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Chronic Obstructive Pulmonary Disease (COPD)-Inhalers Decoded a Review on Types of Techniques and Common Errors in COPD

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Abstract: Chronic Obstructive Pulmonary Disease (COPD) is a major respiratory disorder associated with frequent exacerbations, increased healthcare utilization, and high treatment costs. Triple therapy consisting of an inhaled corticosteroid (ICS), long-acting muscarinic antagonist (LAMA), and long-acting β2-agonist (LABA) is recommended for patients at risk of exacerbations. However, the ideal timing for initiating triple therapy after a COPD exacerbation remains uncertain. This retrospective cohort study evaluated the clinical and economic outcomes of prompt versus delayed initiation of single-inhaler fluticasone furoate/umeclidinium/vilanterol (FF/UMEC/VI) following a COPD exacerbation. Data were obtained from the IQVIA Parametric Plus database. Patients who started FF/UMEC/VI within 30 days after an exacerbation were classified as prompt initiators, while those who started treatment between 31 and 180 days were considered delayed initiators. The study included 1,904 patients, of whom 529 received prompt treatment and 1,375 received delayed treatment. Patients who initiated therapy promptly experienced significantly fewer overall, moderate, and severe COPD exacerbations compared with delayed initiators. Prompt initiation was also associated with lower all-cause and COPD-related healthcare costs, mainly due to reduced hospitalization expenses. In addition, the time to first exacerbation was longer among prompt initiators, indicating improved disease control. In conclusion, early initiation of single-inhaler FF/UMEC/VI after a COPD exacerbation provides better clinical outcomes and reduces healthcare costs when compared with delayed treatment. These findings support the importance of timely escalation to triple therapy in eligible COPD patients following an exacerbation.

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I. INTRODUCTION

Inhaled drug delivery is the cornerstone of therapy for the treatment of obstructive chronic airway diseases, such as asthma and chronic obstructive pulmonary disease (COPD) [1]. Which approximately 630 million inhalers prescribed globally each year [2] and over 60 million used annually in the UK [3]. The most common devices used to administer aerosolized medication in day-to-day respiratory practice are the pressurized metered-dose inhaler (pMDI) and the dry powder inhaler (DPI). pMDIs are most often prescribed [4], but patients need to inhale correctly and coordinate breathing and actuation to ensure effective drug delivery [5–8]. In the UK, pMDIs are the most commonly prescribed inhaler device [9], contributing to climate change primarily through two key pathways: the use of propellant gases and associated life cycle emissions [10]. Inhalers account for approximately 3% of the overall carbon footprint of the National Health Service (NHS) Inhalers can also be classified based on the drug category of the medication content. Common classes include short-acting beta-agonists (SABAs), short- acting muscarinic antagonists, inhaled corticosteroids (ICS), long- acting beta- agonists (LABAs), long-acting muscarinic antagonists (LAMAs) and combination medications containing 2–3 classes of drugs. Of these medication classes, SABA- containing inhalers have the greatest environmental impact due to their frequency of usage as rescue inhalers [12-13]. Inhalers, while essential for managing respiratory conditions, also contribute to environmental harm, which can, in turn, affect human health [14]. The environmental impact, driven by the emissions from propellants and waste generated by inhaler use, can exacerbate respiratory conditions, creating a cyclical relationship where increased inhaler use further harms the environment [14,15]. This systematic review aims to assess inhaler sustain ability by focusing on the effect of inhaler design typology, prescription patterns, usage patterns, disposal and recycling on human health and environmental sustain ability, while also identifying opportunities for improvement. To guide this exploration, we will assess inhaler sustainability through a tripartite framework focusing on people, processes and products, which highlights the interconnected nature of these elements in achieving sustainability outcomes (figure 1).

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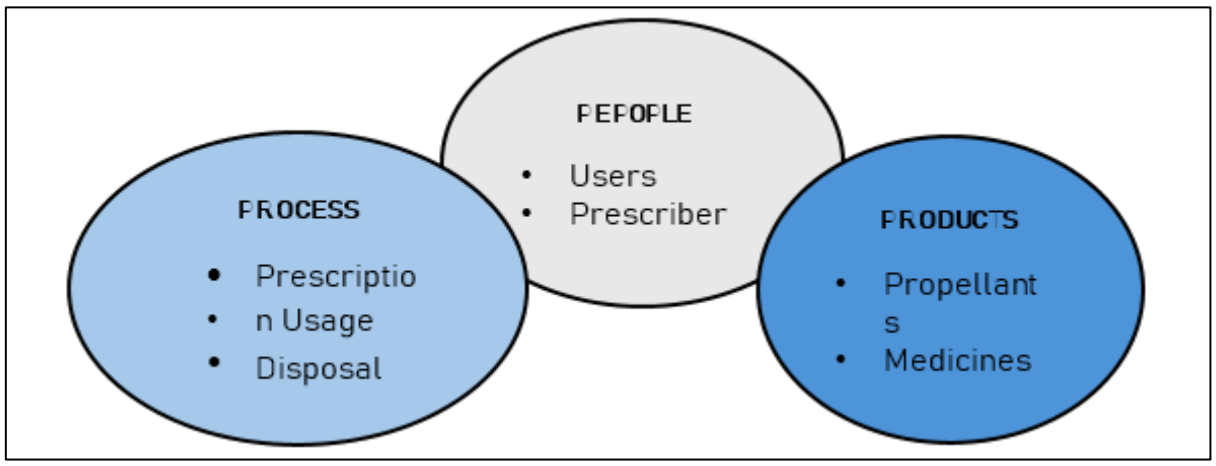


Fig 1 Components of Inhaler Sustainability in Healthcare

The People- Process- Product (PPP) model, also known as the People, Process and Technology model, is a holistic model for process improvement known and used across industries, which can be applied to improving inhaler sustainability [16]. Through this comprehensive multi-perspective analysis, the review aims to identify actionable recommendations for improving inhaler sustainability. The review addresses three interlinked questions that stem from the overarching framework:

- What are the attitudes, actions and outcomes of patients towards the use, adherence to and disposal of sustainable inhaler options (device/medication)?
- What are the attitudes, actions and outcomes of health care professionals in prescribing sustainable inhaler options(device/medication)?
- What is the environmental impact of inhaler devices or medication use?

By addressing these questions, we aim to integrate the people, process and product perspectives, identifying both the opportunities and challenges for promoting inhaler sustainability [17].

➢ *The Importance of Treatment Adherence in COPD Outcome:*

It's important that patients comply with treatment when they have chronic obstructive pulmonary disease (COPD). This is how much patients take medication and use their inhalers as prescribed. Maintenance inhalers help keep respiratory symptoms under control and decrease the likelihood of worsening of the disease. Poor adherence with inhaled medication was reported to be associated with a 40% increase in the odds of COPD exacerbation compared to better adherence in a systematic review and meta-analysis [18].

Failure to adhere may result from the forgetfulness of the patient, stopping the treatment once the symptoms have improved, side effects, treatment cost, and complexity in treatment [19,20].

Furthermore, poor inhaler technique may result in sub-optimal drug delivery to the lungs even with frequent use of an inhaler [21,22]. These problems may contribute to inadequate symptom control and increased healthcare utilization. There is, however, limited and inconsistent evidence to support the association of individual inhaler errors with COPD clinical outcomes [22]. Guidance, check inhaler technique frequently, simplify the treatment if possible and counselling by health care professionals are strategies that can help improve adherence. Pharmacists can show proper inhaler techniques, recognize factors that may hinder adherence to inhaler therapy, and remind patients about their prescribed inhaler regimen. Educational interventions can enhance adherence; however, effectiveness of the various interventions have varied between studies [23,24]. So, it's crucial to evaluate medication adherence and inhaler use to maximize treatment effectiveness and help facilitate better COPD long-term management. [23].

➢ *Reduced Adherence in COPD Factors Affecting it:*

COPD treatment adherence is influenced by factors related to the patient, medication, and socioeconomic factors, which are interactive. Understanding such barriers is crucial as it could have a negative impact on disease management and exacerbation risk if inhalers are not used consistently [25,26]. Patient-related factors: Poor knowledge regarding COPD,low awareness of the long-term effects of maintenance therapy, memory loss and potential side effects may be a problem. Some patients stop taking their medicine when they feel better and some may not understand the benefits of taking medicine regularly. Medication-taking behavior can be further influenced by depression and anxiety, cognitive impairments and limited family support [26–28]. Adherence issues related to medication and inhaled products: Complex doses, multiple inhalers, frequent medication use and expenses may hinder adherence. Medications may not be delivered effectively if inhaler technique is incorrect, there is not enough practical training, or if they are difficult to use. Some problems may be faced by older adults who have low visual acuity or hand coordination deficit and low inspiratory capacity [27,29,30]. Socioeconomic and healthcare related factors: Financial problems, problems getting medicine, lack of access to health care services, inadequate communication with health care providers can lead to missed doses or even to a treatment interruption. Patients may not recognize and correct inhaler use errors if the counselling is inconsistent and/or follow-up is limited [26,31]. In a qualitative study,

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medication affordability, lack of disease knowledge, and forgetfulness or problems accessing health care were identified as important barriers that were reported by individuals with COPD [26]. Likewise, there are some patient characteristics that have been found to be associated with suboptimal adherence, but this does not necessarily imply that they are universal predictors and should be viewed because of observational research [32]. A personalized approach to counselling, a regular review and reassessment of inhaler technique, a simplified inhaler regimen, if clinically appropriate, and an improvement in access to medicines therefore may be helpful to overcome modifiable barriers to adherence [25,33,34].

➢ *Assessment of Adherence in COPD:*

Assessment of treatment adherence is a critical part of the management of chronic obstructive pulmonary disease (COPD) which will help identify whether patients pick up their medication as prescribed and use their inhaler correctly. Initiation, implementation of the prescribed regimen and persistence with the therapy over time are the three aspects generally covered to assess adherence [35]. There are a number of adherence assessment strategies. Self-report questionnaires (such as the Test of Adherence to Inhalers (TAI) and the Morisky Medication Adherence Scale (MMAS) can be used to identify missed doses and patterns of non-adherent behavior. Self-reported adherence, however, can be overstated, as patients might forget to take their medication or give socially desirable responses [36,37]. Medication prescription history in pharmacy records can be used to measure the medication possession ratio (MPR) or proportion of days covered (PDC) to determine if prescribed medications were available to the patient. None of these measures provide evidence that the medication was in fact taken [35,38]. Other information concerning the use of medication is available through dose counters and medication counts, but these cannot provide definitive evidence for proper inhalation. In some electronic systems, technique errors may be detected, and in all systems, the timing and frequency of inhaler use can be recorded [37,39]. A study of adherence to respiratory medications inpatients found that electronic monitoring measured significantly lower adherence than did dose counters or refill records and self-report [40]. The technique of inhaler use should also be assessed by direct observation with a checklist designed for the specific inhaler being used. Patients should be shown their normal inhalation technique to identify and correct errors in inhalation technique by practical counselling [39,41]. Use of adherence questionnaires, refill histories, and/or electronic monitoring when available and direct assessment of inhaler technique when available gives a more thorough assessment than any single technique. Pharmacists and other health care professional should regularly review these for adherence issues and as part of the effective long-term COPD treatment.

Table 1 Advantages and Disadvantages of Different Methods to Measure Adherence in COPD

	Advantages	**Disadvantages**
Direct measurement: PDC Smart apps Pharmacy records	• Easy to use, inexpensive • Provide accurate use and can detect inhaler errors Pharmacy records Provides evidence of drug refill pattern	• Does not always reflect the correct inhalation • Expensive compared to other methods • Need of technology-engaged patients Does not always reflect that the patient took the correct dose
Indirect measurements: Morisky-Green Batalla TAI	• Well validated in COPD • Validated in COPD • Validated in COPD • Specifically designed for inhaled therapies. • Provides information on causes of lack of adherence	• Not specific for inhaled therapies • Reflects patient's understanding of disease Low AUC for detection of non-adherent patterns

➢ *Types of COPD Inhalers:*

- *Pressurized Metered dose Inhalers (pMDIs):*

✓ Preparation: remove the cap, shake and hold the inhaler in a vertical position with the mouthpiece horizontal.
✓ Exhale completely.
✓ Place the teeth and lips around the mouthpiece with the tongue below it and press or click the device whilst start ing a slow inhalation.
✓ Inhale slowly and deeply, without stopping.
✓ Hold the breath for 5 to 10 seconds or for as long as possible.
✓ Put on the cap [31]

- *Dry Powder Inhalers (DPI):*

✓ Preparation: remove the cap, charge the device according to the manufacturer's instructions
✓ Exhale completely.
✓ Place the teeth and lips around the mouthpiece, sealing it.
✓ Take a deep, fast and vigorous breath.
✓ Hold the breath for 5 to 10 seconds or for as long as possible.
✓ Put on the cap

There is also no unanimous consensus to define critical errors. Some of these steps are considered as critical errors by some authors, but not by others [32-35,36,37], Appropriate use of the inhaler starts with preparing the inhaler correctly, which includes taking the mouthpiece cover off the inhaler when necessary [38]. Then, the patient is to place the

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mouthpiece into the mouth in the proper position and seal the lips around it to ensure the medication does not leak out and to allow for the proper aerosol delivery into the respiratory system [32,39].

- *In COPD Patients Poor Inhaler Technique can be Caused by Two Main Reasons:*

Problems with the inhaler device's design and use, and patient limitations. The hand–breath coordination required for pressurized metered-dose inhalers (pMDIs) and the need to inhale at sufficient speed with dry powder inhalers (DPIs) are device-related challenges. Patient factors, including old age, diminished cognitive and/or physical function, use of multiple chronic medications and lack of proper instructions, can also contribute to incorrect inhaler use. Thus, choosing the appropriate device is a very important part of COPD management, as is periodically monitoring the patient's inhalation technique.

- *These are the Reasons why an Inhalation Technique may be Poor Due to the Type of Device:*

Medicines taken by breathing (inhaled) are often used in chronic obstructive pulmonary disease (COPD) to target medicines directly to the respiratory tract. But treatment can only be successful if the patient is able to prepare and use the prescribed inhaler correctly. Inhaler devices have different mechanisms of drug delivery and need to be used in a certain way. Thus, a critical error in one device does not necessarily apply to another device [42–44]. Sub-optimal inhalation technique could lead to less drug being delivered to the lungs which can lead to sub-optimal treatment effects. Typical mistakes involve improper dose preparation, not exhaling properly before inhaling, inadequate inspiratory effort, and lack of coordination and breath holding. These errors can differ in nature and in how often they occur according to the type of inhaler device [42,43].

- *Pressurized Metered-Dose Inhalers (pMDIs):*

Pressurized MDIs are a type of inhaler that delivers an exact dose of aerosol when it is pressed. The devices are typically used in a slow, deep breath, with a synchronized release of the medication [43,44]. The main problem with the devices is a lack of coordination between device activation and breathing. When the patient presses the canister before taking a breath in, or if the patient begins to inhale too late, some medicine may land in the mouth and throat, or escape into the air. Breathing too quickly can also result in greater oropharyngeal deposition [43,45]. Other errors include failing to remove the cap, not shaking the device when required, incorrect priming and failing to prepare subsequent doses properly. Patients can also breathe out straight after breathing in, rather than taking a deep breath, and so the particles will have less time to settle in the lungs [43,44].According to a systematic review and meta-analysis, 86.7% of patients in the studies included committed at least one MDI technique error. Common mistakes were not fully exhaling before inhalation; not holding the breath for long enough; inhaling too quickly; not shaking the device if needed [45]. For patients who are unable to coordinate their inhalation with the actuation of the inhaler, a spacer may be used if it is compatible with the prescribed inhaler and used correctly [44].

- *Dry Powder Inhalers (DPIs):*

Dry powder inhalers (DPIs) are inhalers that release the drug in the form of a powder, which is released by the patient's own breathing. Most DPIs don't need simultaneous manual actuation, as opposed to conventional pMDIs. The patient, however, has to produce a man oeuvre of inspiration suitable for the specific device [43,46]. One of the most common culprits of bad technique is a lack of inspiratory effort. Powder disaggregation and drug delivery may be affected if the patient is not able to produce enough air flow through the DPI. The inspiratory effort required depends on the resistance of the device and should not be the same for all DPIs [46,47]. Another problem is incorrect dose loading. Patients might be required to turn a base or slide a lever, or insert a capsule or pierce a capsule and inhale, depending on the design. If these steps are not carried out properly, the desired dose cannot be achieved [43,46]. Patients can also breathe out through the mouthpiece prior to breathing in, which can moisten the powder. Insufficient lip sealing, improper placement of the device and the improper way of inhaling deeply and forcefully can further affect delivery [43,46]. Results of the multicounty Portal study support assessment of the patient's inspiratory ability and identification of critical DPI errors when assessing COPD therapy [48].

- *Soft-Mist Inhalers (SMIs):*

The aerosol cloud emitted by a soft-mist inhaler is slower moving than most DPIs and in general less inspiratory effort is needed to use a soft-mist inhaler. However, the dosing sequence for patients' needs to be strictly adhered to and the release of the dose should be slow and deep [44,49]. Common mistakes include not holding the device upright, rotating the base the wrong way, not opening the cap, poor coordination between the dose-release button and breath-holding. Additionally, patients may not be able to fully expel air on their way to inhale [49]. In a systematic review and meta-analysis of 12 studies with 1,288 patients, 58.9% of SMI users experienced at least one error of device use. Common errors were lack of complete exhalation prior to inhaling, inability to hold breath and inability to coordinate the release of the dose with the slow, deep inhalation [49].

The results reflect the fact that teaching will not be reduced if the aerosol delivery is simplified. Its prevention and clinical importance.

Why inhalation technique may be poor varies from the type of device. The main requirements of pMDIs are coordination between actuation and breathing; the requirements of DPIs are correct dose preparation and adequate inspiratory effort for the particular device; and the requirements of SMIs are correct manipulation and coordination with slow deep inhalation [42,44,46]. Healthcare professionals should monitor and watch patients perform their inhalers, recognize any mistakes on device-specific checklist and give hands-on training then repeat demonstration. The inspiratory ability, co-ordination, manual dexterity, and ability to perform the necessary steps should all be taken into account when selecting devices [44,47,50]. It is important to regularly review because good technique can

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become lost after a period of time has elapsed. Understanding how to manage device-specific errors can help to maximize inhaled treatment and aid in clinical management of COPD [42,51].

- *Do there Exist Predictive Factors Related to the Patient for Errors in the Inhalation Technique?*

The correct use of inhaler devices in COPD is partly dependent upon the device as well as the patient's physical capacity, cognitive function, level of education or prior training. Some patient-related factors have been shown to be associated with inhaler errors in a number of studies, but not all of them are predictive in all populations or inhaler types [52,53]. Age and physical fitness: Hand strength may decrease, coordination may be affected, vision may be impaired, or joint movement may be affected in older adults. The restrictions may make it more difficult to put together an inhaler, to use the inhaler controls, and/or to match the rate of inhaler medication delivery with breathing. However, age alone is not a good indicator as some studies found no significant age association after controlling for other factors [52,54,55]. Patients with poor education and/or health literacy might struggle to learn the proper inhalation sequence. In one study on 688 persons with COPD, the higher the level of education, the lower the likelihood of poor inhaler technique, but this was an observation and does not imply causation [53]. To ensure correct use of these devices, clear explanations and demonstration may be beneficial to patients with varying levels of education [52,56].Memory difficulties, decreased attention and difficulty with multistep instructions may hinder correct preparation of the device and inhalation, which could be related to cognitive function and prior training. Errors may also be persistent due to lack of prior instruction or inadequate reinforcement. Previous inhaler instruction was highlighted as an important factor associated with improved inhaler technique in a number of studies, but this association was not always seen across all studies identified by a systematic review [52,55]. Arthritis, poor hand-eye coordination, and memory loss or weakness of the respiratory muscles can cause problems with using certain inhalers. Some patients with low inspiratory capacity may experience problems with some dry powder inhalers, and patients with poor hand–breath coordination may have trouble in using conventional pressurized metered-dose inhalers. These abilities should then be taken into account when choosing the device, not just the age and/or diagnosis of the patient [56,57]. Social and treatment-related factors: Poor access to care, lack of health literacy, and socioeconomic status and a need for multiple devices that have different operating requirements may present further obstacles. Another observational COPD trial showed that those who used more than one type of device were more likely to have poor technique with at least one device [53]. But the role of the individual factor varies between studies and results from one population cannot be extrapolated to all patients [52,58]. In general, the characteristics of patients can be of assistance in recognizing patients who might require more support in the use of inhalers; however, no single set of patient characteristics should be relied upon as a definitive predictor of inhaler error. Direct observation of inhaler use, manual dexterity and inspiratory ability assessment and frequent practical training is more reliable in establishing and correcting technique problems [52,57,59].

Regular review and individual counselling are therefore necessary to maximize inhaled treatment in COPD [60,61].

II. CONCLUSION

Inhaled therapy is an essential part of the treatment of chronic obstructive pulmonary disease (COPD) but its benefits are dependent on the choice of inhaled medicines and correct technique. This review identifies that mistakes with pressurized metered-dose inhalers(pMDIs), dry powder inhalers (DPIs) and soft-mist inhalers (SMIs) are still prevalent. Some common issues reported include preparation of the device incorrectly, lack of coordination between the act of inhalation and the act of actuation, poor inspiratory effort during inhalation, exhalation before inhalation and failure to pause on inhalation after a dose. These errors are related to the type of inhaler and the patient's proficiency. Compared with conventional pMDIs, DPIs rely on the appropriate inspiratory effort of the patient, which differs from the device. Unlike conventional pMDIs, the inspiratory effort of the patient must be sufficient relative to the inspiratory effort required by the device. Proper preparation and coordination of dose release with inhalation is also essential for SMIs [63,64]. Patient factors such as reduced dexterity, cognitive impairment, lack of training and decreased knowledge of instructions can add to the possibility of misuse. There is a possibility of under-dosing the medicine as a result of poor inhalation technique, which may be linked to sub-optimal symptom control, exacerbations and increased health care use. There are however various studies that report different associations between individual errors and clinical outcome, and some of the errors observed in the studies have not been shown to have an independent effect on disease progression. As such, errors in inhaler use should be evaluated systematically, and not assumed to have the same effect in all patients. Inhaler technique needs to be improved by a patient-centered approach.

The choice of device should be based on patient's inspiratory ability, coordination, manual dexterity and preference. Errors can be detected and corrected with practical demonstration, patient return demonstration, checklist per device and regular follow-up. In 2025, a systematic review and meta-analysis revealed that repeated, systematic education decreased critical inhale mistakes, further highlighting the significance of repeated, structured education. The pharmacist is a crucial individual who can model appropriate inhaler use, monitor inhaler technique when dispense and on follow-up, provide device-specific information and promote adherence to prescribed therapy. Ensuring the correct technique over time can be achieved through collaboration amongst pharmacists, physicians, nurses and patients. Overall, the use of suitable devices, individual education, with regular reviews, can enhance safe and effective use of inhaled medicines and thus help to manage COPD better.

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