

Contains Nonbinding Recommendations

Draft – Not for Implementation

Draft Guidance on Albuterol Sulfate

August 2024

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|-----------------------------|--|
| Active Ingredient: | Albuterol sulfate |
| Dosage Form: | Aerosol, metered |
| Route: | Inhalation |
| Strength: | EQ 0.09 mg Base/inh |
| Recommended Studies: | Two options: (1) six in vitro bioequivalence studies and two in vivo bioequivalence studies with pharmacokinetic endpoints, or (2) five in vitro bioequivalence studies, one in vivo bioequivalence study with pharmacokinetic endpoints, and one pharmacodynamic bioequivalence study |

I. Option 1: Six in vitro bioequivalence studies and two in vivo bioequivalence studies with pharmacokinetic endpoints

To demonstrate bioequivalence by this option, the test (T) product should contain no difference in inactive ingredients or in other aspects of the formulation relative to the reference standard (RS) product that may significantly affect the local or systemic availability of the active ingredient. For example, the T product can be qualitatively (Q1)¹ and quantitatively (Q2)² the same as the RS product to satisfy no difference in inactive ingredients.

¹ Q1 (qualitative sameness) means that the T product uses the same inactive ingredient(s) as the RS.

² Q2 (quantitative sameness) means that concentrations of the inactive ingredient(s) used in the T product are within $\pm 5\%$ of those used in the RS.

Six in vitro bioequivalence studies:

FDA recommends that prospective applicants conduct the following in vitro bioequivalence studies for the T and RS products. Use at least three batches each of the T and RS products with no fewer than 10 units from each batch. FDA recommends that three primary stability batches be also used to demonstrate in vitro bioequivalence. The three batches of T product should be manufactured from, at a minimum, three different batches of drug substance(s), excipient(s), and device constituent part components. The T product should consist of the final device constituent part and final drug constituent formulation intended to be marketed.

1. Type of study: Single actuation content (SAC)
Design: The SAC test should be performed at the beginning (B), middle (M), and end (E) lifestages³ of the product, using a flow rate of 28.3 L/min or 30 L/min.⁴ United States Pharmacopoeia (USP) <601> Apparatus A or another appropriate apparatus may be used to determine the SAC using a validated assay. The number of actuations per determination should be one.

Bioequivalence based on: Population bioequivalence (PBE) analysis of SAC. Refer to the most recent version of the FDA product-specific guidance on *Budesonide Inhalation Suspension* (NDA 020929)^a for additional information regarding PBE analysis procedures.

2. Type of study: Aerodynamic particle size distribution (APSD)
Design: The APSD test should be performed at the B and E lifestages of the product using a flow rate of 28.3 L/min or 30 L/min. A cascade impactor apparatus for inhalation aerosols as per USP <601> Table 2 or another appropriate method may be used to determine APSD using a validated assay. The APSD determination of each unit should be performed with a minimum number of inhalations justified by the sensitivity of the validated assay.

Additional comments: Drug deposition on individual sites, including the mouthpiece adapter, the induction port, each stage of the cascade impactor, and the filter, is requested. Mass balance accountability should be reported based on the sum of all deposition sites. For electronic submission of the individual cascade impactor data for the T and RS products, provide a table using the format in the appendix, and send them as part of the abbreviated new drug application (ANDA) submission.

³ Based on the labeled number of actuations, the terms, B lifestage, M lifestage, and E lifestage represent the first actuation(s) following the labeled number of priming actuations, the actuation(s) corresponding to 50 percent of the labeled number of actuations, and the actuation(s) corresponding to the labeled number of actuations, respectively.

⁴ The selection of flow rate should match that of the flow rate chosen for APSD testing.

Bioequivalence based on: PBE analysis of impactor-sized mass (ISM)⁵ of the drug. The cascade impactor profiles representing drug deposition on the individual stages of the cascade impactor along with the mass median aerodynamic diameter (MMAD), geometric standard deviation (GSD), and fine particle mass (FPM) should be submitted as supportive evidence for equivalent APSD.

3. Type of study: Spray pattern

Design: The spray pattern test should be performed at the B lifestage of the product and at two different distances from the actuator orifice. The selected distances should be at least 3 cm apart and based on the range of 3 to 7 cm from the RS actuator mouthpiece.⁶ Impaction (thin-layer chromatography plate impaction), non-impaction (laser light sheet technology), or other suitable method may be used to determine the spray pattern.

Additional comments: Spray pattern should be measured quantitatively in terms of ovality ratio and area within the perimeter of the true shape (to include a high proportion, e.g., 95% of the total pattern) for the automated analysis or ovality ratio and D_{max} for the manual analysis. Ovality ratio is defined as the ratio of D_{max} to D_{min} . D_{max} and D_{min} are the longest and shortest diameters, respectively, that pass through the center of mass or the center of gravity, as appropriate. The number of sprays per spray pattern would preferably be one.

Bioequivalence based on: At two selected distances, (i) qualitative comparison of spray shape, and (ii) PBE analysis of ovality ratio and area within the perimeter of the true shape or ovality ratio and D_{max} .

4. Type of study: Plume geometry

Design: The plume geometry test should be performed at the B lifestage of the product. The timed-sequence sound-triggered flash photography method, laser light sheet technology, or other suitable method may be used to determine the plume geometry at the appropriate post-actuation delay time.

Additional comments: Plume geometry measurements should be reported at a single delay time while the fully developed plume is still in contact with the actuator mouthpiece. Plume geometry should be measured quantitatively in terms of plume angle and width. The plume angle is based on the conical region of the plume extending from a vertex that occurs at or near the actuator mouthpiece. The plume width is measured at a distance equal to the greater of the two distances selected for characterization of the spray pattern.

⁵ ISM is defined as a sum of the drug mass on all stages of the cascade impactor plus the terminal filter but excluding the top cascade impactor stage because of its lack of a specified upper cutoff size limit.

⁶ The distance between the actuator orifice and point of spray pattern measurement should be the same for T and RS.

Bioequivalence based on: Ratio of the geometric mean of the three batches of T to that of the three batches of RS (based on log transformed data) for plume angle and width, which should fall within 90% - 111%.

5. Type of study: Priming and repriming

Design: Priming and repriming tests should be based on the emitted dose (ex-actuator) of a single actuation immediately following the specified number of priming or repriming actuations specified in the reference listed drug (RLD) labeling. The repriming test should be performed following storage for the specified period of non-use after initial use and/or other conditions (e.g., dropping), if the RLD labeling provides such repriming information.

Additional comments: For bioequivalence evaluation, the priming and repriming tests should be based on products stored in the valve upright position, with the exception of metered dose inhalers (MDIs) for which the RLD labeling recommends storage in the valve down position. The priming data can be based on the SAC data at the B lifestage.

Bioequivalence based on: PBE analysis of the emitted dose of a single actuation immediately following the specified number of priming or repriming actuations specified in the RLD labeling.

6. Type of study: Realistic APSD

Design: The realistic APSD test should be performed at the B lifestage of the product using mouth-throat models of different sizes (e.g., small and large) and breathing profiles (e.g., weak and strong) that are representative of the entire patient population. A cascade impactor apparatus for inhalation aerosols as per USP <601> Table 2 or another appropriate method may be used to determine APSD using a validated assay. The APSD determination of each unit should be performed with a minimum number of actuations justified by the sensitivity of the validated assay.

Additional comments: Drug deposition on individual sites, including the mouthpiece adapter, the mouth-throat model, the mixing inlet, and each stage of the cascade impactor and the filter, is requested. Mass balance accountability should be reported based on the sum of all deposition sites. For electronic submission of the individual cascade impactor data for the T and RS products, provide a table using the format in the appendix, and send them as part of the ANDA submission.

Bioequivalence based on: PBE analysis or other appropriate statistical analysis of ISM of the drug for each mouth-throat model-breathing profile combination. The cascade impactor profiles representing drug deposition on the individual stages of the cascade impactor along with the MMAD, GSD, and FPM should be submitted as supportive evidence for equivalent APSD. If another statistical analysis is used, it should be adequately and scientifically justified considering the purpose of the study. Prospective applicants are encouraged to discuss other statistical analysis designs with FDA via a pre-ANDA meeting request. For additional information, refer to the most recent version of the FDA guidance for industry, *Formal Meetings Between FDA and ANDA Applicants of Complex Products Under GDUFA*.^b

Two in vivo bioequivalence studies with pharmacokinetic endpoints:

1. Type of study: Fasting
Design: Single-dose, two-way crossover
Dose: EQ 0.18 mg Base (two inhalations)
Subjects: Healthy males and non-pregnant, non-lactating females
Additional comments: (1) The subjects enrolled for in vivo studies should be trained in the use of the inhalation aerosols in a standard fashion prior to each treatment session to assure a relatively consistent inspiratory flow rate and inspiratory duration. (2) Subjects should adhere to the RLD labeling for administration.

Analyte to measure: Albuterol in plasma

Bioequivalence based on: AUC and C_{max} for albuterol. The 90% confidence intervals (CI) for the geometric mean T/R ratios of AUC and C_{max} should fall within the limits of 80.00% - 125.00%.

2. Type of study: Fasting
Design: Single-dose, two-way crossover with charcoal block
Dose: Minimum number of inhalations that is sufficient to characterize the pharmacokinetic profiles by using a sensitive analytical method
Subjects: Healthy males and non-pregnant, non-lactating females

Additional comments: (1) The subjects enrolled for in vivo studies should be trained in the use of the inhalation aerosols in a standard fashion prior to each treatment session to assure a relatively consistent inspiratory flow rate and inspiratory duration. (2) Subjects should adhere to the RLD labeling for administration. (3) A Bio-IND is required prior to conduct of the pharmacokinetic study if the dose exceeds the maximum labeled single dose. (4) Justification for the charcoal dose should be provided in the ANDA submission.

Analyte to measure: Albuterol in plasma

Bioequivalence based on: AUC and C_{max} for albuterol. The 90% CI for the geometric mean T/R ratios of AUC and C_{max} should fall within the limits of 80.00% - 125.00%.

II. Option 2: Five in vitro bioequivalence studies, one in vivo bioequivalence study with pharmacokinetic endpoints, and one comparative clinical endpoint bioequivalence study

To demonstrate bioequivalence by this option, it is recommended to conduct the in vitro bioequivalence studies #1 through #5 and the in vivo pharmacokinetic bioequivalence study #1 as described in Option 1. In addition, it is recommended to conduct the in vivo pharmacodynamic bioequivalence study described below.

One in vivo pharmacodynamic bioequivalence study:

1. Type of study: Pharmacodynamic bioequivalence study
Design: A bronchoprovocation study using a single-dose, double-blind, double-dummy, randomized, crossover design that is recommended at minimum to consist of the following treatment periods:
 - a. Zero dose: One actuation each from two different placebo RS inhalation aerosols and one actuation each from two different placebo T inhalation aerosols
 - b. EQ 0.09 mg Base dose of RS: One actuation each from the RS inhalation aerosol and the placebo RS inhalation aerosol and one actuation each from two different placebo T inhalation aerosols
 - c. EQ 0.18 mg Base dose of RS: One actuation each from two different RS inhalation aerosols and one actuation each from two different placebo T inhalation aerosols
 - d. EQ 0.09 mg Base dose of T: One actuation each from the T inhalation aerosol and the placebo T inhalation aerosol and one actuation each from two different placebo RS inhalation aerosols

Subjects: Males and non-pregnant females with asthma

Inclusion criteria should, at minimum, include:

- a. Male and non-pregnant female subjects (18-65 years of age).
- b. Stable mild asthmatics based on National Asthma Education and Prevention Program^{7,8} guidelines.
- c. Pre-bronchodilator forced expiratory volume in one second (FEV₁) ≥ 80% of predicted.
- d. Airway responsiveness to methacholine demonstrated by a pre-albuterol dose (baseline) PC₂₀ ≤ 8 mg/mL.
- e. Non-smokers for at least six months prior to the study and a maximum smoking history of five pack-years (the equivalent of one pack per day for five years).
- f. Written informed consent.

⁷ Guidelines for the Diagnosis and Management of Asthma: Expert Panel Report 3. National Asthma Education and Prevention Program; National Institute of Health; National Heart, Lung, and Blood Institute. 2007, Publication No. 07-4051.

⁸ 2020 Focused Updates to the Asthma Management Guidelines: A Report from the National Asthma Education and Prevention Program Coordinating Committee Expert Panel Working Group. 2020. <https://www.nhlbi.nih.gov/resources/2020-focused-updates-asthma-management-guidelines>.

Exclusion criteria should, at minimum, include:

- a. Evidence of upper or lower respiratory tract infection (e.g., pneumonia, bronchitis, sinusitis) within six weeks prior to the study.
- b. History of seasonal asthma exacerbations, the subject should be studied outside of the relevant allergen season.
- c. History of cystic fibrosis, bronchiectasis, or significant respiratory diseases other than asthma (e.g., COPD, interstitial lung disease).
- d. Evidence or history of clinically significant disease or abnormality including: congestive heart failure, uncontrolled hypertension, uncontrolled coronary artery disease, myocardial infarction, cardiac dysrhythmia, or ECG with evidence of ischemic heart disease. In addition, historical or current evidence of significant hematologic, hepatic, neurologic, psychiatric, renal, or other diseases that, in the opinion of the investigator, would put the patient at risk through study participation, or would affect the study analyses if the disease exacerbates during the study.
- e. Treatment in an emergency room or hospitalization for acute asthmatic symptoms or need for daily oral corticosteroids within past three months.
- f. Known intolerance or hypersensitivity to any component of the albuterol MDI.

Additional comments:

- a. No less than a 24-hour washout period should be allotted between treatment periods.
- b. The study day evaluation should take into consideration the following:
 - Drug administration should begin within two weeks following screening for admission to the study.
 - Baseline FEV₁ should not be less than 70% of predicted normal value and within 88% - 112% of qualifying day FEV₁ value. If either occurs, the study should be rescheduled.
 - FEV₁ due to the saline control should fall no more than 10% from the baseline FEV₁, or the study should be postponed. This limits the drop in FEV₁ shown by some subjects due to the saline control vehicle in which the challenge agent is dissolved.
 - A subject failing three consecutive visits should be dropped from the study.
- c. A Bio-IND is required prior to conduct of the pharmacodynamic bioequivalence study as the concentration of methacholine chloride solution may exceed the labeled 25.0 mg/mL concentration, particularly at the higher albuterol dose (e.g., EQ 0.18 mg Base) where 25.0 mg/mL methacholine chloride may not lead to a 20% reduction in FEV₁.
- d. Prospective applicants are encouraged to consider the conduct of a pilot study to refine the study design (e.g., inclusion and exclusion criteria) and estimate the study power based on intra- and inter-subject variability and slope of the E_{max} dose-response curve. The method for blinding should be described.
- e. The pharmacodynamic bioequivalence study may enroll all asthma patients who meet the inclusion and exclusion criteria or may be enriched by using a sub-

population of patients predicted to respond well to the study treatment (appropriate justification should be included for the population chosen for the study).

- f. All spirometry should be conducted in accordance with the American Thoracic Society (ATS) standards.
- g. The study protocol should include pre-specified definitions of asthma exacerbation, as well as pre-specified and appropriate escape criteria with consideration to patient safety.
- h. It is the prospective applicant's responsibility to enroll a sufficient number of subjects for the study to demonstrate bioequivalence of the T product to the RS product.
- i. The start and stop date of concomitant medication use during the study should be provided in the data set in addition to the reason for the medication use. The prospective applicant should clearly explain whether the medication was used prior to baseline visit, during the study or both.
- j. All adverse events (AEs) should be reported, whether or not they are considered to be related to the treatment. The report of each AE should include the date of onset, description of AE, severity, relation to study medication, action taken, outcome, and date of resolution. The information will assist FDA in determining whether the incidence and severity of adverse reactions is different between the T and RS products.
- k. Subjects who discontinue from the study early should be identified, and the protocol should clearly prospectively state how missing data will be handled in the statistical analysis and provide justification for the method chosen. The protocol should also include subject retention strategies and other plans to minimize missing data. If there are missing data, adequate justification should be provided that the missing data do not lead to biased F estimation. Detailed information for all subjects who are discontinued from the study should be provided.
- l. Log transformation of the pharmacodynamic data before fitting the E_{\max} model is recommended for dose-scale analysis.

Pharmacodynamic bioequivalence endpoints: Post-dose PC₂₀ or PD₂₀, which are the provocative concentration or dose, respectively, of the methacholine challenge agent required to reduce the FEV₁ by 20% following administration of differing doses of albuterol (or placebo) by inhalation. The 20% reduction in FEV₁ is determined relative to the saline FEV₁ measured before the placebo or albuterol administration.

Bioequivalence based on: Dose-scale analysis of the pharmacodynamic data. For details regarding the dose-scale analysis, refer to the most recent version of the FDA product-specific guidance for *Orlistat Oral Capsule* (NDA 020766; NDA 021887).^a The 90% CIs for the relative bioavailability (F) should fall within 67.00% -150.00% to establish equivalence in the pharmacodynamic study.

Additional information:

Computational model(s) for regional drug delivery:

An optional computational modeling study may be used to support bioequivalence of the T and RS products. Refer to the most recent version of the FDA product-specific guidance on *Formoterol Fumarate; Glycopyrrolate Inhalation Metered Aerosol* (NDA 208294)^a for additional information regarding the development and conduct of an optional computational modeling study. In order to clarify the FDA's expectations for prospective applicants early in product development, and to assist applicants to submit an ANDA as complete as possible, FDA strongly encourages applicants to discuss their development program and plans for conducting an optional computational modeling study with the FDA via the pre-ANDA meeting pathway. For additional information, refer to the most recent version of the FDA guidance for industry on *Formal Meetings Between FDA and ANDA Applicants of Complex Products Under GDUFA*.^b

Device:

The RLD is presented as a MDI. The device constituent part is the actuator with metering valve.

FDA recommends that prospective applicants examine the size and shape, the external critical design attributes, and the external operating principles of the RLD device when designing the T device including:

- Active, metered, multi-dose format
- Number of doses
- Dose indicator/counter

User interface assessment:

An ANDA for this product should include complete comparative analyses so FDA can determine whether any differences in design for the user interface of the proposed generic product, as compared to the RLD, are acceptable and whether the product can be expected to have the same clinical effect and safety profile as the RLD when administered to patients under the conditions specified in the labeling. For additional information, refer to the most recent version of the FDA guidance for industry on *Comparative Analyses and Related Comparative Use Human Factors Studies for a Drug-Device Combination Product Submitted in an ANDA*.^b

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Unique Agency Identifier: PSG_020503

^a For the most recent version of a product-specific guidance, check the FDA product-specific guidance website at <https://www.accessdata.fda.gov/scripts/cder/psg/index.cfm>.

^b For the most recent version of a guidance, check the FDA guidance website at <https://www.fda.gov/regulatory-information/search-fda-guidance-documents>.

APPENDIX

| Variable Name | Variable Type | Content | Notes |
|-------------------|----------------------|----------------------|---|
| Product Name | Character | TEST or REF | Identifier for product |
| LOT Number | Alphanumeric/Numeric | Alphanumeric/Numeric | Identifier for product lot |
| UNIT Number | Numeric | Numeric values | Identifier for unit must be unique for each product (e.g. #1-30 for test and #31-60 for ref). |
| Stage 1 | Numeric | Numeric Values | S1 |
| Stage 2 | Numeric | Numeric Values | S2 |
| Stage 3 | Numeric | Numeric Values | S3 |
| Stage 4 | Numeric | Numeric Values | S4 |
| Stage 5 | Numeric | Numeric Values | S5 |
| Stage 6 | Numeric | Numeric Values | S6 |
| Stage 7 | Numeric | Numeric Values | S7 |
| Stage 8 or Filter | Numeric | Numeric Values | S8 |
| ISM | Numeric | Numeric Values | ISM |
| MMAD | Numeric | Numeric Values | MMAD |
| GSD | Numeric | Numeric Values | GSD |
| FPM | Numeric | Numeric Values | FRM |

Example:

| PRODUCT | LOT | Unit | S1 | S2 | S3 | S4 | S5 | S6 | S7 | S8 or Filter | ISM | MMAD | GSD | FPM |
|---------|------|------|----|----|----|----|----|----|----|--------------|-----|------|-----|-----|
| TEST | 1234 | 1 | | | | | | | | | | | | |
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