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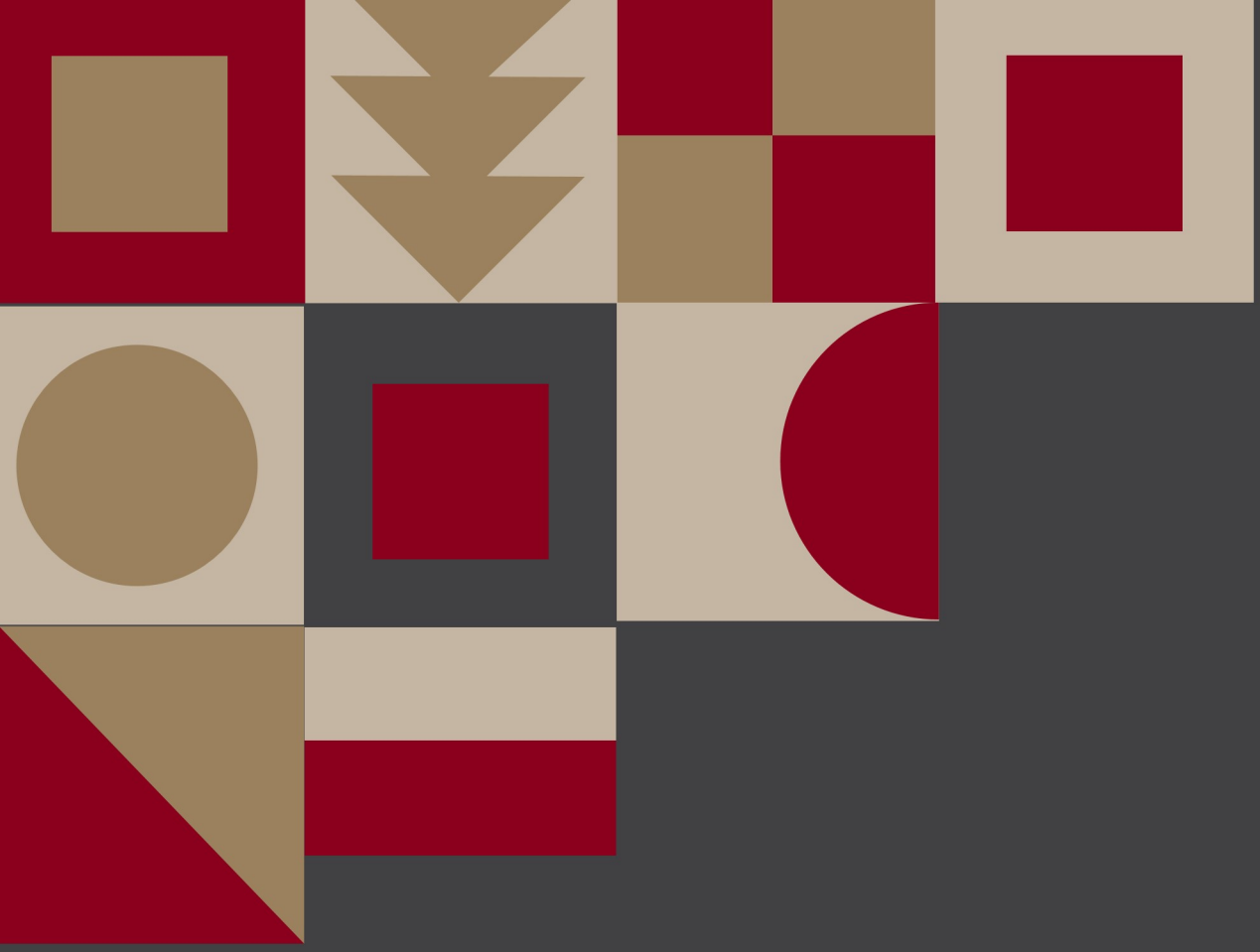

SOUTHERN AFRICAN
HEALTH JOURNAL / 2020

PRODUCTION
Editor in Chief: Charlton Murove
Copy-editor: Peter Wagenaar
Project Co-ordinator: Camille Shamburg
Layout & Design: Mariette du Plessis

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DESIGN OF AN AUTOMATED DIGITAL SYSTEM
to measure asthma control

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EXECUTIVE SUMMARY

Our recent experience with the COVID-19 pandemic has indicated that effective management of chronic diseases is important to reduce morbidity and mortality. Improving the control of chronic diseases will also contribute to reducing the burden of disease. Digital technology may be a suitable approach to improve the efficiency of managing asthma control. The principles applied in this study should be essential for the re-engineering of primary health care in South Africa. The aim of this study was to combine a clinical approach with artificial intelligence to design an automated, real-time, digital system to measure and categorise asthma control in adolescents and adults.

Fifty-eight decision trees were designed, in line with the South African standard treatment guidelines for asthma, to mimic the clinical thinking of health care practitioners. A digital system was designed to characterise a patient's asthma control as uncontrolled, partly controlled or controlled. Such characterisation of the asthma control will allow uncontrolled patients to be referred for intensive disease management. Such a decision can then be based on clinical control rather than other factors such high cost. This automated system was designed so that managed care organisations, family practitioners, pharmacists and nurses can measure asthma control in real time. The approach used in this study can be applied to measure health outcomes for every patient over time for all disease management programmes. It is hoped that this approach will form the basis for disease management programmes in the public and private health care sectors.

INTRODUCTION

Asthma affects about 5% and 15% of adults and children, respectively, in South Africa (National Asthma Education Programme, 2017). According to the Global Asthma Report (2018), South Africa is ranked the 25th highest worldwide for asthma prevalence and the fifth highest for asthma mortality, with an estimated 18.5 deaths per 100 000 cases for adults and children. There is evidence of a significant increase in the number of people who have asthma among all races in South Africa. Asthma is the most common chronic illness in South African children and its prevalence is increasing in both urban and rural areas (The Global Asthma Report, 2018). Over the past 25 years, a 25-200-fold rise in hospital admissions for asthma has been

recorded in hospitals in Durban and Soweto (Western Cape Government). This report does not provide reasons for the increase in hospitalisations, i.e. whether the asthma severity had increased or whether the rise in hospitalisations is due to other reasons such as an increase in comorbid conditions. Lack of appropriate diagnosis, treatment or access to care may be important considerations in tackling asthma morbidity and mortality in South Africa (Global Asthma Report, 2018). Based on these statistics it is clear that more attention should be given to managing asthma.

Respiratory viruses are well-known triggers of asthma exacerbations (Sears, 2008; Wark *et al*, 2013). Coronaviruses are respiratory viruses and have been implicated in both upper respiratory tract infections and asthma exacerbations. Hence, during the coronavirus 2019 (COVID-19) pandemic the availability of a tool to measure asthma control in real time would have been useful for all patients with asthma. Acute exacerbations are a frequent cause of hospitalisations and/or emergency room visits (Wark et al, 2013).

The association between asthma and COVID-19 has not been well established (Chhiba *et al*, 2020). Despite a substantial prevalence of asthma in the COVID-19 cohort, it was not shown by Chhiba *et al* (2020) to be associated with an increased risk of hospitalisation. Similarly, Liu *et al* (2020) reported that existing studies have not shown an expected prevalence of asthma in COVID-19 patients. However, the Centers for Disease Control and Prevention (CDC) advised that patients with moderate-to-severe asthma belong to a high-risk group that is susceptible to severe COVID-19. The CDC has indicated that the risk for hospitalisation in patients with asthma and COVID-19 is 1.5 times greater than in those without asthma. Currently, there are no published data to support asthma as a possible risk factor for severe COVID-19 disease (Chhiba *et al*, 2020; Butler et al, 2020; Lieberman-Cribbin *et al*, 2020). Any viral respiratory tract infection, including COVID-19, may cause worsening of asthma with a loss of asthma control. Asthmatics should aim for excellent asthma control at this time (Allergy Foundation of South Africa).

A prospective study at community health centres in the Western Cape indicated that 54% of the patients were not managed according to the South African standard treatment guidelines for asthma and that the cost associated with asthma increased with non-adherence (Ebrahim, 2005). Such non-adherence will probably lead to poor asthma control. The relationship between non-adherence to standard treatment guidelines and asthma control was not studied. The current study involved designing a digital tool to assist in measuring asthma control as a key aspect of improving management.

Building on this idea, we aimed to develop an automated, real-time, digital system to measure asthma control in line with the South African standard treatment guidelines. The project aimed to combine a clinical approach with artificial intelligence in an automated tool to assess asthma control in real time. It is hoped that improving the measurement of asthma control will lead to appropriate action in terms of the management of the patient's asthma. It is possible that such interventions may reduce the risk of hospitalisation due to COVID-19.

METHODS

A structured questionnaire was developed based on the South African standard treatment guidelines (Lalloo et al, 2007). This questionnaire was compared with the Asthma Control Test (ACT) that had been developed internationally to understand the differences between these. The digital system designed allowed the characterisation of the patient's asthma control as uncontrolled, partly controlled or controlled. The asthma control tool was designed in line with the routine practice of a health care professional (family practitioner, nurse or pharmacist) and hence several potential confounding variables in the study design were considered. These included a change in therapy, change in exercise patterns, change in environment and trigger factors such as chest infections. These variables are known to influence control. This approach allowed the collection of real-world evidence.

> This tool will guide health care practitioners to understand the impact of their interventions to optimise asthma control.

The design will allow health care practitioners and patients to use the same tool to measure asthma control, as the same information will be required irrespective of whether the tool is administrated by the practitioner or the patient. The design will allow a practitioner or patient to assess control by comparing it against the patient's own baseline asthma control, i.e. a 'n=1' study design (Valodia et al, 1998; 1999). Hence, the tool will allow individual patients to be tracked over time. The asthma control tool was designed to be used on a smart phone, tablet or desktop computer, which will allow a patient to measure their asthma control as frequently as they choose.

This tool will guide health care practitioners to understand the impact of their interventions to optimise asthma control. From a patient's perspective such a tool will allow optimisation of treatment based on their own measurement of control and will support changes in behaviour, such as improvement in adherence to treatment.

The questionnaire was designed in line with the South African standard treatment guidelines to ensure that it would be acceptable. Another asthma control questionnaire, i.e. the ACT, was assessed. It differed from the study tool in the following four ways:

- Does not assess day-time wheezing
- Does not assess frequency of emergency treatment
- Does not assess peak flow
- Asks patients to rate their asthma control. The latter is too subjective as the purpose of the tool is to rate asthma control and hence it is not necessary to ask this question.

RESULTS

To measure control, a structured questionnaire was developed consisting of five questions. Each of these five questions had a few response options that related to day-time wheezing, night-time symptoms, day-time symptoms, reliever pump or nebuliser use and emergency treatment. The sixth question related to peak flow readings, if these were available. Asthma control was assessed based on the first five questions. The peak flow reading, if available, will be used by the health care practitioner to make the final decision about asthma control. In future, as more patients measure peak flow, this parameter could be included in the algorithm to measure control. Based on the questionnaire 58 possible combinations of responses to the five questions were mapped. Based on these responses 58 decision trees were designed to categorise each patient as uncontrolled, partly controlled or controlled. The approach resembled an ideal clinical approach that a health care practitioner, i.e. the family practitioner, nurse or pharmacist, should follow to assess the patient's control.

The tool was based on the clinical categorisation of asthma and not on a scoring system. It resembled the way health care practitioners should measure asthma control, i.e. categorise asthma control as uncontrolled, partly controlled or controlled based on clinical measures. The tool strictly follows the method of categorising control based on the South African guidelines. Hence, there is no risk of misclassification unless there is a flaw in the guidelines. This tool improves efficiency by using a digital system to categorise control according to these guidelines.

DISCUSSION

The COVID-19 pandemic is an opportunity to reflect on traditional models of health care delivery, to make them more efficient, while maintaining the highest quality of care. It is now time to advance digital health, to improve the management of chronic conditions that play an important role in the treatment of pandemics such as COVID-19. Irrespective of the controversy about the role of asthma in COVID-19, it is nevertheless time to embrace digital health to improve efficiency of care.

The asthma control tool will collect data and analyse the information to categorise patients as uncontrolled, partly controlled or controlled. Such characterisation of the control will allow uncontrolled patients to be referred for intensive disease management. The approach developed will allow each patient in a clinical practice or managed health care system to be tracked individually over time to assess progress. The patient's asthma control can be compared automatically against a baseline measurement to assess whether it is improving or worsening. The digital system could also be included in a patient self-management programme to measure control over time and assess the impact of interventions such as medicines.

The automated tool designed in this study is pivotal for the assessment of health outcomes for asthma. Due to the use of a structured questionnaire it ensures the collection of data in a way that is measurable, reproducible, reliable and interpretable. This was achieved in this study by using scientific principles. Figure 1 indicates the basic principles of how health outcomes are assessed, whereby the health care practitioner or patient will be able to compare their asthma control over time, i.e. compare post-intervention control with baseline control.

FIGURE 1. HEALTH OUTCOMES MEASUREMENT FOR ASTHMA

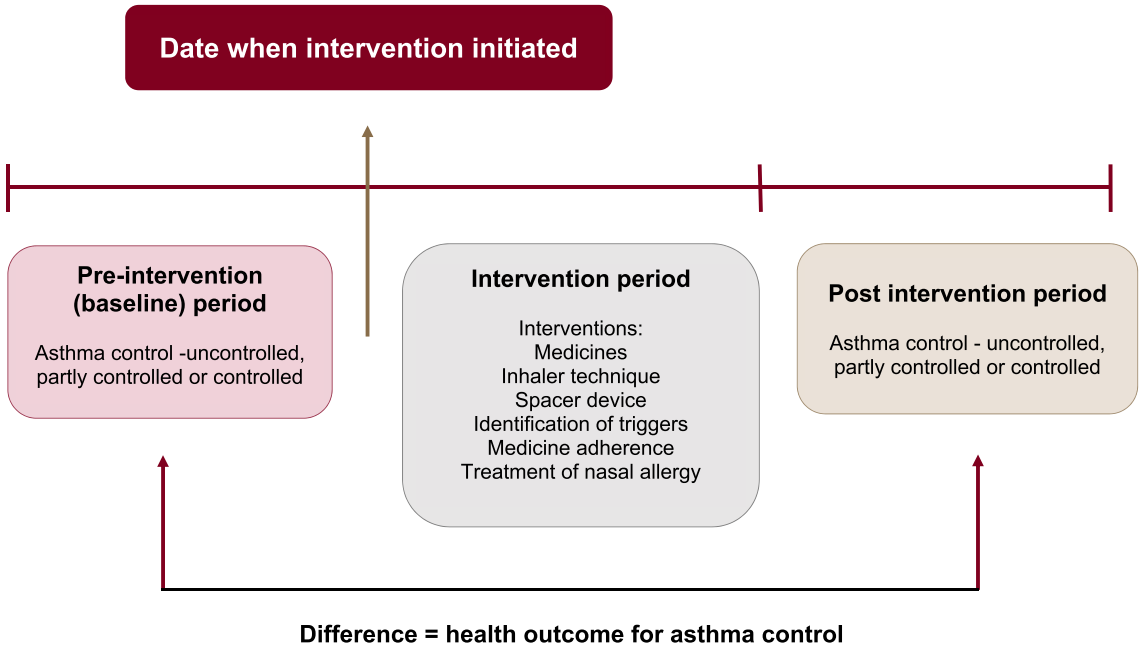

Figure 1 on page 144 indicates the process that should be followed to measure the health outcome of an intervention for asthma using the assessment of control as the outcome measure. The International Society for Pharmaco-economics and Outcomes Research (ISPOR) (Berger *et al*, 2003) defines outcome research as the scientific discipline that evaluates the effect of health care interventions on patient-related, if not patient-specific, economic, clinical and humanistic outcomes. The key focus is on understanding the relationship between the intervention and the outcome.

The health outcome measurements will occur according to a timeline for each patient. Three time periods are involved:

a) the baseline period during which asthma control is assessed
b) the intervention period during which an intervention, such as a medicine or improved inhaler technique, is applied
c) the post-intervention period during which control is again assessed.

The tool will be administered at baseline and the post-intervention period. The difference in asthma control between the baseline and post-intervention period is the health outcome, which reflects the value of an intervention. This approach is generally lacking; not only for asthma but for other diseases as well. The principles applied in the development of this automated tool can be used for other conditions with a high burden of disease.

In future, this tool can be developed so that the health care practitioner will be able to track the patient's progress over time, accessing the tool by using a patient's password or thumbprint. There could also be a graphic display of the patient's asthma control.

The public and private sectors are encouraged to use the tool. It will be useful for medical schemes and managed care organisations to improve asthma control in their beneficiaries. The tool can also be used to develop performance-based re-imbursement for health care practitioners, if required. Such a tool will also improve efficiency in measuring asthma control and thereby allow the health care practitioner to spend more time with the patient to individualise and optimise management.

All role-players, especially regulators, should ensure that health outcomes measurement is a requirement for accreditation purposes for third-party service providers in health care. This is supported by Porter (2010), who indicated that outcome measurement is perhaps the single most powerful tool for revamping the health care system.

As a separate programme, the asthma control tool in this study was incorporated into eight patient tutorials developed to empower patients to optimise and individualise their treatment. The approach also clearly demonstrated that health outcomes such as asthma control can be measured by patients themselves, using an automated digital system. It is hoped that in future, patients who complete the asthma tutorials and have obtained a certificate of completion will be able to obtain loyalty points from their wellness service providers.

The next step will be to implement the tool in the real world to test its efficiency with healthcare practitioners and patients.

CONCLUSION

An effective automated system was designed to measure asthma control in real time for managed healthcare, family practitioners, nurses and pharmacists using decision trees. The principles applied in this study can be linked to measuring health outcomes over time for all disease management programmes. It is hoped that this approach will form the basis for disease management programmes in the public and private sectors.

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