Guidelines for the Use of Antiretroviral Agents in Pediatric HIV Infection

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Dosing Recommendations

Neonate and Infant Dose:
- Not Food and Drug Administration-approved or recommended for use in neonates and infants aged <2 years.

Child (Aged ≥2 Years to <12 Years) Dose:
- 8 mg/kg/dose once daily

TDF Oral Powder Dosing Table

<table>
<thead>
<tr>
<th>Body Weight</th>
<th>TDF Oral Powder</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 kg to &lt;12 kg</td>
<td>2 scoops (80 mg)</td>
</tr>
<tr>
<td>12 kg to &lt;14 kg</td>
<td>2.5 scoops (100 mg)</td>
</tr>
<tr>
<td>14 kg to &lt;17 kg</td>
<td>3 scoops (120 mg)</td>
</tr>
<tr>
<td>17 kg to &lt;19 kg</td>
<td>3.5 scoops (140 mg)</td>
</tr>
<tr>
<td>19 kg to &lt;22 kg</td>
<td>4 scoops (160 mg)</td>
</tr>
<tr>
<td>22 kg to &lt;24 kg</td>
<td>4.5 scoops (180 mg)</td>
</tr>
<tr>
<td>24 kg to &lt;27 kg</td>
<td>5 scoops (200 mg)</td>
</tr>
<tr>
<td>27 kg to &lt;29 kg</td>
<td>5.5 scoops (220 mg)</td>
</tr>
<tr>
<td>29 kg to &lt;32 kg</td>
<td>6 scoops (240 mg)</td>
</tr>
<tr>
<td>32 kg to &lt;34 kg</td>
<td>6.5 scoops (260 mg)</td>
</tr>
<tr>
<td>34 kg to &lt;35 kg</td>
<td>7 scoops (280 mg)</td>
</tr>
<tr>
<td>≥35 kg</td>
<td>7.5 scoops (300 mg)</td>
</tr>
</tbody>
</table>

Selected Adverse Events

- Asthenia, headache, diarrhea, nausea, vomiting, flatulence
- Renal insufficiency, proximal renal tubular dysfunction that may include Fanconi syndrome
- Decreased bone mineral density

Special Instructions

- Do not crush tablets; TDF oral powder formulation is available for patients unable to swallow tablets.
- TDF oral powder should be measured only with the supplied dosing scoop: 1 level scoop = 1 g powder = 40 mg TDF.
- Mix TDF oral powder in 2 to 4 oz of soft food that does not require chewing (e.g., applesauce, yogurt). Administer immediately after mixing to avoid the bitter taste.
- Do not try to mix the TDF oral powder with liquid. The powder may float on the top even after vigorous stirring.
- Although TDF can be administered without regard to food, food requirements vary depending on the other ARV drugs contained.
TDF Tablet Dosing Table for Patients Aged ≥2 Years and Weighing ≥17 kg

<table>
<thead>
<tr>
<th>Body Weight</th>
<th>TDF Tablet Once Daily</th>
</tr>
</thead>
<tbody>
<tr>
<td>17 kg to &lt;22 kg</td>
<td>150 mg</td>
</tr>
<tr>
<td>22 kg to &lt;28 kg</td>
<td>200 mg</td>
</tr>
<tr>
<td>28 kg to &lt;35 kg</td>
<td>250 mg</td>
</tr>
<tr>
<td>≥35 kg</td>
<td>300 mg</td>
</tr>
</tbody>
</table>

Adolescent (Weighing ≥35 kg) and Adult Dose:
- TDF 300 mg once daily

[Truvada] Emtricitabine plus TDF (FTC/TDF)

Pediatric Dose:
Truvada Pediatric Dosing Table

<table>
<thead>
<tr>
<th>Body Weight</th>
<th>FTC/TDF Tablet Once Daily</th>
</tr>
</thead>
<tbody>
<tr>
<td>17 kg to &lt;22 kg</td>
<td>1 FTC/TDF 100 mg/150 mg tablet</td>
</tr>
<tr>
<td>22 kg to &lt;28 kg</td>
<td>1 FTC/TDF 133 mg/200 mg tablet</td>
</tr>
<tr>
<td>28 kg to &lt;35 kg</td>
<td>1 FTC/TDF 167 mg/250 mg tablet</td>
</tr>
<tr>
<td>≥35 kg</td>
<td>1 FTC/TDF 200 mg/300 mg tablet</td>
</tr>
</tbody>
</table>

Adolescent (Weighing ≥35 kg) and Adult Dose:
- 1 FTC/TDF 200 mg/300 mg tablet once daily

[Atripla] Efavirenz plus Emtricitabine plus TDF

Adolescent (Weighing ≥40 kg) and Adult Dose:
- 1 tablet once daily

[Complera] Emtricitabine plus Rilpivirine plus TDF

Adolescent (Weighing ≥35 kg) and Adult Dose:
- 1 tablet once daily in treatment-naive adults with baseline viral load <100,000 copies/mL or virologically suppressed adults who are currently on their first or second regimen and have no history of virologic failure or resistance to rilpivirine and other antiretroviral (ARV) drugs.
- Administer with a meal of at least 500 calories.

[Stribild] Elvitegravir plus Cobicistat plus Emtricitabine plus TDF

Adolescent (Weighing >35 kg with a Sexual Maturity Rating of 4 or 5) and Adult Dose:
- 1 tablet once daily in treatment-naive adults. This dose of Stribild can also be used to replace the current ARV regimen in patients who have been virologically suppressed (HIV-1 RNA <50 copies/mL) on a stable ARV regimen for at least 6 months with no history of treatment failure and no known in a FDC tablet. Food requirements are listed with dosing recommendations.
- Measure serum creatinine and urine dipstick for protein and glucose before starting a TDF-containing regimen and monitor serum creatinine and urine dipstick for protein and glucose at intervals (see Table 15) during continued therapy. Measure serum phosphate if there is clinical suspicion of hypophosphatemia.
- Screen patients for hepatitis B virus (HBV) infection before using TDF. Severe acute exacerbation of HBV infection can occur when TDF is discontinued; therefore, in patients with HBV infection, monitor hepatic function and hepatitis B viral load for several months after therapy with TDF is stopped.
- When using FDC tablets, see other drug sections for special instructions and additional information about the individual drug components.
- Tenofovir alafenamide (TAF) has less bone and renal toxicity than TDF, but equal antiviral efficacy. Do not use TAF and TDF together. Consider switching from TDF to TAF in appropriate clinical settings.

Metabolism/Elimination
- TDF is renally excreted.

TDF Dosing in Patients with Renal Insufficiency:
- TDF dose should be decreased in patients with impaired renal function (creatinine clearance [CrCl] <50 mL/min). Consult manufacturer’s prescribing information for adjustment of dose in accordance with CrCl.
- The FDCs Atripla, Complera, and Symfi Lo should not be used in patients with CrCl <50 mL/min or in patients requiring dialysis.
- The FDC Truvada should not be used in patients with CrCl <30 mL/min or in patients requiring dialysis.
- The FDC Stribild should not be initiated in patients with estimated CrCl <70 mL/min and should be discontinued in patients with estimated CrCl <50 mL/min.
- Stribild should not be used in patients with severe hepatic impairment.
Drug Interactions (see also the Adult and Adolescent Guidelines and HIV Drug Interaction Checker)

- Tenofovir disoproxil fumarate (TDF) is a substrate of the adenosine triphosphate-dependent transporters P-glycoprotein (P-gp) and breast cancer resistance protein. When TDF is co-administered with inhibitors of these transporters, an increase in TDF absorption may be observed, with the potential for enhanced TDF toxicity.\(^1\)

- Renal elimination: Drugs that decrease renal function or compete for active tubular secretion could reduce clearance of plasma tenofovir (TFV).

- Other nucleoside reverse transcriptase inhibitors (NRTIs): Didanosine serum concentrations increase when the drug is co-administered with TDF, and this combination should not be used because of increase in didanosine toxicity.

- Protease inhibitors: Because TDF decreases atazanavir plasma concentrations, atazanavir without ritonavir should not be co-administered with TDF. In addition, the combination of atazanavir and lopinavir/ritonavir increases plasma tenofovir concentrations and potentiates TDF-associated toxicity.\(^2\)

- Use of Stribild: If using Stribild, please see the Elvitegravir section of the drug appendix for additional information.

Major Toxicities

- More common: Nausea, diarrhea, vomiting, and flatulence.

- Less common (more severe): TDF caused bone toxicity (osteomalacia and reduced bone mineral density [BMD]) in animals when given in high doses. Decreases in BMD have been reported in both adults and children taking TDF. Renal toxicity, including increased serum creatinine, glycosuria, proteinuria, phosphaturia, and/or calciuria and decreased serum phosphate, has been observed. Patients at increased risk of renal glomerular or tubular dysfunction should be closely monitored. Cases of lactic acidosis and severe hepatomegaly with steatosis, including fatal cases, have been reported.

Resistance

The International Antiviral Society-USA (IAS-USA) maintains a list of updated resistance mutations and the Stanford University HIV Drug Resistance Database offers a discussion of each mutation.
**Pediatric Use**

**Approval**

TDF is Food and Drug Administration (FDA)-approved for use in children aged ≥2 years when used as a component of antiretroviral therapy (ART).

TDF has antiviral activity and efficacy against hepatitis B virus (HBV) and is FDA-approved for HBV treatment in children aged ≥12 years. The use of TDF to treat HIV/HBV coinfection is reviewed in the Pediatric Opportunistic Infection Guidelines.

**Efficacy in Clinical Trials in Adults Compared to Children and Adolescents**

The standard adult dose approved by the FDA for adults and children aged ≥12 years and weighing ≥35 kg is TDF 300 mg once daily. For children aged 2 years to 12 years, the FDA-approved dose is TDF 8 mg/kg/dose administered once daily, which closely approximates the dose of TDF 208 mg/m²/dose used in early studies in children.³

In adults, the recommended TDF dose is highly effective. In comparative clinical trials in adults, TDF administered with lamivudine or emtricitabine as a dual-NRTI backbone in combination with efavirenz had better viral efficacy than zidovudine used with lamivudine and efavirenz.⁴⁻⁶ TDF administered with emtricitabine has been compared to abacavir administered with lamivudine in several adult studies and meta-analyses, with variable results.⁷⁻¹¹

In children, the published efficacy data for TDF are mixed, but potency equal to that in adults is seen in pediatric patients aged 3 years to 18 years with susceptible virus. In children aged 2 years to <12 years, TDF 8 mg/kg/dose once daily was noninferior to twice-daily zidovudine- or stavudine-containing ART over 48 weeks of randomized treatment.¹²,¹³ Virologic success is lower in treatment-experienced patients with extensive drug resistance.¹⁴⁻¹⁶

**Pharmacokinetics**

**Relationship of Drug Exposure to Virologic Response**

Virologic suppression is most closely related to intracellular tenofovir diphosphate (TFV-DP) concentrations, and for TDF, intracellular TFV-DP is linked to plasma TFV concentration.¹⁷ A modeling study suggests that children and adolescents treated with TDF may have higher intracellular TFV-DP concentrations than adults,¹⁸ even though plasma TFV concentrations are lower in children and adolescents, because renal clearance of TFV is higher in children than in adults.³,¹⁹,²⁰

**Formulations**

**Special Considerations**

The taste-masked granules that make up the TDF oral powder give the vehicle (e.g., applesauce, yogurt) a gritty consistency. Once mixed with a vehicle, TDF should be administered promptly because its taste becomes bitter if it is allowed to sit too long.

**Toxicity**

**Bone Toxicity**

TDF administration is associated with decreased BMD in both adults²¹,²² and children.¹³,²³⁻²⁵ When treated with TDF, younger children with Sexual Maturity Ratings (SMRs; previously Tanner Stages) 1 and 2 may be at higher risk of decreased BMD than children with more advanced pubertal development (i.e., SMR ≥3).¹⁹ Discontinuation of TDF results in partial or complete recovery of BMD.²³

In the industry-sponsored study that led to FDA approval of TDF in adolescents aged ≥12 years and weighing ≥35 kg, six of 33 participants (18%) in the TDF arm experienced a >4% decline in absolute lumbar spine BMD in 48 weeks, while only one of 33 participants (3%) in the placebo arm experienced this decline.¹⁴
TDF administration disrupts vitamin D metabolism,\textsuperscript{26,27} and the decrease in BMD associated with TDF initiation was attenuated in adults with co-administration of high doses of vitamin D3 (4000 International Units [IU] daily) and calcium carbonate (1000 mg daily) for the first 48 weeks of TDF treatment.\textsuperscript{28} During chronic TDF administration, youth with HIV who received vitamin D3 supplements (50,000 IU once monthly) had decreased serum parathyroid hormone\textsuperscript{29} and increased lumbar spine BMD.\textsuperscript{30} The serum 25-hydroxy vitamin D concentration in the group with improved BMD was 37 ng/mL. Since this improvement in lumbar spine BMD was seen in patients with and without baseline vitamin D deficiency, some practitioners recommend vitamin D supplementation in all patients treated with TDF-containing ART.

Plasma concentrations of the TDF metabolite plasma TFV have been associated with TDF-related endocrine disruption and low BMD.\textsuperscript{26} Tenofovir alafenamide (TAF), which is associated with lower plasma TFV concentrations than TDF, causes less decline in BMD than TDF (see the \textit{Tenofovir Alafenamide} section for more information). Consider switching from TDF to TAF in appropriate clinical settings.

\section*{Monitoring Potential Bone Toxicity}

The Panel on Antiretroviral Therapy and Medical Management of Children Living with HIV (the Panel) does not recommend routine dual-energy absorptiometry (DXA) monitoring for children or adolescents treated with TDF. Given the potential for BMD loss in children treated with TDF, some experts obtain a DXA before initiation of TDF therapy and approximately 6 months after starting TDF, especially in prepubertal patients and those early in puberty (i.e., SMR 1 and 2). If DXA results are abnormal, consider referral to a subspecialist in pediatric endocrinology or a related field.

Despite the ease of use of a once-daily drug and the efficacy of TDF, the potential for BMD loss during the important period of rapid bone accrual in childhood and early adolescence is concerning and favors use of abacavir or TAF in children with SMRs 1 to 3, because children with perinatally acquired HIV are at risk for low peak bone mass.\textsuperscript{30,31}

\section*{Renal Toxicity}

New onset or worsening of renal impairment has been reported in adults\textsuperscript{32} and children\textsuperscript{33,34} receiving TDF. In one study, renal toxicity led to discontinuation of TDF in 3.7\% of children with HIV (6/159 children) who were treated with TDF.\textsuperscript{16} While TDF is clearly associated with a decline in glomerular filtration rate, the effect is generally small, and severe glomerular toxicity is rare.\textsuperscript{32,33} Irreversible renal failure is quite rare, but cases have been reported.\textsuperscript{35}

The main target of TDF nephrotoxicity is the renal proximal tubule.\textsuperscript{33} Case reports highlight the infrequent but most severe manifestations of renal Fanconi syndrome, hypophosphatemia, hypocalcemia, diabetes insipidus, myalgias, bone pain, and fractures.\textsuperscript{36,37}

Subclinical renal tubular damage is more common than clinically apparent renal tubular injury. Increased urinary beta-2 microglobulin was identified in 27\% of children (12/44 children) treated with TDF and in 4\% of children (2/48 children) not treated with TDF.\textsuperscript{38} The risks of TDF-associated proteinuria and chronic kidney disease increase with the duration of treatment.\textsuperscript{39,40} Of 89 participants aged 2 years to 12 years who received TDF in Gilead Study 352 (where participants had a median drug exposure of 104 weeks), four participants were discontinued from the study for renal tubular dysfunction, with the discontinuations occurring between 84 and 156 weeks on TDF therapy.\textsuperscript{12}

\textbf{Plasma TFV is the TDF metabolite most closely associated with both glomerular\textsuperscript{26,41} and proximal tubular\textsuperscript{42} toxicity. TAF, which generates lower plasma TFV concentrations than TDF, is associated with less renal toxicity than TDF (see the \textit{Tenofovir Alafenamide} section).}

\section*{Monitoring Potential Renal Toxicity}

Because TDF has the potential to decrease creatinine clearance and cause renal tubular dysfunction, the Panel recommends measuring serum creatinine and using a urine dipstick to check protein and glucose levels prior to drug initiation. It is unclear how often creatinine and renal tubular function (urine protein and glucose)
should be monitored in asymptomatic patients. Many Panel members monitor creatinine with other blood tests every 3 to 4 months and perform urinalysis every 6 to 12 months. Serum phosphate should be measured if clinically indicated; renal phosphate loss can occur in the presence of normal creatinine and the absence of proteinuria. Because nephrotoxicity increases with the duration of TDF treatment, monitoring should be continued during long-term therapy with the drug.

Because renal glomerular damage primarily increases the urine concentration of albumin, and proximal renal tubular damage increases urine concentrations of low-molecular-weight proteins like beta-2 microglobulin, dipstick urinalysis (measuring primarily urine albumin) may be a relatively insensitive marker for TDF-associated tubular damage. Measuring urine albumin and urine protein and calculating the urine albumin to urine protein ratio can be helpful in identifying the nonalbumin proteinuria that is seen in TDF-associated nephrotoxicity. While these more complex and expensive tests may be used in research settings, in clinical practice, renal tubular damage is perhaps easiest to identify by using a renal dipstick to identify normoglycemic glycosuria and proteinuria.

References


