommend a set of research methodologies that include user-acceptance measures to aid in trial design of mHealth solutions.

Integrating new technologies into the NHS

The NHS needs to become the best place for innovation. As highlighted through the UK Government's Accelerated Access Review, there are a number of barriers and tensions preventing innovation in the NHS – from a lack of a clear digital pathway to complexities around local commissioning and complex procurement rules.⁶⁵ Similarly, Personalised Health and Care 2020 highlighted that the lack of integration and information sharing as further hindering adoption of digital technologies.⁶⁶ These are issues that are slowing progress on innovations for all health conditions, and require urgent solutions to help ensure that asthma innovations being developed can be quickly integrated into the NHS.

Of particular concern is the lack of clear guidance on the development of health apps. Uncertainty in relation to medical devices legislation creates a risk-averse approach from regulators and research sponsors that can present significant barriers to innovators.

Improving the regulatory process

The regulatory approval process is generally well understood by manufacturers of conventional medical devices and pharmaceuticals but for mHealth the process can be less clear and challenging to navigate, particularly for those developing innovations from non-healthcare backgrounds.⁶⁷ The current approach can also work against healthcare innovation.⁶⁸

In order to ensure that future innovations for tech-enabled asthma management are able to be rapidly adopted in the UK:

- the UK Government should consider the long-term implications of current regulation of and guidance on mHealth solutions and ensure that these are proportionate to risk while encouraging innovation and rapid deployment, and
- there needs to be clarity on the process through which mHealth solutions need to be validated to become widely adopted in the NHS.

Introducing smart inhalers to the UK

Smart inhalers show promise in potentially offering a technology solution to improving rates of adherence to asthma treatments and are currently in the process of being introduced within healthcare systems outside the UK.

NHS bodies should:

- establish a testing programme for smart inhalers via current test beds and innovation schemes aimed at improving adherence to asthma medications.

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All product and company names mentioned throughout the report are the trade marks, service marks or trading names of their respective owners, and do not represent endorsements from Asthma UK.

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All hyperlinks in the references above, and elsewhere in the report as a whole, are accessible as of July 2016.

Every ten seconds someone in the UK has a potentially life-threatening asthma attack and three people die every day. Tragically two thirds of these deaths could be prevented, whilst others still suffer with asthma so severe current treatments don't work.

This has to change. That's why Asthma UK exists. We work to stop asthma attacks and, ultimately, cure asthma by funding world leading research and scientists, campaigning for change and supporting people with asthma to reduce their risk of a potentially life threatening asthma attack.

We fight asthma in three ways:

- We fund world class asthma research.
- We campaign to improve the quality of care received by people with asthma.
- We help hundreds of thousands of people a year with our expert advice and support.

To find out more about Asthma UK's work:



Asthma UK Helpline:

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