

# Notes on the design of bioequivalence study: Emtricitabine/Tenofovir Disoproxil Fumarate/Efavirenz

Notes on the design of bioequivalence studies with products invited for submission to the WHO Prequalification Unit – Medicines Assessment Team (PQT/MED) are issued to aid manufacturers with the development of their product dossier. Deviations from the approach suggested below can be considered acceptable if justified by sound scientific evidence.

The current notes should be read and followed in line with the general guidelines of submission of documentation for WHO prequalification. For guidance on issues related to bioequivalence (BE) studies for immediate-release, solid oral dosage forms, see the ICH Harmonised Guideline M13A [Bioequivalence for Immediate-Release Solid Oral Dosage Forms](#) (2024). For BE issues outside the scope of the ICH M13A guideline, e.g., for additional strength biowaivers, please consult the "[Multisource \(generic\) pharmaceutical products: guidelines on registration requirements to establish interchangeability](#)" in: *Fifty-seventh report of the WHO Expert Committee on Specifications for Pharmaceutical Preparations*, Geneva, World Health Organization, 2024. WHO Technical Report Series, No. 1052, Annex 8.

Below, additional specific guidance is provided on the invited immediate release products containing emtricitabine, tenofovir disoproxil fumarate (TDF), efavirenz.

## **Pharmacokinetics of Emtricitabine, Tenofovir Disoproxil Fumarate, and Efavirenz**

Maximum emtricitabine and tenofovir concentrations are observed in plasma within 0.5 to 3.0 hours of dosing in the fasted state. Efavirenz peak plasma concentrations are typically reached within 5 h post-dose.

The elimination half-life of emtricitabine and tenofovir is 10 hours, whereas the mean terminal half-life of efavirenz is 52– 76 h following single doses.

Administration of emtricitabine with a high-fat meal does not affect systemic exposure ( $AUC_{0-inf}$ ) of emtricitabine; therefore, emtricitabine may be administered with or without food.

Administration of TDF with food increases tenofovir AUC and  $C_{max}$  approximately 35% and 15%, respectively, when administered with a high fat or light meal, compared to administration in the fasted state. In order to optimize the absorption of tenofovir from TDF, it is recommended that TDF should preferably be taken with food in the European Union, but with or without food in the United States.

Relative to fasted conditions, the administration of a single dose of efavirenz with a standardized high-fat meal increases the rate and extent of absorption of efavirenz. For this reason, efavirenz is to be administered on an empty stomach, preferably at bedtime. Therefore, the fixed combination of emtricitabine/tenofovir disoproxil fumarate/efavirenz should be administered in fasted state.

Efavirenz appears to demonstrate non-linear pharmacokinetics with less than proportional increases in AUC observed with increasing dose, due to very limited solubility.

## **Guidance for the design of bioequivalence studies**

Taking into account the pharmacokinetic properties of emtricitabine, tenofovir, and efavirenz the following guidance with regard to the study design should be taken into account:

**Design:** A single-dose crossover design is recommended.

**Dose:** As per Section 2.1.6 of the ICH M13A guideline, for APIs with non-linear pharmacokinetics within the range of strengths due to limited solubility of the API and resulting in less than proportional increases in AUC with increasing dose such as efavirenz, bioequivalence studies should be conducted on at least the lowest strength (or a strength in the linear range) and the highest strength of a series of strengths.

As the EoI includes only the fixed combination of emtricitabine/tenofovir disoproxil fumarate/efavirenz 200mg/300mg/400mg, this strength should be used in the bioequivalence study.

**Fasted/fed:** The bioequivalence study should be conducted in the fasted state.

**Subjects:** Healthy adult subjects should be recruited. It is not necessary to include patients in the bioequivalence studies.

**Parent or metabolite data for assessment of bioequivalence:** The parent drug is considered to best reflect the biopharmaceutical quality of the product. The data for the parent compound should be used to assess bioequivalence of emtricitabine and efavirenz. In contrast, for tenofovir disoproxil, which is the water soluble diester prodrug of the active ingredient tenofovir and which following absorption is rapidly converts into tenofovir, bioequivalence should be based on the determination of tenofovir.

**Sample size:** Emtricitabine, tenofovir disoproxil, and efavirenz are not highly variable drugs. Information currently available to PQT/MED indicates that the intra-subject variability for emtricitabine, tenofovir, and efavirenz is around 20-25%. These data may facilitate the calculation of a sufficient sample size for the bioequivalence study.

**Washout:** Taking into account the elimination half-life of efavirenz in the fasted state of 52–76 h, a washout period of 28–35 days is considered sufficient to prevent carry-over.

**Blood sampling:** The blood sampling should be intensive for the first three hours after administration to properly characterize the  $C_{max}$  of emtricitabine and tenofovir, and during the first five hours after administration to properly characterize the  $C_{max}$  of efavirenz. Blood samples for the characterization of efavirenz pharmacokinetics should be taken for 72 h post-dose in order to determine truncated AUC values ( $AUC_{0-72h}$ ). For example, blood samples might be taken at pre-dose, 0.17, 0.25, 0.50, 0.75, 1.00, 1.25, 1.50, 1.75, 2.00, 2.25, 2.50, 3.00, 3.50, 4.00, 4.50, 5.00, 5.50, 6.00, 8.00, 10.00, 12.00, 24.00, 48.00, and 72.00 h after drug administration.

**Analytical considerations:** Information currently available to PQT/MED indicates that it is possible to measure emtricitabine, tenofovir, and efavirenz in human plasma using LC-MS/MS analytical methodology. The bioanalytical method should be sufficiently sensitive to detect concentrations that are 5% of the  $C_{max}$  in most profiles of each formulation (test or comparator). The bioanalytical method for each analyte should be validated in the presence of the other two analytes (See [Guideline on bioanalytical method validation and study sample analysis](#). In: WHO Technical Report Series, No. 1060, Annex 6, or the ICH Harmonised [Guideline M10](#) for more information on bioanalytical recommendations).

**Statistical considerations:** The data for emtricitabine, tenofovir, and efavirenz should meet the following bioequivalence standards in a single-dose cross-over design study:

- The 90% confidence interval of the relative mean  $AUC_{0-t}$  for emtricitabine and tenofovir and  $AUC_{0-72h}$  for efavirenz of the test to reference product should be within 80.00–125.00%.
- The 90% confidence interval of the relative mean  $C_{max}$  of the test to reference product should be within 80.00–125.00%.