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Original research

Effects of switching from a metered dose inhaler to a dry powder inhaler on climate emissions and asthma control: post-hoc analysis

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ABSTRACT

Objective To compare the effects of switching from a pressurised metered dose inhaler (pMDI)-based to a dry powder inhaler (DPI)-based maintenance therapy versus continued usual care on greenhouse gas emissions (carbon dioxide equivalents, CO_2e) and asthma control.

Methods This post-hoc analysis was based on a subset of 2236 (53%) patients from the Salford Lung Study in Asthma who at baseline were using a pMDI-based controller therapy. During the study patients were randomised to fluticasone furoate/vilanterol (FF/VI) via the ELLIPTA DPI (switched from pMDI to DPI) (n=1081) or continued their usual care treatment (n=1155), and were managed in conditions close to everyday clinical practice. Annual CO_2e (kg) was calculated for the total number of maintenance and rescue inhalers prescribed. Asthma control was assessed by the proportion of ACT responders (composite of ACT total score ≥20 and/or increase from baseline ≥3).

Results The groups were well matched for demographic characteristics and baseline Asthma Control Test (ACT) total score (mean age: 49 years; mean ACT score: usual care, 16.6; FF/VI, 16.5). Annual CO_2e kg per patient (maintenance plus rescue therapy) was significantly lower with FF/VI DPI treatment ('switch' group) than usual care (least squares geometric mean 108 kg (95% CI 102 to 114) vs 240 kg (95% CI 229 to 252), p<0.001). Asthma control was consistently superior over the 12 months in the FF/VI DPI group compared with usual care.

Conclusions Patients switching from a pMDI-based to a DPI-based maintenance therapy more than halved their inhaler carbon footprint without loss of asthma control. The remaining inhaler carbon footprint could be reduced through switches from pMDI to DPI rescue medications or alternative lower-carbon footprint rescue inhalers if available. Asthma control improved in both groups, with greater control demonstrated in those initiated on FF/VI DPI.

Trial registration number NCT01706198.

Key messages

What is the key question?

⇒ Under conditions close to routine clinical practice, what are the effects of switching from a pressurised metered dose inhaler (pMDI)-based to a dry powder inhaler (DPI)-based maintenance therapy versus continued usual care on greenhouse gas emissions (carbon dioxide equivalents) and asthma control?

What is the bottom line?

⇒ Patients switching from a pMDI-based to a DPI-based maintenance therapy more than halved their inhaler carbon footprint without loss of asthma control.

Why read on?

⇒ These data indicate that switching from a pMDI to a DPI is an acceptable and worthwhile option for most patients managed in normal everyday practice.

INTRODUCTION

The healthcare sector is a large contributor of greenhouse gas emissions and there is a growing interest in reducing the carbon footprint of healthcare organisations.[1–3] Chlorofluorocarbons (CFCs) were banned from being used as aerosol propellants under the 1987 Montreal Protocol agreement due to their harmful effects on global warming and ozone depletion.[4] While the hydrofluorocarbons (HFCs) that replaced CFCs in pressurised metered dose inhalers (pMDIs) do not deplete the ozone layer, they are potent greenhouse gases,[5 6] which are now planned to be phased down under the Kigali Amendment to the Montreal Protocol in 2016,[4] and through national F-gas regulations in Europe[7] and the USA.[8] HFC pMDIs account for 3%–4% of the total carbon footprint related to healthcare in the UK, with the majority of emissions associated with use and disposal of pMDIs rather than their manufacture.[5 9–11] To put this in context, a single dose from an HFC-134a pMDI is approximately equivalent to driving 1 mile in a family car.[12]

In recognition of the impact of HFCs on the environment, in the UK, the government, the National Health Service (NHS) and the British Thoracic Society (BTS) all highlight the desirability of switching from pMDI to low carbon-impact alternatives,[9 10 13] supported by derived data that the carbon footprint of a dry powder inhaler (DPI) is in the range of 20–200 times less than an HFC pMDI.[5 11 14] Producers of respiratory medicines are also developing alternative, sustainable inhalers, including greener propellants for pMDIs. While most patients can generate an adequate peak

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inspiratory flow for dose delivery from a range of DPIs,[15–17] a few patients (eg, children or the elderly) prefer or require a pMDI with spacer, and patients' capabilities and preferences are key components in determining inhaler choice.[13 18 19]

The cost of treatment is another consideration when choosing between treatment options.[18 19] In the UK, for controller medications, there is a range of DPI alternatives at comparable prices to pMDIs.[5] However, salbutamol pMDIs are very inexpensive and less than half the cheapest, commonly available DPI salbutamol.[5] The cost of goods in switching to an alternative low-carbon inhaler to the healthcare provider or individual patient should be considered in the context of the comparative cost-effectiveness of the two treatments,[13] as well as the long-term financial cost of their environmental impact.[5] A more effective inhaler which reduced exacerbations and rescue use could reduce overall cost.

The aim of this post-hoc analysis was to evaluate the effects of patients switching maintenance therapy from a pMDI to a DPI compared with those who continued pMDI-based treatment according to usual care on carbon footprint and asthma control. We used data from the Salford Lung Study in Asthma[20] because it included a broad asthma population in a primary care setting with minimal intervention/supervision during the treatment period and a large proportion of patients who were using a pMDI prior to recruitment. During the study patients were allowed to switch to maintenance therapy, making it representative of routine UK clinical practice.

METHODS

Study design and study population

Full details of the study design and results for the primary study have been published previously.[20 21] In brief, the study was a 12-month, open-label, primary care study in which adults with symptomatic asthma who were taking regular maintenance therapy (inhaled corticosteroids (ICS) or ICS/long-acting beta-agonist) were randomised to either a combination of fluticasone furoate/vilanterol (FF/VI) via the ELLIPTA DPI or to continue their usual care as prescribed by their general practitioner. For this post-hoc analysis, all patients who used a pMDI-based controller therapy prior to screening and randomisation were the subset of interest. At the randomisation visit, the study staff trained patients in both treatment groups to follow the correct inhaler techniques. During the 1-year treatment period, patients could have their maintenance treatment adjusted, including dose or inhaler type, at the physician's discretion; that is, they were managed in conditions close to normal everyday clinical practice with no additional prompts or reminders to encourage adherence. The groups included in this analysis were based on the treatment at randomisation.

The study also measured the clinical outcomes of asthma control and rescue medication use. Asthma control was assessed using the Asthma Control Test (ACT)[22] at baseline and at 12, 24, 40 and 52 weeks of treatment. Rescue medication use was measured as the total number of salbutamol inhalers prescribed over the whole treatment period.

Carbon footprint analysis

Total carbon footprint over 12 months was calculated separately for the total number of maintenance and rescue therapy inhalers prescribed during the study, using previously published carbon footprint data expressed as carbon dioxide equivalents (CO_2e kg),[5 11] summarised in table 1. For each subject, the total CO_2e of each inhaler was calculated as the following: (number of inhalers prescribed) × (CO_2e per inhaler), where the CO_2e per inhaler was adjusted for the number of actuations in each inhaler, according to inhaler category (table 1). Within the primary study, there were a wealth of inhalers prescribed in the usual care arm, and given the data came from patients' medical records it could not always be made certain which inhaler type the treatment was contained in. A medical expert review was performed on the prescription data to determine which inhaler the treatments were associated with based on dose, frequency of inhalation, total number of actuations, etc, and they determined which were in DPI, metered dose inhaler (MDI) or undeterminable. The inhalers were then associated to one of the CO_2e categories listed in table 1 and adjusted based on the total number of actuations. For example, if the inhaler had 60 actuations and the category it was associated with was one based on 200 actuations, the inhaler was adjusted to a lower level of carbon emission, as less actuations result in lower levels of emission.

Table 1 Summary of CO_2e (kg) categories by inhaler type

Inhaler	CO_2e kg/inhaler*†	Actuations per inhaler
Small-volume SABA (Salamol)	9.870*	200
Large-volume SABA (VENTOLIN)	25.260*	200
SAMA (Atrovent)	14.590*	200
LABA (Salmeterol)	17.300*	120
ICS (Clenil)	20.350*	200
HFA-134a ICS/LABA	19.650*	120
HFA-227ea ICS/LABA	36.500*	120
RELVAR ELLIPTA‡	0.800†	30
VENTOLIN ACCUHALER (DISKUS)§	0.600†	60

*Wilkinson *et al*.[5]
†Janson *et al*.[11]
‡All maintenance dry powder inhalers (ELLIPTA plus others) were categorised as having CO_2e kg/pack of 0.8.
§All rescue medication dry powder inhalers were categorised as having CO_2e kg/pack of 0.6.
CO_2e, carbon dioxide equivalent; HFA, hydrofluoroalkane; ICS, inhaled corticosteroid; LABA, long-acting beta$_2$-agonist; SABA, short-acting beta$_2$-agonist; SAMA, short-acting muscarinic antagonist.

There was no imputation for missing data. Instead, this emission was adjusted for the subjects' time on study medication, so it corresponded to 12 months on treatment. This approach was taken due to the real-world nature of the study as participants could have ended treatment before or after 12 months of study duration. Treatment groups were compared using a generalised linear model (GLM) assuming a log-normal distribution and by implementing an identity link function adjusting for randomised treatment, age, gender, and both ACT total score and asthma maintenance therapy at baseline per randomisation stratification. The carbon footprint data were analysed on the log scale, and the least square (LS) means of the treatment effects were computed from the GLM. The LS treatment means and 95% CI results on the log scale were back-transformed via the exponential to obtain least squares geometric means (LS GM) and 95% CI for the results to be interpretable on the original scale. Similarly, for the log difference between the LS treatment means and 95% CI, the results were back-transformed via the exponential to obtain the ratio of the LS GM and 95% CI.

Clinical outcomes analysis

Treatment differences in the percentage of patients defined as an ACT responder (an ACT total score ≥20 and/or an increase from baseline in ACT total score of ≥3[23 24]) were analysed using

a logistic regression model for all assessment time points (weeks 12, 24, 40 and 52). The model was adjusted for randomised treatment, asthma maintenance therapy at baseline (per randomisation stratification), baseline ACT total score, baseline ACT total score squared, gender and age. The time point for the primary analysis was 24 weeks. Changes from baseline in ACT total score were analysed via a mixed model repeated measures assuming an unstructured covariance matrix and adjusted for randomised treatment, asthma maintenance therapy at baseline per randomisation stratification, baseline ACT total score, randomised treatment by baseline ACT total score interaction, gender, age, visit, and randomised treatment by visit interaction, with visit included as a repeated measures factor. The number of salbutamol inhalers (adjusted to an equivalence of 200 actuations) prescribed per patient over the 12-month treatment period was analysed using an analysis of covariance model adjusted for randomised treatment, asthma maintenance therapy at baseline per randomisation stratification, ACT total score at baseline per randomisation stratification, gender, age and number of salbutamol inhalers prescribed in the year prior to randomisation.

Patient and public involvement

For this post-hoc analysis, the authors had no direct contact information of the study participants because anonymised data were used in accordance with strict confidentiality guidelines. Therefore, it was not appropriate for any patient to have involvement in developing the hypothesis, specific aims, research questions or plans for the study's design or implementation. No patient was involved in the interpretation or writing of the results. There are no plans to disseminate the results of this study to the individual study participants.

RESULTS

Analysis groups and treatment pathways

We studied patients from the Salford Lung Study in Asthma taking MDI-based controller therapy prior to randomisation. This subset of patients (2236 of 4233, 53%) comprised 1155 and 1081 patients randomised to the usual care and FF/VI DPI groups, respectively. The groups were well matched for demographic characteristics and baseline ACT total score (mean age: 49 years; mean ACT score: usual care, 16.6; FF/VI, 16.5) (table 2). During this real-world study, patients were able to shift from FF/VI DPI to usual therapy as per normal clinical practice, and on usual therapy some patients switched to DPI controller medications (not FF/VI which was not permitted). Over 1 year, the majority of patients in each group remained on the same inhaler type, that is, 80% remained on a pMDI in the usual care group and 85% remained on a DPI in the FF/VI group (table 3). The analysis was based on the prescribed treatment.

Table 2 Baseline characteristics of patients included in the analysis

	Usual care (n=1155)	FF/VI (n=1081)
Age (years), mean (SD)	49 (17)	49 (16)
Female, n (%)	654 (57)	637 (59)
Body mass index (kg/m^2), mean (SD)	29.5 (6.8)	29.6 (6.7)
ACT total score, mean (SD)	16.6 (4.3)	16.5 (4.3)

ACT, Asthma Control Test; FF/VI, fluticasone furoate/vilanterol.

Table 3 Treatment pathways during the study

	Usual care (n=1155)	FF/VI (n=1081)
Inhaler type initiated on, n (%)		
n	1155	1081
DPI	46 (4)	1081 (100)
pMDI	1004 (87)	0
DPI+pMDI	25 (2)	0
Undetermined	80 (7)	0
Number of patients on inhaler type path, n (%)		
DPI during the whole period	39 (3)	916 (85)
pMDI during the whole period	922 (80)	0
DPI → pMDI	5 (<1)	129 (12)
Undetermined	60 (5)	0
pMDI → undetermined	44 (4)	0
pMDI → DPI	18 (2)	0
DPI → undetermined	2 (<1)	12 (1)
Other	65 (6)	24 (2)

DPI, dry powder inhaler; FF/VI, fluticasone furoate/vilanterol; pMDI, pressurised metered dose inhaler.

Carbon footprint

Over the 12-month treatment period, the LS GM total carbon footprint (maintenance plus rescue therapy) was more than halved in patients taking FF/VI (108 kg, 95% CI 102 to 114) ('switch' group) compared with those continuing usual care treatment (240 kg, 95% CI 229 to 252; LS GM ratio usual care vs FF/VI 2.23, 95% CI 2.08 to 2.39, p<0.001) (figure 1 and table 4). The carbon footprint of maintenance therapy alone was 10-fold lower for FF/VI compared with usual care (LS GM 118 kg (95% CI 112 to 125) vs 11 kg (95% CI 10 to 12) for usual care and FF/VI groups, respectively; LS GM ratio of 10.65 (95% CI 9.86 to 11.50), p<0.001). The amount of rescue medication (almost all salbutamol MDIs) was also lower in the FF/VI group (LS GM 88 kg (95% CI 82 to 93) vs 109 kg (95% CI 103 to 116), respectively; LS GM ratio usual care vs FF/VI of 1.25 (95% CI 1.15 to 1.35), p<0.001).

The data for the carbon footprint analyses demonstrated variable levels of skewness and kurtosis. The quantile-quantile plots of the residuals showed adequate evidence of normality for the combined and rescue inhaler analyses; however, the maintenance alone analysis showed some evidence of kurtosis, indicating inferences should be interpreted with caution in this group.

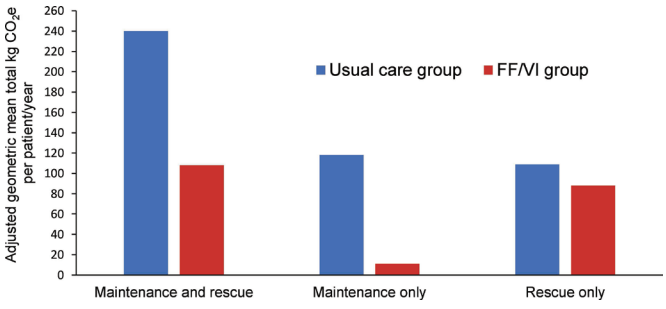

Figure 1 Adjusted annual carbon footprint following maintenance and rescue medication in the usual care and FF/VI groups. CO_2e, carbon dioxide equivalent; FF/VI, fluticasone furoate/vilanterol.

Table 4 Summary of carbon footprint data

	Usual care (n=1155)	FF/VI (n=1081)
Maintenance and rescue inhalers		
n	1155	1081
Total CO_2e* over the 12-month treatment period	351 870	175 470
LS geometric mean CO_2e per patient (95% CI)	240 (229 to 252)	108 (102 to 114)
Ratio of LS geometric means† (95% CI)	2.23 (2.08 to 2.39)	
P value	<0.001	
Maintenance only		
n	1095	1081
Total CO_2e* over the 12-month treatment period	165 894	27 119
LS geometric mean CO_2e per patient (95% CI)	118 (112 to 125)	11 (10 to 12)
Ratio of LS geometric means† (95% CI)	10.65 (9.86 to 11.50)	
P value	<0.001	
Rescue only		
n	1131	1061
Total CO_2e* over the 12-month treatment period	185 975	148 351
LS geometric mean CO_2e per patient (95% CI)	109 (103 to 116)	88 (82 to 93)
Ratio of LS geometric means† (95% CI)	1.25 (1.15 to 1.35)	
P value	<0.001	

*For each subject, the total CO_2e of each inhaler was calculated as the following: (number of inhalers prescribed) × (CO_2e per inhaler), where the CO_2e per inhaler is adjusted for the number of actuations in each inhaler. This emission was adjusted, taking the subjects' time on study medication into account, so it corresponded to 12 months on treatment. Inhalers' total actuations are adjusted by the inhaler category they were assigned to (see table 1).
†Usual care vs FF/VI.
CO_2e, carbon dioxide equivalent; FF/VI, fluticasone furoate/vilanterol; LS, least squares.

Table 5 Summary of change from baseline in ACT total score and number of prescribed salbutamol inhalers

	Usual care (n=1155)	FF/VI (n=1081)
Change from baseline in ACT total score		
Week 12		
n	1104	1021
LS mean change (SE)	1.89 (0.115)	3.40 (0.120)
Difference* (95% CI)	1.51 (1.19 to 1.83), p<0.001	
Week 24		
n	1063	988
LS mean change (SE)	1.75 (0.125)	3.24 (0.130)
Difference* (95% CI)	1.49 (1.14 to 1.84), p<0.001	
Week 40		
n	1048	957
LS mean change (SE)	1.67 (0.127)	3.13 (0.134)
Difference* (95% CI)	1.45 (1.10 to 1.81), p<0.001	
Week 52		
n	1046	962
LS mean change (SE)	1.60 (0.124)	3.05 (0.130)
Difference* (95% CI)	1.45 (1.10 to 1.80), p<0.001	
Number of salbutamol inhalers prescribed during the study		
n (patients)	1154	1076
LS mean (SE)	8.0 (0.14)	7.2 (0.14)
Difference* (95% CI)	−0.8 (−1.2 to −0.5), p<0.001	

*FF/VI vs usual care.
ACT, Asthma Control Test; FF/VI, fluticasone furoate/vilanterol; LS, least squares.

Clinical outcomes

Asthma control improved in both treatment arms (table 5). At week 24, the odds of being an ACT responder (ACT total score of ≥20 and/or an increase from baseline of ≥3) in the FF/VI group (76%) were approximately twice that of being a responder in the usual care group (63%) (adjusted OR: 1.91 (95% CI 1.57 to 2.33), p<0.001), and this difference was consistent over the 12-month treatment period (figure 2). Patients who switched to FF/VI were prescribed approximately one fewer salbutamol inhalers over the 12-month treatment period compared with those who continued on usual care (LS mean of 7.2 vs 8, respectively).

DISCUSSION

This post-hoc analysis of data from the Salford Lung Study in Asthma showed that switching from a pMDI to a DPI maintenance therapy, in conditions representing everyday clinical practice, more than halved the per-patient annual carbon footprint for those on FF/VI DPI compared with those continuing on predominantly pMDI maintenance therapy. The remaining carbon footprint was almost all due to salbutamol MDI rescue, which was also significantly lower in the FF/VI DPI arm. There was no loss of asthma control in either group. Indeed, asthma control was consistently better throughout the 12 months in those patients randomised to FF/VI DPI, consistent with the findings of the primary study.[20]

The approximate per-patient annual carbon footprint saving demonstrated in this study was 130 kg CO_2e. If these carbon savings were scaled up to include all adult patients with asthma in the UK who use a pMDI (n≈3 million[13 25]), this could result in an annual reduction of approximately 390 CO_2e kilotons. This saving would represent approximately

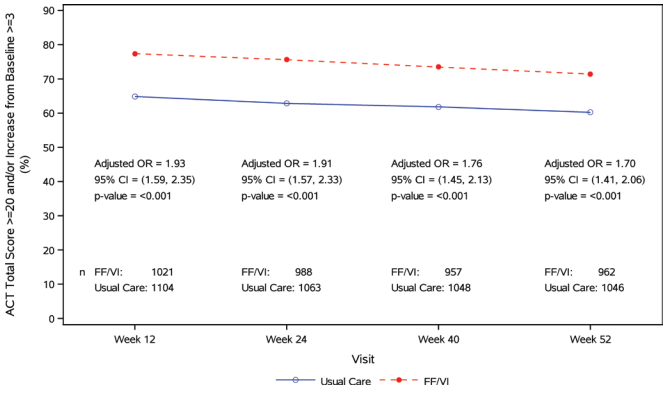

Figure 2 Responders according to ACT score. The analysis method at each visit was logistic regression adjusted for randomised treatment, asthma maintenance therapy at baseline per randomisation stratification, baseline ACT total score, baseline ACT total score squared, gender and age. ACT, Asthma Control Test; FF/VI, fluticasone furoate/vilanterol.

40% of the total carbon footprint due to MDIs in the UK, which is reported to be one megaton of CO_2e.[5] The potential for carbon saving could be much greater if patients also switched to a rescue medication administered via a DPI as, in this study, the majority of patients used pMDI rescue medication inhalers, typical of usual care in the UK.[5 11] Nonetheless, there was still a small carbon saving observed with respect to rescue medication in the group switching to FF/VI treatment, as a result of patients using less rescue medication in this group due to their improved asthma control.

A previous study on SERETIDE and VENTOLIN given via pMDI, based on an assumption of full adherence, calculated the annual per-patient total carbon footprint to be 439 kg CO_2e.[11] The annual per-patient total carbon footprint of 240 kg CO_2e in the usual care group (using pMDI as maintenance as well as rescue medication) in the current study is lower due to lower adherence in real-world data. It was calculated using actual prescribed data and, although it could not be determined if patients picked up the pharmacy prescription and took the medication, it is much more likely to represent the real picture in the UK. In addition, the real-world nature of the Salford Lung Study in Asthma design allowed patients to switch inhaler type during the study (ie, patients in the usual care group could potentially switch to a DPI), which although small in number may have resulted in the carbon footprint estimation not being totally representative of the designated treatment group. This shows that substantial carbon savings can be made in a real clinical setting while improving asthma control. We acknowledge that any study with some degree of intervention cannot exactly reflect routine clinical practice; however, the Salford Lung Study in Asthma was managed to represent conditions as close to routine clinical practice as possible.

The study design was also in keeping with position statements from the UK government, NHS and BTS that highlight the need to implement switches from pMDIs to low carbon-impact alternatives,[9 10 13] and the ability to switch back from a DPI to a pMDI in the usual care arm increases the external validity of our results. An encouraging message from this study is that the majority of patients who switched from a pMDI-based treatment to FF/VI did not switch back during the 1-year treatment period, suggesting that they tolerated DPI therapy well and without any detriment to their asthma control. The quality of the data collected was good overall, with only a relatively small number of prescriptions being undeterminable (table 3). The distribution of the greenhouse gas inhaler data exhibited heavy skewness due to the extremities in CO_2e between MDI and DPI categories used in this analysis.[11] The log-normal distribution was assessed and selected as the best fitting for these data, which is also in line with previous literature that describes the log-normal distribution to be a good fit for greenhouse emission data.[26 27] Although the maintenance alone analysis showed some evidence of kurtosis, indicating a degree of caution should be taken in interpreting these results, the combined (maintenance plus rescue use) and rescue alone analyses showed adequate evidence of normality to provide reassurance that these results are robust.

The UK is an outlier compared with the rest of Europe in its high continued use of pMDIs.[13] The results of this analysis support the growing calls from official bodies that, where possible, switches from pMDI to low carbon-impact alternatives should be sought, for example from pMDI to DPI or from high-volume pMDI to low-volume pMDI.[5 9 10 13] Together with the role of pharmaceutical companies in producing accessible alternatives, prescribers, pharmacists and patients should be made aware of the significant differences in the global warming potential of different inhalers.[13] The carbon footprint data used in our analysis were based on the cradle-to-grave emissions analysis previously described.[11] We do recognise, however, that there are current shortcomings in the disposal of inhalers in terms of the level of recycling.

DPIs are an effective and cost-effective alternative to pMDIs[13] and, as these results suggest, one that appears is well tolerated by patients with asthma. This latter point is also supported by real-life, primary care data that showed patients made fewer errors using DPIs compared with pMDIs.[28] The ELLIPTA DPI, used in the Salford Lung in Asthma study, has also been shown to result in fewer critical errors compared with other inhalers, including pMDIs.[29]

In conclusion, in the subset of patients of the Salford Lung Study in Asthma who at enrolment were on a pMDI-based asthma maintenance therapy and who switched to a DPI therapy (FF/VI DPI), there was a substantial reduction in carbon footprint without loss of asthma control. The remaining inhaler carbon footprint could be further reduced through switches from pMDI to rescue medications in DPIs or to alternative lower-carbon footprint rescue inhalers if and when they become available. Both groups showed improvements in asthma control, with greater control demonstrated in those initiated on FF/VI. These data indicate that switching from a pMDI to a DPI is an acceptable and worthwhile option for most patients managed in normal everyday practice.

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Contributors AAW, JR, LF, ML, AM and DL were involved in the study design and collection of data. JR and LF were responsible for data analysis. All authors were involved in the data interpretation and in the drafting, critical revision and approval of the manuscript. The corresponding author attests that all listed authors meet the authorship criteria and that no others meeting the criteria have been omitted. DL is the guarantor and affirms that the manuscript is an honest, accurate and transparent account of the study being reported and that no important aspects of the study have been omitted.

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Disclaimer GlaxoSmithKline-affiliated authors had a role in study design, collection of data, data interpretation and writing of the report.

Competing interests All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare the following: AAW discloses speaker fees and expenses from GlaxoSmithKline and advisory expenses from Novartis, outside of the submitted work. He is also Chairman of, and shareholder in, Reacta Biotech. JR, DL, LF, ML and AM are employees of GSK and hold shares. MH has no conflicts of interest to declare. CJ reports personal fees from AstraZeneca, Boehringer Ingelheim, Chiesi, GlaxoSmithKline, Novartis and TEVA, outside the submitted work.

Patient consent for publication Not required.

Ethics approval The Salford Lung Study in Asthma involved human participants and was approved by the National Research Ethics Service Committee North West, Greater Manchester South (reference 12/NW/0455; IRAS ID 106072). Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. Information on GlaxoSmithKline R&D's data sharing commitments and request access can be found at https://www.clinicalstudydatarequest.comhttps://www.clinicalstudydatarequest.com.

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