Once-Daily Single-Inhaler Triple versus Dual Therapy in Patients with COPD

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BACKGROUND

The benefits of triple therapy for chronic obstructive pulmonary disease (COPD) with an inhaled glucocorticoid, a long-acting muscarinic antagonist (LAMA), and a long-acting β₂-agonist (LABA), as compared with dual therapy (either inhaled glucocorticoid–LABA or LAMA–LABA), are uncertain.

METHODS

In this randomized trial involving 10,355 patients with COPD, we compared 52 weeks of a once-daily combination of fluticasone furoate (an inhaled glucocorticoid) at a dose of 100 μg, umecilimum (a LAMA) at a dose of 62.5 μg, and vilanterol (a LABA) at a dose of 25 μg (triple therapy) with fluticasone furoate–vilanterol (at doses of 100 μg and 25 μg, respectively) and umecilimum–vilanterol (at doses of 62.5 μg and 25 μg, respectively). Each regimen was administered in a single Ellipta inhaler. The primary outcome was the annual rate of moderate or severe COPD exacerbations during treatment.

RESULTS

The rate of moderate or severe exacerbations in the triple-therapy group was 0.91 per year, as compared with 1.07 per year in the fluticasone furoate–vilanterol group (rate ratio with triple therapy, 0.85; 95% confidence interval [CI], 0.80 to 0.90; 15% difference; P<0.001) and 1.21 per year in the umecilimum–vilanterol group (rate ratio with triple therapy, 0.75; 95% CI, 0.70 to 0.81; 25% difference; P<0.001). The annual rate of severe exacerbations resulting in hospitalization in the triple-therapy group was 0.13, as compared with 0.19 in the umecilimum–vilanterol group (rate ratio, 0.66; 95% CI, 0.56 to 0.78; 34% difference; P<0.001). There was a higher incidence of pneumonia in the inhaled-glucocorticoid groups than in the umecilimum–vilanterol group, and the risk of clinician-diagnosed pneumonia was significantly higher with triple therapy than with umecilimum–vilanterol, as assessed in a time-to-first-event analysis (hazard ratio, 1.53; 95% CI, 1.22 to 1.92; P<0.001).

CONCLUSIONS

Triple therapy with fluticasone furoate, umecilimum, and vilanterol resulted in a lower rate of moderate or severe COPD exacerbations than fluticasone furoate–vilanterol or umecilimum–vilanterol in this population. Triple therapy also resulted in a lower rate of hospitalization due to COPD than umecilimum–vilanterol. (Funded by GlaxoSmithKline; IMPACT ClinicalTrials.gov number, NCT02164513.)

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TRIPLE INHALED THERAPY FOR CHRONIC obstructive pulmonary disease (COPD) comprises an inhaled glucocorticoid, a long-acting muscarinic antagonist (LAMA), and a long-acting β₂-agonist (LABA). Such treatment is recommended in the Global Initiative for Chronic Obstructive Lung Disease (GOLD) management strategy for COPD in patients who have clinically significant symptoms despite treatment with an inhaled glucocorticoid–LABA or LAMA–LABA and who are at increased risk for frequent or severe exacerbations. Although studies have shown that triple inhaled therapy has positive effects on lung function and COPD symptoms as compared with dual therapy, its use until recently has required patients to use multiple inhalers several times per day.

Recently, single inhalers containing an inhaled glucocorticoid, a LABA, and a LAMA have been developed; these inhalers offer potential advantages in practicality and adherence to therapy. However, the effectiveness of combination inhaled therapies has not been comprehensively evaluated in patients with COPD who have the highest symptom burden. Controversy exists regarding the use of inhaled glucocorticoids in COPD and the relative benefits of triple therapy as compared with dual therapy (inhaled glucocorticoid–LABA or LAMA–LABA) in patients with a history of previous exacerbations. The Informing the Pathway of COPD Treatment (IMPACT) trial evaluated the relative benefits and risks of these three regimens in patients with symptomatic COPD and a history of exacerbations. Here we report the primary, secondary, and other efficacy and safety outcomes.

METHODS

TRIAL DESIGN AND OVERSIGHT

The IMPACT trial was a phase 3, randomized, double-blind, parallel-group, multicenter trial. The primary objective was to evaluate the effects of 52 weeks of a once-daily combination of fluticasone furoate (an inhaled glucocorticoid) at a dose of 100 μg, umeclidinium (a LAMA) at a dose of 62.5 μg, and vilanterol (a LABA) at a dose of 25 μg (triple therapy), as compared with fluticasone furoate–vilanterol (at doses of 100 μg and 25 μg, respectively) or the dual bronchodilator umeclidinium–vilanterol (at doses of 62.5 μg and 25 μg, respectively), on the rate of moderate or severe COPD exacerbations. Each regimen was administered in a single-dry-powder inhaler (Ellipta, GlaxoSmithKline).

Patients enrolled were 40 years of age or older and had symptomatic COPD (COPD Assessment Test [CAT] score, ≥10; range, 0 to 40, with higher scores indicating more symptoms; minimal clinically important difference, 2 units). Patients had to have either a forced expiratory volume in 1 second (FEV₁) that was less than 50% of the predicted normal value and a history of at least one moderate or severe exacerbation in the previous year, or an FEV₁ of 50 to 80% of the predicted normal value and at least two moderate exacerbations or one severe exacerbation in the previous year. Patients continued to take their own medication, which could include a LAMA, a LABA, or an inhaled glucocorticoid alone or in combination, during a 2-week run-in period before randomization.

The trial was performed in 37 countries from June 2014 through July 2017. It was conducted in accordance with Good Clinical Practice guidelines and the provisions of the Declaration of Helsinki and received approval from local institutional review boards or independent ethics committees. All the patients provided written informed consent. The patients and treatment groups are described in Tables S1 through S3 in the Supplementary Appendix, available with the full text of this article at NEJM.org.

All the patients underwent baseline chest radiography at trial entry, and all initial and subsequent chest images were overread centrally by radiologists who were unaware of the clinical information or trial treatment. The assignment of a diagnosis of pneumonia and the labeling of an event as an exacerbation were determined according to the clinical judgment of the investigator. The protocol required that all the patients with a suspected pneumonia, or moderate or severe exacerbation, have a chest radiograph obtained to help confirm the presence of a new infiltrate and better capture and understand these adverse events. When a diagnosis of pneumonia was made, the clinician also considered increased cough, sputum purulence, dyspnea, and signs on physical examination or laboratory testing.

The trial was designed by academic partners and the sponsor (GlaxoSmithKline), which also paid for editorial support; the lead author is an employee of the sponsor. All the authors dis-
discussed and interpreted the results, agree with
the completeness and accuracy of the data and
analyses, and vouch for the adherence of the
trial to the protocol, available at NEJM.org. All
the authors contributed to the data analyses and
writing of the manuscript.

**PRIMARY EFFICACY OUTCOME**
The primary efficacy outcome was the annual
rate of moderate or severe exacerbations during
treatment (including 1 day after the last dose
was administered). The two coprimary treatment
comparisons were triple therapy versus umeclidinium–vilanterol, and triple therapy versus
fluticasone furoate–vilanterol.

Patients completed an electronic diary each
morning to record their symptoms and were
alerted to contact their trial investigator if symp-
toms suggestive of an exacerbation worsened
over the course of 2 consecutive days. The inves-
tigator confirmed the presence or absence of an
exacerbation. The severity of an exacerbation was
defined according to the treatment. A mild exacer-
bation was worsening of symptoms treated
with increased albuterol. A moderate exacerba-
tion was defined as an exacerbation leading to
treatment with antibiotics or systemic glucocor-
ticoids. A severe exacerbation was one resulting
in hospitalization or death.

**SECONDARY AND OTHER EFFICACY OUTCOMES**
Secondary outcomes in the statistical hierarchy
were grouped sequentially according to lung
function and symptoms and the time to the first
exacerbation. The first analysis block included
spirometry to assess trough FEV₁ and the change
in the St. George’s Respiratory Questionnaire
(SGRQ) total score, as measured by the COPD-
specific version, to assess health-related quality
of life (scores range from 0 to 100, with lower
scores indicating better health-related quality
of life; minimal clinically important difference,
4 points). The second block in the hierarchy as-
sessed the time to the first moderate or severe
COPD exacerbation during treatment (Fig. S2 in
the Supplementary Appendix).

Prespecified protocol-defined secondary out-
comes that were not in the hierarchy included
the annual rate of moderate or severe exacerba-
tions and the time to the first moderate or severe
exacerbation among patients with a blood eosino-
phil count of at least 150 cells per microliter at
baseline, and the annual rate of severe exacerba-
tions. Protocol-defined other outcomes included
analyses of lung function, time to death from
any cause, health-related quality of life, and all
exacerbations (mild, moderate, or severe) in the
entire patient population and dyspnea in a sub-
set of patients as assessed according to the Base-
line Dyspnea Index and Transition Dyspnea In-
dex (TDI; values range from −9 to 9, with lower
values indicating worsening severity of dyspnea;
minimal clinically important difference, 1 unit).
(For details, see the section on additional statis-
tical information in the Supplementary Appen-
dix or see the protocol and statistical analysis
plan, available with the protocol.)

**SAFETY ASSESSMENTS**
Incidence of adverse events, serious adverse
events, pneumonia, cardiovascular events, bone
fractures, and other adverse events of special
interest (prespecified adverse events associated
with the use of inhaled glucocorticoids, LAMAs,
or LABAs) were documented at each clinic visit.
Supporting radiography was used to document
incidences of pneumonia.

Electrocardiographic (ECG) measurements and
vital signs were assessed at screening and after
4, 28, and 52 weeks of treatment. Clinical
(chemical and hematologic) assessments were
performed at screening and at 16, 28, and 52
weeks. All reports of serious adverse events and
all trial deaths were adjudicated by an indepen-
dent adjudication committee whose members
were unaware of the treatment assignments.

**STATISTICAL ANALYSIS**
It was estimated a priori that the annual rate of
moderate or severe exacerbations would be 0.80
among patients treated with triple therapy, 0.91
among those treated with fluticasone furoate–
vilanterol, and 0.94 among those treated with
umeclidinium–vilanterol. On the basis of a two-
sided 1% significance level and 90% power and
assuming a negative binomial model with a
dispersion parameter of 0.75, we calculated that
approximately 4000 patients would be needed in
the triple-therapy group, 4000 in the fluticasone
furoate–vilanterol group, and 2000 in the umecli-
dinium–vilanterol group. The truncated Hoch-
berg method was used in a closed testing hier-
archy across the coprimary and key secondary
treatment comparisons to control type I error at
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the 5% level. Efficacy and safety analyses were performed in the intention-to-treat population, except for the TDI, which was assessed in a subset of 5058 patients. Further details are provided in the section on additional statistical information and Figure S2 in the Supplementary Appendix.

Table 1. Baseline Characteristics of the Patients (Intention-to-Treat Population).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Triple Therapy (N = 4151)</th>
<th>Fluticasone Furoate–Vilanterol (N = 4134)</th>
<th>Umeclidinium–Vilanterol (N = 2070)</th>
<th>Total (N = 10,355)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age — yr</td>
<td>65.3±8.2</td>
<td>65.3±8.3</td>
<td>65.2±8.3</td>
<td>65.3±8.3</td>
</tr>
<tr>
<td>Female sex — no. (%)</td>
<td>1385 (33)</td>
<td>1386 (34)</td>
<td>714 (34)</td>
<td>3485 (34)</td>
</tr>
<tr>
<td>Body-mass index†</td>
<td>26.6</td>
<td>26.7</td>
<td>26.6</td>
<td>26.6</td>
</tr>
<tr>
<td>Former smokers — no. (%)‡</td>
<td>2715 (65)</td>
<td>2711 (66)</td>
<td>1342 (65)</td>
<td>6768 (65)</td>
</tr>
<tr>
<td>Moderate or severe COPD exacerbations in the previous yr — no. (%)</td>
<td>2 (&lt;1)</td>
<td>5 (&lt;1)</td>
<td>2 (&lt;1)</td>
<td>9 (&lt;1)</td>
</tr>
<tr>
<td>1</td>
<td>1853 (45)</td>
<td>1907 (46)</td>
<td>931 (45)</td>
<td>4691 (45)</td>
</tr>
<tr>
<td>2</td>
<td>1829 (44)</td>
<td>1768 (43)</td>
<td>890 (43)</td>
<td>4487 (43)</td>
</tr>
<tr>
<td>≥3</td>
<td>467 (11)</td>
<td>454 (11)</td>
<td>247 (12)</td>
<td>1168 (11)</td>
</tr>
<tr>
<td>≥2 Moderate COPD exacerbations in the previous yr — no. (%)</td>
<td>1967 (47)</td>
<td>1921 (46)</td>
<td>989 (48)</td>
<td>4877 (47)</td>
</tr>
<tr>
<td>≥1 Severe COPD exacerbation in the previous yr — no. (%)</td>
<td>1087 (26)</td>
<td>1069 (26)</td>
<td>515 (25)</td>
<td>2671 (26)</td>
</tr>
<tr>
<td>≥2 Severe COPD exacerbations in the previous yr — no. (%)</td>
<td>147 (4)</td>
<td>148 (4)</td>
<td>76 (4)</td>
<td>371 (4)</td>
</tr>
<tr>
<td>Postbronchodilator FEV1 — % of predicted normal value</td>
<td>45.7±15.0</td>
<td>45.5±14.8</td>
<td>45.4±14.7</td>
<td>45.5±14.8</td>
</tr>
<tr>
<td>Mean score on the COPD Assessment Test at screening§</td>
<td>20.1±6.1</td>
<td>20.1±6.1</td>
<td>20.2±6.2</td>
<td>20.1±6.1</td>
</tr>
</tbody>
</table>

* Plus–minus values are means ±SD. Patients in the triple-therapy group received a once-daily inhaled combination of 100 μg of fluticasone furoate, 62.5 μg of umeclidinium, and 25 μg of vilanterol. Patients in the fluticasone furoate–vilanterol group received a once-daily inhaled combination of 100 μg of fluticasone furoate and 25 μg of vilanterol. Patients in the umeclidinium–vilanterol group received a once-daily inhaled combination of 62.5 μg of umeclidinium and 25 μg of vilanterol. A moderate exacerbation of chronic obstructive pulmonary disease (COPD) was defined as one leading to treatment with antibiotics or systemic glucocorticoids. A severe COPD exacerbation was defined as one resulting in hospitalization or death. FEV1 denotes forced expiratory volume in 1 second.

† The body-mass index is the weight in kilograms divided by the square of the height in meters.

‡ All the patients were required to have at least a 10 pack-year smoking history. Former smokers were defined as those who had stopped smoking at least 6 months before screening.

§ Scores on the COPD Assessment Test range from 0 to 40, with higher scores indicating more symptoms. The minimal clinically important difference is 2 units.

RESULTS

TRIAL POPULATION

The intention-to-treat population included 10,355 patients who underwent randomization and received investigational medication (4151 received triple therapy, 4134 received fluticasone furoate–vilanterol, and 2070 received umeclidinium–vilanterol). Overall, 9087 patients (88%) completed the trial, and 7991 (77%) completed the trial while receiving investigational medication (Fig. S1 in the Supplementary Appendix). In the intention-to-treat population, there were no clinically significant differences among the three treatment groups with regard to baseline demographic characteristics, COPD exacerbations, lung function, and CAT score (Table 1). The majority of patients (66%) were male, and the mean age was 65.3 years. A total of 18% of the patients had bronchodilator reversibility (defined as an increase in FEV1 of ≥12% and ≥200 ml after administration of albuterol). A total of 43% had a baseline blood eosinophil level of less than 150 cells per microliter.

On trial entry, 38% of the patients were re-
receiving triple therapy including an inhaled glucocorticoid, a LABA, and a LAMA; 29% were receiving an inhaled glucocorticoid and a LABA; and 8% were receiving a LAMA and a LABA. Details on medications at trial entry are provided in Table S4 in the Supplementary Appendix. After the initiation of investigational medication, the rate of premature discontinuation of treatment was lower in the triple-therapy group than in the dual-therapy groups; 758 patients (18%) withdrew from triple therapy, 1040 (25%) from fluticasone furoate–vilanterol, and 566 (27%) from umeclidinium–vilanterol.

**Primary Efficacy Analysis**

The rate of moderate or severe exacerbations during treatment among patients assigned to triple therapy was 0.91 per year, as compared with 1.07 per year among those assigned to fluticasone furoate–vilanterol (rate ratio with triple therapy, 0.85; 95% confidence interval [CI], 0.80 to 0.91; 15% difference; P<0.001) and 1.21 per year among those assigned to umeclidinium–vilanterol (rate ratio with triple therapy, 0.75; 95% CI, 0.70 to 0.81; 25% difference; P<0.001). Thus, the rate of moderate or severe exacerbations was significantly lower with the combination of fluticasone furoate, umeclidinium, and vilanterol than with fluticasone furoate–vilanterol or umeclidinium–vilanterol (Fig. 1A).

**Secondary Efficacy Analyses**

Triple therapy was associated with a lower risk of moderate or severe exacerbations during treatment than dual therapy, as assessed in a time-to-first-event analysis. The hazard ratio for triple therapy versus fluticasone furoate–vilanterol was 0.85 (95% CI, 0.80 to 0.91; 15% difference; P<0.001), and the hazard ratio for triple therapy versus umeclidinium–vilanterol was 0.84 (95% CI, 0.78 to 0.91; 16% difference; P<0.001) (Fig. 1B).

The annual rate of moderate or severe exacerbations was lower with triple therapy than with either dual-therapy combination, regardless of eosinophil level, although a greater reduction in the exacerbation rate was observed in patients with eosinophil levels of at least 150 cells per microliter. Among patients with eosinophil levels of less than 150 cells per microliter, the annual rate of moderate or severe exacerbations was 0.85 (95% CI, 0.80 to 0.91) with triple therapy, 1.06 (95% CI, 0.99 to 1.14) with fluticasone furoate–vilanterol, and 0.97 (95% CI, 0.88 to 1.07) with umeclidinium–vilanterol. Among patients with...
The annual rate was 0.95 (95% CI, 0.90 to 1.01) with triple therapy, 1.08 (95% CI, 1.02 to 1.14) with fluticasone furoate–vilanterol, and 1.39 (95% CI, 1.29 to 1.51) with umeclidinium–vilanterol.

The annual rate of severe exacerbations during treatment was 0.13 among patients assigned to triple therapy, 0.15 among those assigned to fluticasone furoate–vilanterol (rate ratio with triple therapy, 0.87; 95% CI, 0.76 to 1.01; 13% difference; P=0.06), and 0.19 among those assigned to umeclidinium–vilanterol (rate ratio with triple therapy, 0.66; 95% CI, 0.56 to 0.78; 34% difference; P<0.001). Thus, the rate was not significantly lower with triple therapy than with fluticasone furoate–vilanterol but was significantly lower with triple therapy than with umeclidinium–vilanterol.

For the spirometric outcome of the mean change from baseline in trough FEV₁, the difference between the triple-therapy and fluticasone furoate–vilanterol groups was 97 ml (95% CI, 85 to 109; P<0.001), and the difference between the triple-therapy and umeclidinium–vilanterol groups was 54 ml (95% CI, 39 to 69; P<0.001). There were significant differences between the triple-therapy group and the fluticasone furoate–vilanterol and umeclidinium–vilanterol groups in the mean change from baseline in the SGRQ total score and in the percentage of patients who had a response as defined by a decrease in the SGRQ total score of at least 4 points (P<0.001 for both comparisons on both outcomes) (Table 2).

Table 2. Trough FEV₁ and St. George’s Respiratory Questionnaire (SGRQ) Total Score (Intention-to-Treat Population). *

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Triple Therapy (N=4151)</th>
<th>Fluticasone Furoate–Vilanterol (N=4134)</th>
<th>Umeclidinium–Vilanterol (N=2070)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trough FEV₁</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of patients evaluated</td>
<td>3366</td>
<td>3060</td>
<td>1490</td>
</tr>
<tr>
<td>Mean at wk 52 (95% CI) — ml</td>
<td>1274 (1265 to 1282)</td>
<td>1177 (1168 to 1185)</td>
<td>1220 (1208 to 1232)</td>
</tr>
<tr>
<td>Mean change from baseline (95% CI) — ml</td>
<td>94 (86 to 102)</td>
<td>–3 (–12 to 6)</td>
<td>40 (28 to 52)</td>
</tr>
<tr>
<td>Difference between triple therapy and dual-therapy comparator (95% CI) — ml</td>
<td>—</td>
<td>97 (85 to 109)</td>
<td>54 (39 to 69)</td>
</tr>
<tr>
<td>SGRQ total score‡</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of patients evaluated</td>
<td>3318</td>
<td>3026</td>
<td>1470</td>
</tr>
<tr>
<td>Mean at wk 52 (95% CI)</td>
<td>45.0 (44.5 to 45.4)</td>
<td>46.8 (46.3 to 47.2)</td>
<td>46.8 (46.1 to 47.4)</td>
</tr>
<tr>
<td>Mean change from baseline (95% CI)</td>
<td>–5.5 (–5.9 to –5.0)</td>
<td>–3.7 (–4.2 to –3.2)</td>
<td>–3.7 (–4.4 to –3.0)</td>
</tr>
<tr>
<td>Difference between triple therapy and dual-therapy comparator (95% CI)</td>
<td>—</td>
<td>–1.8 (–2.4 to –1.1)</td>
<td>–1.8 (–2.6 to –1.0)</td>
</tr>
<tr>
<td>Response according to SGRQ total score at wk 52</td>
<td>1723 (42)</td>
<td>1390 (34)</td>
<td>696 (34)</td>
</tr>
<tr>
<td>— no. (%)§</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Odds ratio for triple therapy vs. dual-therapy comparator (95% CI)</td>
<td>—</td>
<td>1.41 (1.29 to 1.55)</td>
<td>1.41 (1.26 to 1.57)</td>
</tr>
</tbody>
</table>

* The means presented are least-squares means.
† P<0.001.
‡ Total scores on the SGRQ range from 0 to 100, with lower scores indicating better health-related quality of life.
§ A response was defined as a decrease in the SGRQ total score of at least 4 units, as compared with the baseline value.

**ANALYSES OF OTHER OUTCOMES**

All tests within the predefined statistical testing hierarchy achieved statistical significance, with P<0.001. No adjustments for multiplicity were made for the other comparisons, and P values of less than 0.05 were considered to indicate statistical significance. Beyond the prespecified primary and secondary outcomes, there were multiple prespecified protocol-defined other outcomes, among which were death from any cause during treatment, all exacerbations (mild, moderate, or severe), and dyspnea according to the TDI. Results for these other outcomes provided support for the primary findings, although treatment comparisons were not corrected for multiplicity.
Death during treatment occurred in 50 patients (1%) in the triple-therapy group, 49 patients (1%) in the fluticasone furoate–vilanterol group, and 39 patients (2%) in the umeclidinium–vilanterol group. All-cause mortality was significantly lower with the regimen that included the inhaled glucocorticoid fluticasone furoate (triple therapy and fluticasone furoate–vilanterol) than with umeclidinium–vilanterol. The hazard ratio for triple therapy versus umeclidinium–vilanterol was 0.58 (95% CI, 0.38 to 0.88; 42% difference; unadjusted \( P=0.01 \)), and the hazard ratio for fluticasone furoate–vilanterol versus umeclidinium–vilanterol was 0.61 (95% CI, 0.40 to 0.93; 39% difference; unadjusted \( P=0.02 \)). The results of a prespecified analysis of the time to death from any cause including data from patients during treatment and not during treatment provided support for the findings during treatment. Further details are provided in the Supplementary Appendix.

An analysis of adjudicated cause–specific death during treatment showed a lower rate of deaths from both cardiovascular and respiratory causes in the inhaled-glucocorticoid groups than in the umeclidinium–vilanterol group. There were 16 adjudicated cardiovascular deaths during treatment in the triple-therapy group, 21 in the fluticasone furoate–vilanterol group, and 15 in the umeclidinium–vilanterol group (rate per 1000 patient-years, 4.2, 6.0, and 8.7, respectively). There were 15 adjudicated deaths from respiratory causes during treatment in the triple-therapy group, 12 in the fluticasone furoate–vilanterol group, and 9 in the umeclidinium–vilanterol group (rate per 1000 patient-years, 4.0, 3.4, and 5.2, respectively). The rate of deaths that were associated with the patients’ underlying COPD according to the independent adjudicators was lower in the inhaled-glucocorticoid groups than in the umeclidinium–vilanterol group. There were 18 deaths during treatment that were determined to be associated with the patient’s COPD in the triple-therapy group, 14 in the fluticasone furoate–vilanterol group, and 15 in the umeclidinium–vilanterol group (rate per 1000 patient-years, 4.8, 4.0, and 8.7, respectively). Similar results were observed in an analysis that included deaths that occurred in patients no longer receiving treatment. For a summary of adjudicated causes of death, see Tables S9 and S10 in the Supplementary Appendix.

Findings similar to those of the primary efficacy analysis were observed when mild exacerbations (those determined to require only increased albuterol) were included. The annual rate of mild, moderate, or severe exacerbations was 1.05 with triple therapy, 1.25 with fluticasone furoate–vilanterol, and 1.40 with umeclidinium–vilanterol. The rate was 16% lower with triple therapy than with fluticasone furoate–vilanterol (rate ratio, 0.84; 95% CI, 0.79 to 0.89; \( P<0.001 \)) and 25% lower with triple therapy than with umeclidinium–vilanterol (rate ratio, 0.75; 95% CI, 0.70 to 0.81; \( P<0.001 \)).

In a subset of 5058 patients, the percentage of patients who had a response as defined by an increase in the TDI of at least 1 unit was higher with triple therapy than with either dual therapy. The rate of response was 36% in the triple-therapy group, 29% in the fluticasone furoate–vilanterol group, and 30% in the umeclidinium–vilanterol group. The odds ratio for response with triple therapy versus fluticasone furoate–vilanterol (95% CI, 1.19 to 1.55; \( P<0.001 \)) and 1.33 for triple therapy versus umeclidinium–vilanterol (95% CI, 1.13 to 1.57; \( P<0.001 \)).

SAFETY AND ADVERSE-EVENT PROFILE

Overall, the adverse-event profile of triple therapy was similar to that of the dual-therapy comparators, and there were no new safety findings associated with the use of an inhaled glucocorticoid, a LAMA, or a LABA in combination (Table 3). There were no clinically relevant differences in ECG measurements, vital signs, or clinical laboratory values among the treatment groups.

The incidence of adverse events during treatment that led to discontinuation of trial treatment or withdrawal from the trial was 6% for triple therapy, 8% for fluticasone furoate–vilanterol, and 9% for umeclidinium–vilanterol; the incidence of discontinuation or withdrawal due to an adverse event of COPD was 2%, 2%, and 3%, respectively. Serious adverse events during treatment occurred in 895 patients (22%) receiving triple therapy, 850 (21%) receiving fluticasone furoate–vilanterol, and 470 (23%) receiving umeclidinium–vilanterol. A total of 14 patients (<1%) receiving triple therapy, 25 (<1%) receiving fluticasone furoate–vilanterol, and 14 (<1%) receiving umeclidinium–vilanterol were reported to have had a nonserious adverse event.
of COPD worsening. A serious adverse event of pneumonia occurred in 184 patients (4%), 152 patients (4%), and 54 patients (3%), respectively. Further details are provided in Table S12 in the Supplementary Appendix.

There was a higher incidence of pneumonia in the inhaled-glucocorticoid groups than in the umeclidinium–vilanterol group, and the risk of clinician-diagnosed pneumonia was significantly higher with triple therapy than with umeclidinium–vilanterol, as assessed in a time-to-first-event analysis (hazard ratio, 1.53; 95% CI, 1.22 to 1.92; P<0.001). There was no significant difference in the risk of pneumonia between triple therapy and fluticasone furoate–vilanterol (hazard ratio, 1.02; 95% CI, 0.87 to 1.19; P=0.85).

**DISCUSSION**

In this trial, once-daily single-inhaler triple therapy with fluticasone furoate, umeclidinium, and vilanterol resulted in a significantly lower rate of moderate or severe COPD exacerbations and better lung function and health-related quality of life than dual therapy with fluticasone furoate–vilanterol or the dual bronchodilator umeclidinium–vilanterol among patients with symptomatic COPD and a history of exacerbations. These benefits were observed regardless of the patients’ blood eosinophil levels at randomization.

Our trial also showed that fluticasone furoate–vilanterol was superior to umeclidinium–vilanterol with respect to the rates of COPD exacerbations (moderate or severe exacerbations and all exacerbations). These findings are in contrast to those of the FLAME trial, which showed a benefit of LAMA–LABA over inhaled glucocorticoid–LABA for the prevention of exacerbations. This difference in findings between our trial and the FLAME trial is probably due to the differences in the patient populations and the design of the two trials. In the FLAME trial, all the patients were treated with tiotropium during a 1-month run-in period. Therefore, any patients who would require an inhaled glucocorticoid may have had an increase in exacerbations and a decrease in lung function during the run-in period and would have been forced to leave the trial. In addition, it is also possible that patients who could not

| Table 3. Adverse Events of Special Interest in the Intention-to-Treat Population.* |
|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| Event                                        | Triple Therapy (N=4151)                        | Fluticasone Furoate–Vilanterol (N=4134)       | Umeclidinium–Vilanterol (N=2070)               |
|                                              | No. of Patients (%) Rate per 1000 Patient-Yr (No. of Events) | No. of Patients (%) Rate per 1000 Patient-Yr (No. of Events) | No. of Patients (%) Rate per 1000 Patient-Yr (No. of Events) |
| Anticholinergic syndrome                     | 184 (4) 60.8 (226)                              | 140 (3) 47.1 (163)                              | 70 (3) 47.7 (81)                              |
| Asthma or bronchospasm                       | 27 (<1) 7.5 (28)                               | 34 (<1) 10.1 (35)                               | 16 (<1) 9.4 (16)                               |
| Cardiovascular effects                       | 450 (11) 167.2 (621)                           | 430 (10) 157.0 (543)                           | 224 (11) 166.6 (283)                           |
| Cardiac arrhythmia                           | 153 (4) 50.9 (189)                             | 161 (4) 51.5 (178)                             | 81 (4) 51.2 (87)                              |
| Cardiac failure                              | 138 (3) 42.5 (158)                             | 126 (3) 42.8 (148)                             | 68 (3) 44.8 (76)                              |
| CNS hemorrhages and cerebrovascular conditions | 41 (<1) 12.1 (45)                             | 28 (<1) 9.3 (32)                               | 11 (<1) 6.5 (11)                              |
| Hypertension                                 | 113 (3) 35.5 (132)                             | 115 (3) 35.0 (121)                             | 54 (3) 34.2 (58)                              |
| Ischemic heart disease                       | 80 (2) 26.1 (97)                               | 57 (1) 18.5 (64)                               | 47 (2) 30.6 (52)                              |
| Lower respiratory tract infection, excluding pneumonia | 200 (5) 63.0 (234)                       | 199 (5) 69.7 (241)                             | 108 (5) 76.0 (129)                             |
| Pneumonia                                    | 317 (8) 95.8 (356)                             | 292 (7) 96.6 (334)                             | 97 (5) 61.2 (104)                              |
| Urinary retention                            | 8 (<1) 2.7 (10)                                | 12 (<1) 3.5 (12)                               | 9 (<1) 5.3 (9)                                |

* Adverse events of special interest are based on an analysis of a group of prespecified adverse events that are associated with the use of inhaled glucocorticoids, long-acting muscarinic antagonists, or long-acting β2-agonists. See Table S15 in the Supplementary Appendix for the full listing of adverse events of special interest. CNS denotes central nervous system.
withdraw from an inhaled glucocorticoid were knowingly not enrolled, leading to a biased patient population. In contrast, patients in our trial who were assigned to the LAMA–LABA group and had been previously receiving an inhaled glucocorticoid would have had to abruptly stop the inhaled glucocorticoid, whereas patients in the inhaled-glucocorticoid groups would have continued to take an inhaled glucocorticoid. It is unknown whether the abrupt discontinuation of inhaled glucocorticoids could have contributed to our finding of a lower rate of exacerbations in the inhaled-glucocorticoid groups than in the LAMA–LABA group. In addition, the patients who were assigned to the triple-therapy group and had been previously receiving an inhaled glucocorticoid, a LABA, and a LAMA might not have been expected to have a benefit. Further research using different trial designs will be needed to resolve these issues.

Triple therapy and fluticasone furoate–vilanterol also showed a signal toward lower all-cause mortality during treatment than umeclidinium–vilanterol. However, the Study to Understand Mortality and Morbidity in COPD (SUMMIT) involving patients with moderate COPD and heightened cardiovascular risk, was powered to study all-cause mortality and did not show a significant effect for fluticasone furoate–vilanterol. It is possible that our finding is fragile; further investigation will be needed to understand the reasons for this finding.

The strengths of the IMPACT trial include the large number of patients enrolled and the comparison of triple therapy with dual therapies using the same molecules in the same delivery device. The trial used an electronic diary for rapid and reliable identification of symptoms suggestive of an exacerbation, and the measurement of health-related quality of life has been recognized as important to help physicians and patients achieve greater understanding of a treatment effect. A robust approach was taken for capture and evaluation of pneumonias to ensure that expected adverse events of pneumonia were appropriately understood.

Safety results showed a higher incidence of pneumonia in the inhaled-glucocorticoid groups than in the umeclidinium–vilanterol group, as would be expected. However, the rate of pneumonia was 95.8, 96.6, and 61.2 events per 1000 patient-years with triple therapy, fluticasone furoate–vilanterol, and umeclidinium–vilanterol, respectively, whereas the rate of moderate or severe COPD exacerbations was 922.8, 1051.5, and 1147.6 events per 1000 patient-years, respectively. No new safety signals emerged.

In summary, the results of the IMPACT trial show that a once-daily combination of fluticasone furoate, umeclidinium, and vilanterol resulted in a lower rate of moderate or severe COPD exacerbations and better lung function and health-related quality of life than dual therapy with fluticasone furoate–vilanterol or umeclidinium–vilanterol. Triple therapy also resulted in a lower rate of hospitalization due to COPD than umeclidinium–vilanterol in this symptomatic patient population.

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