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DESIGN INSIGHT

Postable peak flow meters: Improving remote patient monitoring from the home

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SUMMARY
As healthcare providers globally adapt/change their practices because of the ongoing global pandemic, a greater emphasis is being placed on remote/telemedicine diagnostic/monitoring models. To support such a model, especially for respiratory diseases—ie, asthma, chronic obstructive pulmonary disease (COPD), or interstitial lung disease (ILD)—it is essential that data are collected over a sustained time period. As such, the distribution of portable medical devices to patients' homes poses a significant logistical challenge. We present the user-centred design approach undertaken by a multidisciplinary design team consisting of product designers, design engineers, electronics/programming experts, and healthcare professionals to develop a postable modular peak flow meter.

Key Words
Patient monitoring; Peak flow; Peak expiratory flow; Respiratory diseases; User-centred design

INTRODUCTION & BACKGROUND

The importance of remote patient monitoring and the collection of accurate patient data has become fundamental to the services healthcare providers must provide. As the United Kingdom's (UK) National Health Services (NHS) adapts to changing circumstances due to the COVID-19 pandemic, healthcare services have been forced to work within a more robust remote distancing diagnostic/monitoring model. During the COVID-19 pandemic, the diagnosis, management, and monitoring of respiratory diseases has become more challenging, especially where patients need to be monitored over a sustained time frame. This issue has increased pressure on logistics and associated costs for the healthcare providers distributing medical equipment to a patient's home for remote monitoring/recording. During a pandemic, it is more cost effective and safer to send equipment to the patients rather than sending large numbers of healthcare professionals into the community or receive the patients at a clinic or surgery.

Remote monitoring of respiratory diseases during the COVID-19 pandemic has proven to be challenging[1] as it may not have been appropriate for a patient to attend a face-to-face respiratory assessment. However, another issue identified is the reliability of distributing/delivering respiratory equipment such as peak flow meters to a patient's home, and with the limited

availability of community care workers, remote methods of recording peak expiratory flow (PEF) have become essential to healthcare trusts around the UK resulting in peak flow meters being sent to patients. Peak flow meters measure the lung function of patients suffering from asthma and other respiratory diseases. It is estimated that in the UK alone 8 million people suffer from asthma, with an estimated 160,000 new diagnoses every year.[2]

A peak flow meter is a device used in clinical practice[3] to measure PEF and is a standardised test used within the NHS for monitoring and diagnosing airway diseases. Healthcare professionals rely upon validated methods of reporting patient statistics; therefore, it is important that PEF readings are taken and recorded on a regular basis (twice a day) and as such the distribution of peak flow meters is a critical service.

SUMMARY

In recent years, remote monitoring and assessment of respiratory diseases through new or existing technologies has been seen as a positive patient experience[4,5] with home compliance positively recognised through the use of digital solutions.[4] Traditional mechanical peak flow meters can be difficult to read, but more significantly, they also do not fit through the standard domestic letterbox opening. This issue has resulted in a significant number of missed deliveries resulting in increased logistic costs for healthcare providers. The home use of such equipment has become a significant issue during the COVID-19 pandemic where general practitioner (GP) services have been drastically reduced or stopped. In addition, there has been a noticeable increase in waiting times for referrals to secondary care/specialist expertise (eg, respiratory disease) or tertiary care (specialist long-term care), as such patients have not been able to collect or return equipment. In response to these issues, the project team sought to develop a simplified digital PEF that can be easily posted through a letterbox safely and securely to a patient for use within their own homes.

During the research and design phase, the project team used a user-centred design approach. The team completed a full assessment of the current state-of-the-art and the market, including teardowns and examination of existing technologies and solutions. Using recognised research and design activities such as literature reviews, observational research, interviews with medical professionals, ergonomic and anthropometric research, product design specification definition, concept generation, design detailing and packaging design, the team produced a final product solution.

Critically, the team conducted five semi-structured interviews with medical professionals at a teaching hospital within the East Midlands, UK. The interviewees included a lead nurse in adult asthma and allergy, a respiratory consultant, a clinical doctor in respiratory medicine, a clinical physiologist, and a deputy lead nurse in respiratory treatment. The team identified numerous themes from the interviews resulting in critical design criteria being identified (Table 1). The design criteria informed the design development of the newly developed postable peak flow meter.

Table 1: Key themes and critical design criteria derived from semi-structured interviews

Key Theme	Quote From Medical Professional	Critical Design Criteria
Distribution & Product Use	• *"I think there are better ways of holding it."* (P1) • *"Think about how the patient is going to grip it, think about when you did it and how hard it was to grip, now imagine how it feels if you don't have teeth."* (P1) • *"It is hard to go through a post box, so they have to pick it up sometimes or they get it somewhere and sometimes they won't even bother to get it." (P1)* • *"I'd want it to be something that can fit into people's handbag so they can take it around with them."* (P2) • *"How are we going to get this product through the mail service so it can get to the user on the other end?"* (P5) • *"You get a lot of people that get confused about filling in a peak flow diary."* (P5) • *"Can they rebuild it at the other end? (P5)*	• The solution must be postable—ie, no bigger than 254mm x 38mm. • The solution should be digital and have memory features. • The solution should link to a peak flow diary, which is simple to complete. • The device should be easily rebuilt once removed from its packaging. • The device should consider critical ergonomic data for patient demographic.
Aspirational Design Features	• *"(device can) detect if they've done the procedure correctly."* (P2) • *"Small and portable, but still accurate."* (P2) • *"You recognise it as soon as you see it, you know it's a peak flow meter."* (P3) • *"Any way to make the mouthpiece more intuitive."* (P4) • *"Even though it has a simplistic design (the) patient can still struggle."* (P5) • *"Nice to have a marker on the peak flow that represents their sort of normal."* (P5)	• The solution should have hold and have memory features. • The device must be simple and easy to use with self-explanatory instructions. • Readings should be easily readable once displayed on a digital screen.
Sterilization	• *"Easier to clean, no small spaces that bacteria can hide as this is a risk to the user"* (P1) • *"There's risk if they don't keep it clean."* (P1) • *"Single patient use; once issued they should use it.... Indefinitely."* (P2)	• The solution must have no indents or crevices. • The materials must be able to withstand exposure to antibacterial solutions.
User Friendly Interface	• *"Has to be user friendly, no point having a snazzy gadget if it isn't used for intended purpose."* (P1) • *"If your vision isn't great, the numbers are kind of small . . . some of our older generation might find difficulty with that."* (P3)	• The digital solution should be self-explanatory requiring no additional programming or setup. • The device must be robust and withstand general wear and tear and misuse.

	• *"Sometimes trying to work out which one it has really fallen on (reading) can be difficult."* (P3) • *"So if you've got like an LCD display that I guess like it'll just show you your measurement once you've done it, yeah it just feels a lot more user friendly."* (P4)	• The results should be displayed digitally.
Accuracy & Digital Solution	• *"Less chance for error when recording results"* (P2) • *"I'd want it to be digital and connected."* (P2) • *"Making it more readable"* (P3) • *"You get objective data that nobody is going to quibble with."* (P4) • *"Reproducibility (of results)"* (P5)	• The display screen must clearly indicate the results. • The results should stay on screen for a sustained time period.

The designed peak flow meter consisted of the following features:

- An ergonomically designed peak flow meter chamber with detachable mouthpiece(s) connected via a push fit, to allow for ease of cleaning and sterilisation.
- A peak flow meter chamber comprising adjusted dimensions that can be placed inside suitably designed packaging (160mm x 200mm x 35mm) and posted through a standard UK post box.
- A time-of-flight (TOF) sensor integrated into the main peak flow meter chamber to provide accurate recoding of the change in chamber size/volume during the peak flow measurement process.
- An LCD screen to clearly display the results of the PEF reading with memory/hold features.

LESSONS LEARNED

We cannot overstate the importance of using multidisciplinary research, the design process, and a design team. Generating design criteria based on primary research activities such as interviews provided by healthcare professionals, allowed the project team consisting of product designers, design engineers, and electronics/programming experts to devise a suitable solution while in consultation with healthcare professionals. Using a user-centred design approach, the design development process required the project team to assess a range of electronic components, various designed mouthpieces forms, various shapes of the main body, and the means to calculate the volume necessary to allow appropriate air flow within the device. Such a skillset is unlikely to be captured in one individual.

The designed peak flow meter (DigiPeak) is a portable solution that can be easily disassembled/reassembled into multiple components and placed into packaging that can be easily posted through a standard UK-sized letter box. Where possible, medical devices that are designed/redesigned in the future should consider home delivery restrictions in scenarios such as those today where face-to-face contact must be avoided due to the ongoing global pandemic. Therefore, designing medical devices to be modular allows for more creative and sustainable packaging solutions to be produced while also ensuring delivery to patients in their homes, thus minimising additional logistical pressures/costs.

Through detailed material selection processes, the materials selected ensured that a durable device could be produced yet still perform accurately upon receipt by the patient, even if the product/package is mishandled by postal services. The packaging of a medical device should ideally be split into two layers (internal and external layers) thus ensuring that if in a worst-case scenario the external packaging layer is compromised during transportation and delivery, the internal packaging layer is not contaminated.

Finally, simplistic digital displays should be considered for patient-operated devices. The DigiPeak solution uses an LCD display to communicate a single large reading that is clearly communicated to the user for a sustained period of time while being written into a peak flow diary. These results can then be easily communicated during an online consultation through any digital means, which was a key requirement derived from the interviews conducted.

DESIGN INSIGHT

Peak flow meters have been a key part of monitoring patients with obstructive airways disease. Multiple parts to this project have addressed some of the key issues:

- The scope to deliver the device intact via the postal service.
- The accuracy of the results from deployment of the peak flow meter.
- The ability to relay the readings for professional advice.

The most important element in this design process was integrating the perspective of the professional staff involved in the assessment and care of patients. What is missing in this process is the end-user perspective. Future research on this device must evaluate that perspective and the impact of this device in practice. Patients understanding of the significance of readings should include safeguards to prevent them from developing life-threatening exacerbations without an awareness of the growing risks. It is crucial that there is no danger of patients with poorly controlled illness being falsely reassured.

The authors have quite rightly underlined the enormous value of patient-led monitoring as a key aspect of the pandemic environment; however, even in other circumstances there is a risk that patients pay far too much attention to readings on machines and not on how they feel or when there is something that requires urgent attention. The readings of peak flow meters are one element in the follow-up of patients with obstructive airways disease. There are many other aspects that may be amenable to close monitoring, including the frequency of use of inhalers, symptoms such as nocturnal and exercise-induced coughs, and perhaps other markers that may come to light in the future. Therefore, the development of a digital device that is familiar to patients may lead to the integration of other measures that could be incorporated into such a device. This was a step in the right direction.

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PEER REVIEW

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CONFLICTS OF INTEREST

The authors declare that they have no competing interests.

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ETHICS COMMITTEE APPROVAL

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