CAPMEDIC™: SIMPLIFYING INHALERS FOR REGULAR AND CORRECT USE

In this article, Rajoshi Biswas, PhD, Architect and Clinical Lead, Cognita Labs, discusses the CapMedic device, which transforms a typical metered dose inhaler into a more user-friendly, efficacious delivery system through its ability to provide feedback on inhaler technique and real-time cues to avoid errors during inhaler use. She also discusses research using CapMedic to estimate the amount of drug successfully deposited in the lung with each use.

THE PATIENT PERSPECTIVE

Metered dose inhalers (MDIs) are necessary for millions of patients worldwide, yet continue to be very challenging to use for most. Seen from a distance, the inhaler looks innocuously simple to use – simply shake and inhale. However, that simplicity hides a very important fact that most people use their inhalers incorrectly. Correct use requires eight to ten steps (as stated in inhaler use guidelines), and study after study has confirmed that patients make several errors, despite repeated training.

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The incorrect use of an inhaler is clinically important. Unlike pills, which when swallowed ensure delivery of a pre-determined amount of medication, inhalers provide no guarantee on how much medication is actually delivered. Each error leads to an unknown loss of medication to the respiratory tract, often in the mouth and

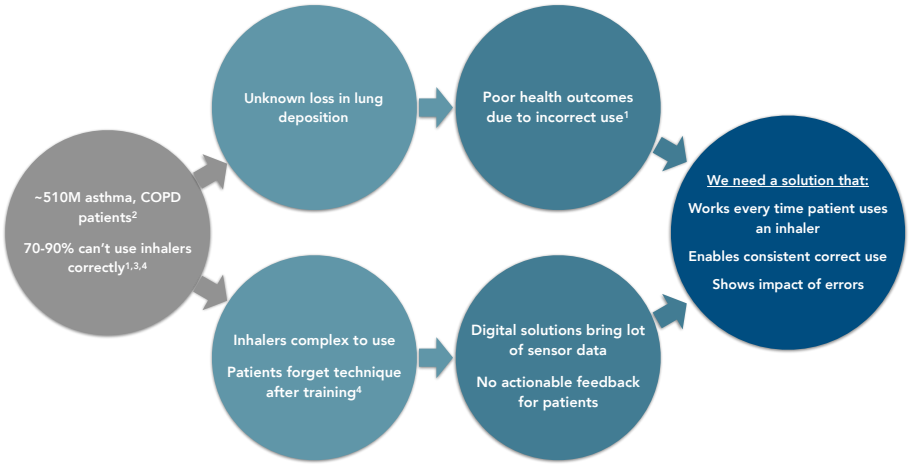

Figure 1: The inhaler misuse challenge and the kind of sustainable innovation needed for patients.

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throat, leading to an unknown amount of medication delivered to the lungs. Perhaps more importantly, incorrect inhaler use has been linked to poor healthcare outcomes. A recent patient study,[1] along with other evidence,[3] demonstrated that reduced asthma control is strongly correlated with errors in co-ordination, orientation and exhalation. As we shall discuss later, many of these errors are hard to spot for clinicians and even harder for patients to recognise themselves. Thus, despite the recommended practice of checking inhaler use on regular visits to the physician, there is little progress in the population-wide improvement of inhaler-use competence.[4]

The difficulty in MDI usability has sparked extensive research and innovation, largely to eliminate difficult steps from the process of inhaler use. Notably, spacers, dry powder inhalers (DPIs) and soft mist inhalers (SMIs) have reduced the burden of correct usage to some extent. However, DPIs and SMIs also suffer from patient misuse and hence much of the discussion and solutions in this article apply to these classes of inhaler too. Furthermore, current digital technologies for inhalers fall short in providing consistent, long-term improvement in inhaler-use competence and quantifiable, actionable feedback on everyday drug delivery. As shown in Figure 1, the importance of improving inhaler use competence cannot be overstated.

WHAT SHOULD WE INVENT?

Inspiration can be taken from the automotive industry. The conceptual design of a "box on wheels" is still no different from the day it was invented, but the experience, safety and efficiency of driving a car continue to evolve. For example, many new features have improved the safety of driving, such as systems that warn the driver if they are drifting out of lane, driving over the speed limit, backing up into an obstacle or if there is a vehicle in their blind spot. Taking inspiration from this analogy, something similar can be done for MDIs by keeping the efficient delivery mechanism but completely changing the patient experience of using it. For example, an inhaler could:

- **Measure what the user is doing (right or wrong)**: For an inhaler, this means not only measuring when it is used (like inhaler caps that measure adherence) but measuring the correctness of use.
- **Teach by informing the user just-in-time**: An inhaler needs to have indicators that teach what to do and how to do it correctly, at the right time.
- **Help build good habits**: By designing feedback to help build good habits, a user's competence could be improved over time.

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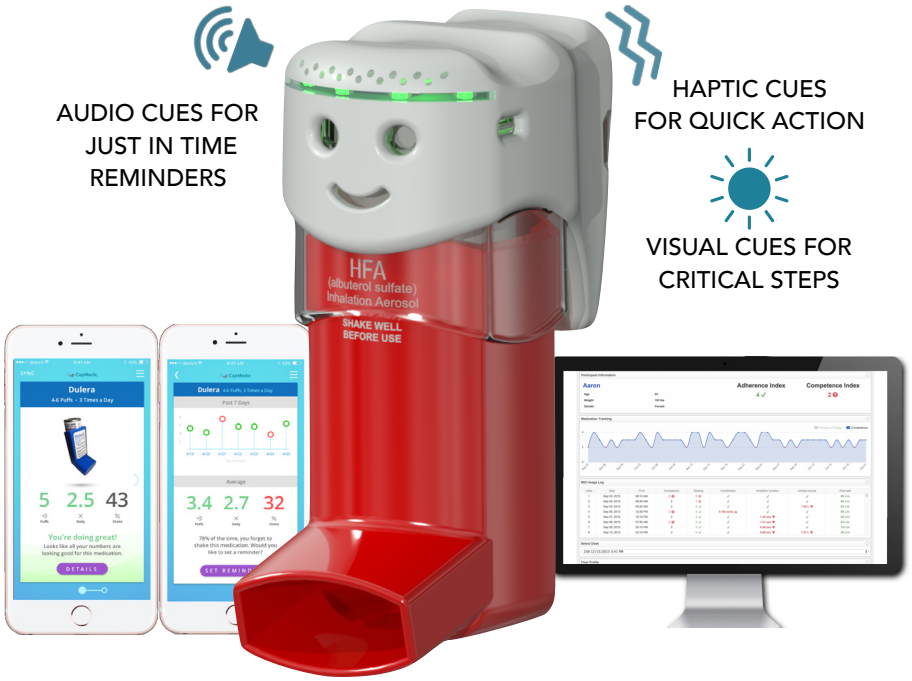

Figure 2: CapMedic can provide instant feedback in three configurable ways: audio instructions, visual feedback and haptic cues.

COGNITA LABS' CAPMEDIC™

Cognita Labs has developed a first-of-its-kind inhaler cap for most on-the-market MDIs, with the following features:

- **Comprehensive measurements**: CapMedic™ enables measurement of nearly all critical steps in MDI usage. Specifically, CapMedic measures seven steps/errors for MDI use, including important parameters like orientation, co-ordination and inspiration.
- **An always-available live-coach**: CapMedic converts these measurements into a highly capable audio-visual-haptic coach. For example, the coach can talk the user through the steps of inhaler use, such as reminding them to shake the inhaler, helping them time their actuation, encouraging deep inspiration and reminding them to hold their breath after inhalation. The coach is reconfigurable via the accompanying app, allowing users to change the method of feedback based on their personal needs (Figure 2).
- **Habit-building design**: CapMedic is a fully integrated design that can operate without an app. This is crucial, for two reasons. First, the coach is always active and in the right place – on top of the inhaler. Second, a coaching inhaler reduces the cognitive load of a user, in that they no longer have to remember to remember the steps themselves. They can simply follow the instructions every time, assured that they will recieve the optimal amount of medication.

NEW INSIGHTS FROM CAPMEDIC

Both Patients & Clinicians Get it Wrong

In a collaborative study conducted at the Baylor College of Medicine (Houston, TX, US), the inhaler manoeuvres of 23 participants, all of whom were experienced inhaler users (19 asthma, 4 COPD, ages

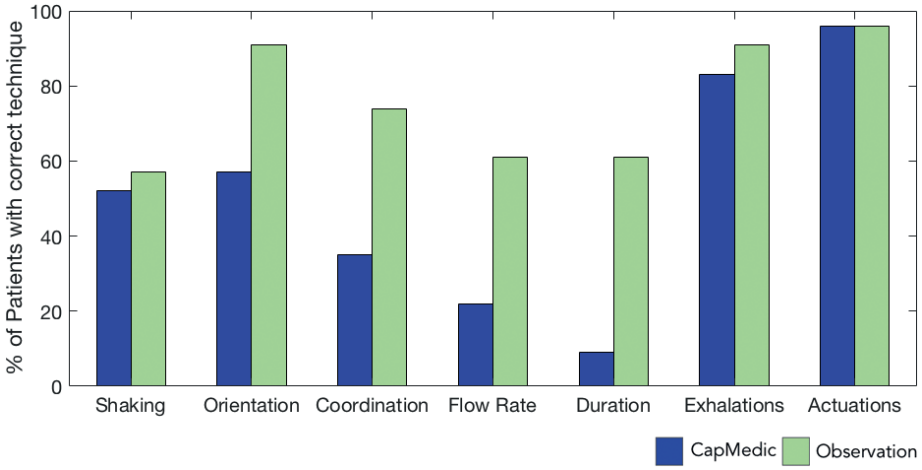

Figure 3: MDI-use competence (correctness of MDI use steps of shaking, orientation, coordination, inspiratory flow and duration of inspiration) and errors (exhalations into the MDI and multiple actuation) measured by CapMedic.

> "The CapMedic on-board coach guides with real-time cues to avoid errors in the first place, and the same sensor suite data can potentially be used to estimate the amount of drug deposition achieved."

20–65, 6 male, 17 female), were measured.[5] The participants used a CapMedic-equipped inhaler in the presence of a member of clinical staff, who was trained to spot errors in all steps of the manoeuvre. The results summarised in Figure 3 show the errors detected by the trained staff and CapMedic sensor-powered algorithms. For visually noticeable errors – whether the participant shook their inhaler, actuated the inhaler multiple times and exhaled, clinical observations match the CapMedic measurements. However, for four steps, the observation-based count is significantly lower than the errors detected by the CapMedic. CapMedic's error detection algorithms have been extensively validated with over 1,000 MDI techniques, based on measurements from patients and emulated using a custom robotic testbed. Thus, it is likely that the observation-based studies may be under-reporting the number and extent of errors.

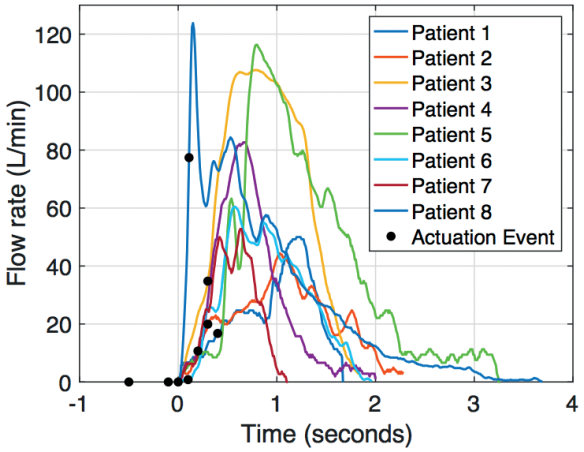

Figure 4: MDI-use technique measured by CapMedic.

Sensors Reveal Inhalation Flow Curves

Beyond error detection, CapMedic provides deep insights based on custom sensor data about each use of an inhaler. An important aspect of inhaler use is the inhalation through the MDI. Using CapMedic's highly accurate inhalation flow measurements, the patient's actual inhalation flow curve can be visualised. Figure 4 shows the flow curves for eight patients, with the black dot showing the precise time of actuation in their inhalation cycle. The flow curves show that these patients have very diverse breathing patterns, which has a significant impact on how much medication is actually delivered to the lungs. Additionally, the patients actuated their inhalers at diverse times, with the co-ordination varying from positive (actuating after the start of inhalation) to negative (actuating before the start of inhalation). Again, this co-ordination error has a significant impact on how much medication is actually deposited in the lungs.

Co-ordination Error – Hard to Detect Visually but with a Significant Loss in Deposition

Using a custom testbed (Figure 5) containing both MDI use emulation and *in vitro* lung deposition measurement

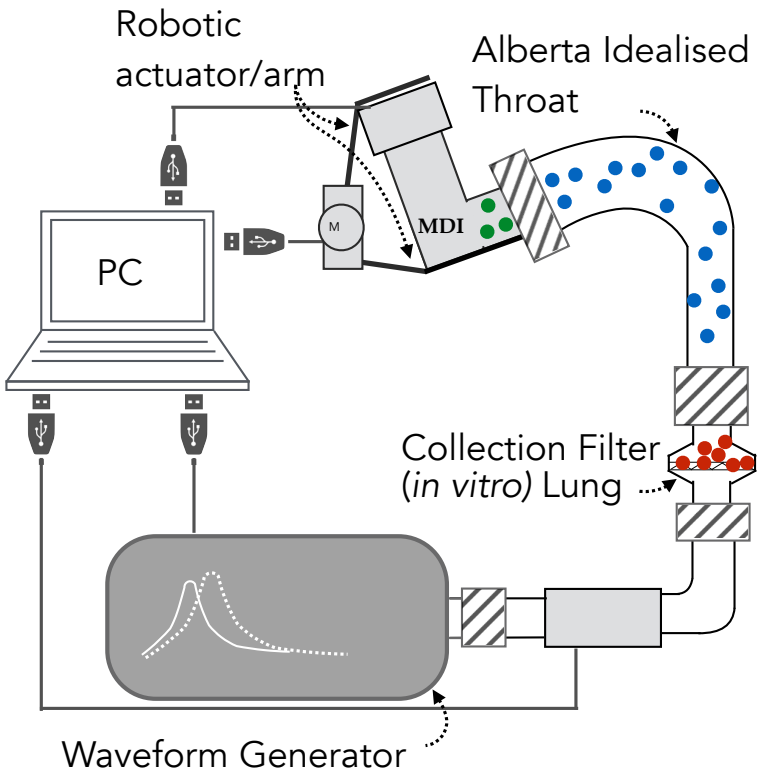

Figure 5: Test-bed for MDI-use emulation and *in vitro* lung deposition estimation.

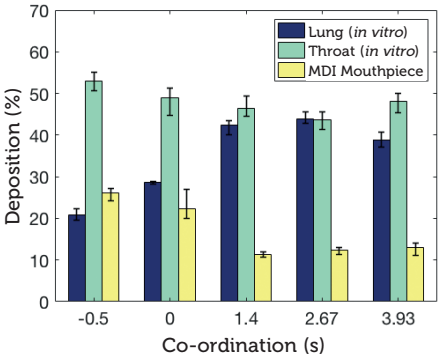

Figure 6: Results showing the dependence of lung deposition on the MDI use parameter co-ordination. Co-ordination refers to the delay in actuating MDI from the start of inspiration (negative when actuated before inspiration).

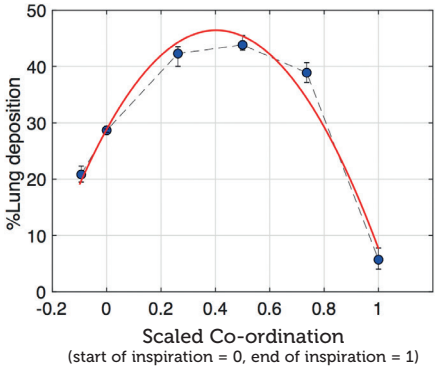

Figure 7: Early results from controlled experiments show the dependence of lung deposition on MDI use technique/errors. Here, coordination is scaled to the duration of inspiration (actuation before inspiration <0, for actuation at start of inspiration = 0, for actuation at end of inspiration = 1).

components, a study at Rice University (Houston, TX, US) evaluated how much medication is delivered in lungs, throat and mouthpiece depending on whether the co-ordination was negative, simultaneous or positive.[6] Figures 6 and 7 show the same data in two different ways. Figure 6 breaks it into the location of deposition in the *in vitro* model, either the lung, throat or mouthpiece. Note that a negative co-ordination of 0.5s, barely perceptible by humans, leads to a large loss in lung deposition, with only 20% of the medication reaching the lungs, compared with the maximum of >40% achieved for a range of positive co-ordination values.[6]

Towards the First "Digital" Drug

Looking forward, Cognita Labs firmly believes that CapMedic holds the potential to change patient care in many ways. First and foremost, by allowing a measurement of both adherence and competence, it may no longer be necessary for patients to bring their inhalers on every visit to their clinician. All that would be needed is a report from the CapMedic cloud detailing the usage data, allowing the clinician to discuss the patient's improvement and challenges with concrete data.

Secondly, perhaps by combining the data collected by CapMedic and modelling the corresponding drug deposition, it would be possible to estimate the lung deposition every time a patient uses their inhaler. This closed-loop solution could become the basis for a "digital drug", where digital feedback provides guidance to the patient that results in higher medication deposition. The CapMedic on-board coach guides with real-time cues to avoid errors in the first place, and the same sensor suite data can potentially be used to estimate the amount of drug deposition achieved.

CapMedic as an enabler of a digital drug could also answer the question "What to do with the sensor data?" beyond retrospective reporting. As the estimate of the delivered drug correlates with health outcomes, CapMedic can simplify everyday MDI competence data to a single actionable estimate of drug deposition with each use. This way, CapMedic can overcome the established difficulties of proper inhaler technique and guide users to use their inhalers correctly, providing meaningful information about drug delivery for every use.

ABOUT THE COMPANY

Founded by leading researchers from Rice University, Cognita Labs has developed patent-pending respiratory innovations to bring high-quality diagnostics and monitoring to the most vulnerable populations, including young children, seniors, and low-resource communities. The CapMedic™ device and cloud platform turns regular inhalers into a personal butler that helps patients use their inhalers regularly and correctly to better manage their disease. PulmoScan is a diagnostic and a monitoring device for detecting small airways changes that cannot be captured by traditional spirometry testing. As opposed to spirometry, PulmoScan allows effort-free <1 min testing, enabling use cases such as pediatric and geriatric diagnosis, home monitoring and volume screening. Cognita Labs' mature devices have been used and validated in various clinical studies.

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ABOUT THE AUTHOR

Rajoshi Biswas is the Architect and Clinical Lead at Cognita Labs. She holds a PhD in Electrical and Computer Engineering from Rice University (Houston, TX, US), specialising in the modelling of aerosol drug deposition, based on quantified patient inhaler-use competence. Through her past collaborations with Baylor College of Medicine (Houston, TX, US) and Texas Children's Hospital, she has focused her efforts at Cognita Labs to develop patient-centric engineering innovations for pulmonary medication monitoring and diagnostics.