Non-Nucleoside Reverse Transcriptase Inhibitors

Glossary of Terms for Supplement
Carcinogenic: Producing or tending to produce cancer • Some agents, such as certain chemicals or forms of radiation, are both mutagenic and clastogenic. • Genetic mutations and/or chromosomal damage can contribute to cancer formation.
Clastogenic: Causing disruption of or breakages in chromosomes
Genotoxic: Damaging to genetic material such as DNA and chromosomes
Mutagenic: Inducing or capable of inducing genetic mutation
Teratogenic: Interfering with fetal development and resulting in birth defects

Five non-nucleoside analogue reverse transcriptase inhibitors (NNRTIs) are currently approved: delavirdine, efavirenz, etravirine, nevirapine, and rilpivirine. Delavirdine is no longer available in the United States.

For information about potential interactions between NNRTIs and methergine, see the Postpartum Hemorrhage, Antiretroviral Drugs, and Methergine Use section.

Efavirenz (Sustiva, EFV)

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Regarding embryo-fetal toxicity, the Food and Drug Administration (FDA) advises women to avoid becoming pregnant while taking efavirenz and health care providers to avoid administration in the first trimester of pregnancy as fetal harm may occur.[1]

Animal Studies

Carcinogenicity

Efavirenz was neither mutagenic nor clastogenic in a series of *in vitro* and animal *in vivo* screening tests. A study evaluating genotoxicity of efavirenz in mice noted DNA damage in brain cells after daily dosing for 36 days; no damage was seen in liver, heart, or peripheral blood cells.[2] Long-term animal carcinogenicity studies with efavirenz have been completed in mice and rats. At systemic drug exposures approximately 1.7-fold higher than in humans receiving standard therapeutic doses, no increase in tumor incidence above background was observed in male mice, but in female mice, an increase above background was seen in hepatocellular adenomas and carcinomas and pulmonary alveolar/bronchiolar adenomas. No increase in tumor incidence above background was observed in male and female rats with systemic drug exposures lower than that in humans receiving therapeutic doses.[1]

Reproduction/Fertility

No effect of efavirenz on reproduction or fertility in rodents has been seen.[1]

Teratogenicity/Developmental Toxicity

An increase in fetal resorption was observed in rats at efavirenz doses that produced peak plasma concentrations and area under the curve (AUC) values in female rats equivalent to or lower than those achieved in humans at the recommended human dose (600 mg once daily). Efavirenz produced no reproductive toxicities when given to pregnant rabbits at doses that produced peak plasma concentrations similar to and AUC values approximately half of those achieved in humans administered efavirenz (600 mg once daily).[1] Central nervous system (CNS) malformations and cleft palate were observed in 3 of 20 infants born to pregnant cynomolgus monkeys receiving efavirenz from gestational days 20 to 150 at a dose of 60 mg/kg/day (resulting in plasma concentrations 1.3 times that of systemic human therapeutic exposure, with fetal umbilical venous drug concentrations approximately 0.7 times the maternal values).[3] The malformations

included anencephaly and unilateral anophthalmia in one fetus, microphthalmia in another fetus, and cleft palate in a third fetus.[1]

Placental and Breast Milk Passage

Efavirenz readily crosses the placenta in rats, rabbits, and primates, producing cord blood concentrations similar to concentrations in maternal plasma. Maternal and fetal blood concentrations in pregnant rabbits and cynomolgus monkeys are equivalent, while fetal concentrations in rats exceeded maternal concentrations.[1]

Human Studies in Pregnancy

Pharmacokinetics/Pharmacogenomics

In an intensive sampling pharmacokinetic (PK) study of 25 pregnant women receiving efavirenz during the third trimester as part of clinical care, efavirenz clearance was slightly increased and trough levels were decreased compared with levels measured postpartum.[4] These differences are not of sufficient magnitude to warrant dose adjustment during pregnancy. A recent review of this study plus four others that measured single efavirenz concentrations in pregnant women found that efavirenz concentrations were not significantly affected by pregnancy and that high rates of HIV RNA suppression at delivery were achieved with efavirenz regimens.[5]

In a pharmacogenomics study, non-pregnant individuals with the CYP2B6 516 TT genotype had more than 3-fold increases in both short-term and long-term efavirenz exposure, as measured by plasma and hair drug levels, suggesting there could be significant variation in drug levels with CYP2B6 polymorphisms.[6] The frequency of this allele varies between different ethnic populations, ranging from 3.4% in white, 6.7% in Hispanic, and 20% in African Americans.[4]

PK interactions between efavirenz and some hormonal contraceptives have been reported, with the potential for failure of the progesterone component, potentially affecting efficacy of emergency contraception, combined oral contraceptive pills, progestin-only pills, and progestin implants.[7-10] A retrospective chart review study suggests that efavirenz may decrease the efficacy of levonorgestrel implants (e.g., Jadelle).[11] Pregnancy occurred among 15 (12.4%) of 115 women on efavirenz using Jadelle, compared to no pregnancies among 208 women on nevirapine-based regimens and no pregnancies among 13 women on lopinavir/ritonavir-based regimens ($P < 0.001$) (see Preconception Counseling and Care). In a prospective clinical trial by Scarsi et al, 3 out of 20 (15%) Ugandan women became pregnant between 36 and 48 weeks with the combination of levonogestrel and efavirenz-based antiretroviral therapy (ART) regimen. In comparison to the ART-naive women, the women on efavirenz-based regimens had lower levonorgestrel PK.[12] Patients should be informed of the potential interactions and possible decreased effectiveness with certain hormonal contraceptives. Barrier contraception should strongly be recommended. A different contraceptive regimen may also be considered. A study evaluating the interaction between efavirenz and depot medroxyprogesterone acetate (DMPA) in 17 women found no change in the PK profile of either efavirenz or DMPA with concomitant use.[13] DMPA levels remained above the level needed for inhibition of ovulation throughout the dosing interval. In addition, intrauterine devices (both copper-containing and levonorgestrel-containing) would be expected to maintain efficacy.

Placental and Breast Milk Passage

In a study of 25 mother-infant pairs, median efavirenz cord blood/maternal blood concentration was 0.49 (range 0.37–0.74).[4] In a study of 13 women in Rwanda, efavirenz was given during the last trimester of pregnancy and for 6 months after delivery.[14] Efavirenz concentrations were measured in maternal plasma, breast milk, and infant plasma. Efavirenz concentration was significantly higher in maternal plasma than in skim breast milk (mean breast milk to mean maternal plasma concentration ratio 0.54) and higher in skim breast milk than in infant plasma (mean skim breast milk to mean newborn plasma concentration ratio 4.08). Mean infant plasma efavirenz concentrations were 860 ng/mL and the mean infant plasma efavirenz concentration was 13.1% of maternal plasma concentrations. All infants had detectable plasma concentrations of efavirenz, and 8 of 13 newborns had plasma efavirenz concentrations below the minimum therapeutic concentration of 1000 ng/mL recommended for treatment of HIV-infected adults. In a study of 51 women in

Nigeria receiving efavirenz 600 mg daily, the median (range) milk/maternal plasma ratio was 0.82 (0.51–1.1) and the median (range) infant efavirenz concentration was 178 (88–340) ng/mL.[15] In a study of plasma and hair drug concentration in 56 mother-infant pairs receiving efavirenz-based therapy during pregnancy and breastfeeding, infant plasma levels at delivery and hair levels at age 12 weeks suggested moderate *in utero* transfer during pregnancy and breastfeeding, with approximately one-third of transfer occurring postpartum (40% cumulative with 15% during breastfeeding).[16] All mothers and infants had detectable efavirenz plasma levels at 0, 8, and 12 weeks and mean infant-to-maternal-hair concentration at 12 weeks postpartum was 0.40 for efavirenz. No data currently are available about the safety and PK of efavirenz in neonates.

Teratogenicity Data

In pregnancies with prospectively reported exposure to efavirenz-based regimens in the Antiretroviral Pregnancy Registry through January 2015, birth defects were observed in 21 of 883 live births with first-trimester exposure (2.4%, 95% confidence interval [CI], 1.5% to 3.6%).[17] Although these data provide sufficient numbers of first-trimester exposures to rule out a 2-fold or greater increase in the risk of **overall** birth defects, the low incidence of neural tube defects in the general population means that a larger number of exposures are still needed to be able to definitively rule out an increased risk of this specific defect. Prospective reports to the Antiretroviral Pregnancy Registry of defects after first-trimester efavirenz exposure have documented one neural tube defect case (sacral aplasia, myelomeningocele, and hydrocephalus with fetal alcohol syndrome) and one case of bilateral facial clefts, anophthalmia, and amniotic band. An undefined abnormality of the cerebral vermis was seen on ultrasound and reported in 2014; however, at birth and with follow-up, the infant is noted to be developing normally as per the parents, who have also declined further testing.[17] Among retrospective cases, there are six reports of CNS defects, including three cases of meningomyelocele in infants born to mothers receiving efavirenz during the first trimester.[1] Retrospective reports can be biased toward reporting of more unusual and severe cases and are less likely to be representative of the general population experience.

In an updated meta-analysis of 23 studies (including the Antiretroviral Pregnancy Registry data) reporting on birth outcomes among women exposed to efavirenz during the first trimester, there were 44 infants with birth defects among 2,026 live births to women receiving first-trimester efavirenz (rate of overall birth defects (1.63%, 95% CI, 0.78% to 2.48%).[18] The rate of overall birth defects was similar among women exposed to efavirenz-containing regimens and non-efavirenz-containing regimens during the first trimester (pooled relative risk [RR] 0.78, 95% CI, 0.56–1.08). Across all births, one neural tube defect (myelomeningocele) was observed, giving a point prevalence of 0.05% (95% CI, <0.01 to 0.28), within the range reported in the general population. However, the number of reported first-trimester efavirenz exposures still remains insufficient to rule out a significant increase in low-incidence birth defects (incidence of neural tube defects in the general US population is 0.02% to 0.2%).

A recent French study of 13,124 live births between 1994 and 2010 included an analysis of 372 infants born after first-trimester efavirenz exposure.[19] In the primary analysis using the European Surveillance of Congenital Anomalies (EUROCAT) classification system, no increase in birth defects after first-trimester efavirenz exposure was detected compared to those without efavirenz exposure in pregnancy (adjusted odds ratio 1.16, 95% CI, 0.73–1.85). In a secondary analysis using the modified Metropolitan Atlanta Congenital Defect Program classification used by the Antiretroviral Pregnancy Registry, an association was found between first-trimester efavirenz exposure and neurologic defects. However, none of the four defects (i.e., ventricular dilatation with anomalies of the white substance, partial agenesis of the corpus callosum, subependymal cyst, and pachygyria) were neural tube defects, and none of the defects had common embryology.[20] First-trimester efavirenz exposure was not associated with an increased risk of defects in a Pediatric HIV/AIDS Cohort Study analysis that included 2,580 live births, 94 after first-trimester efavirenz exposure,[21] or an analysis of a national cohort in Italy that included 1,257 pregnancies, 80 after first-trimester efavirenz exposure.[22]

Although two small studies (Pediatric AIDS Clinical Trials Group [PACTG] protocol 219/219C and PACTG protocol P1025) reported a higher rate of birth defects among infants with first-trimester exposure

to efavirenz compared with those without exposure, the number of exposures was small (35 exposures in PACTG 219/219C and 42 in P1025) and there is overlap in defect cases between the two studies.[23-25] Thus, additional data are needed on first-trimester efavirenz exposures to more conclusively determine if risk of neural tube defects is elevated.

The FDA advises women to avoid becoming pregnant while taking efavirenz and health care providers to avoid administration in the first trimester of pregnancy as fetal harm may occur. Although the limited data on first-trimester efavirenz exposure cannot rule out a 2- or 3-fold increased incidence of a rare outcome, such as neural tube defects, the available data from the meta-analysis on more than 2,000 births suggest that there is not a large increase (e.g., a 10-fold increase to a rate of 1%) in the risk of neural tube defects with first-trimester exposure. Pregnancy should be avoided in women receiving efavirenz, and treatment with efavirenz should be avoided during the first 8 weeks of pregnancy (the primary period of fetal organogenesis) whenever possible because of the potential for teratogenicity. Women of childbearing potential should undergo pregnancy testing before initiation of efavirenz and should be counseled about the potential risk to the fetus and desirability of avoiding pregnancy. Alternate antiretroviral (ARV) regimens that do not include efavirenz should be strongly considered in women who are planning to become pregnant (or who are sexually active and not using effective contraception) if such alternative regimens are acceptable to provider and patient and will not compromise the woman's health. However, given that the risk of neural tube defects is restricted to the first 5 to 6 weeks of pregnancy (the neural tube closes at 36 to 39 days after the last menstrual period), pregnancy is rarely recognized before 4 to 6 weeks of pregnancy, and ARV drug changes in pregnancy may be associated with loss of viral control and thus increase risk of transmission to the infant,[26] efavirenz can be continued in pregnant women receiving efavirenz-based ART who present for antenatal care in the first trimester. In such situations, additional fetal monitoring (e.g., second-trimester ultrasound) should be considered to evaluate fetal anatomy.

Excerpt from Table 8[a]

Generic Name (Abbreviation) *Trade Name*)	Formulation	Dosing Recommendations	Use in Pregnancy
Efavirenz (EFV) *Sustiva* (EFV/TDF/FTC) *Atripla*	EFV (Sustiva) *Capsules:* • 50 mg • 200 mg *Tablet:* • 600 mg Atripla: • EFV 600 mg plus TDF 300 mg plus FTC 200 mg tablet	Standard Adult Dose *EFV (Sustiva):* • 600 mg once daily at or before bedtime, on empty stomach to reduce side effects *Atripla:* • 1 tablet once daily at or before bedtime, on empty stomach to reduce side effects PK in Pregnancy: • AUC decreased during third trimester, compared with postpartum, but nearly all third-trimester participants exceeded target exposure. Dosing in Pregnancy: • No change in dose indicated.	Moderate placental transfer to fetus.[b] Potential fetal safety concern: cynomolgus monkeys receiving EFV during the first trimester at a dose resulting in plasma levels comparable to systemic human therapeutic exposure had 3 of 20 infants with significant CNS or other malformations. In humans, there is no increase in overall birth defects with first-trimester EFV exposure. However, in humans with first-trimester exposure, there have been 6 retrospective case reports and 1 prospective case report of CNS defects and 1 prospective case report of anophthalmia with facial clefts. The relative risk with first-trimester exposure is unclear. Non-pregnant women of childbearing potential should undergo pregnancy testing before EFV initiation and counseling about potential risk to the fetus and desirability of avoiding pregnancy while on EFV-containing regimens. Alternate ARV regimens that do not include EFV should be strongly considered in women who are planning to become pregnant or who are sexually active and not using effective contraception. Because the risk of neural tube defects is restricted to the first 5–6 weeks of pregnancy and pregnancy is rarely recognized before 4–6 weeks, and unnecessary ARV drug changes during pregnancy may be associated with loss of viral control and increased risk of perinatal transmission, EFV may be continued in pregnant women receiving an EFV-based regimen who present for antenatal care in the first trimester (see HIV-Infected Pregnant Women Who are Currently Receiving Antiretroviral Treatment).

[a] Individual antiretroviral drug dosages may need to be adjusted in renal or hepatic insufficiency (for details, see Adult and Adolescent Guidelines, Appendix B, Table 7).

[b] Placental transfer categories—Mean or median cord blood/maternal delivery plasma drug ratio:

High: >0.6 **Moderate:** 0.3–0.6 **Low:** <0.3

Key to Acronyms: ARV = antiretroviral; AUC = area under the curve; CNS = central nervous system; EFV = efavirenz; FTC = emtricitabine; PK = pharmacokinetic; TDF = tenofovir disoproxil fumarate

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