Review

Safety of Tumor Necrosis Factor Inhibitors during Pregnancy and Breastfeeding

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Received: 12 April 2012
Accepted: 6 August 2012
Published: 21 September 2012

Keywords: tumor necrosis factor (TNF) inhibitors; uveitis; pregnancy; breastfeeding


Purpose: Tumor necrosis factor (TNF) inhibitors are useful in the treatment of numerous inflammatory and immunologic disorders. Since many of these conditions occur in women of childbearing age, safety during pregnancy and breastfeeding is of considerable importance.

Methods: This paper is a review of the literature on the safety of TNF inhibitors during pregnancy and breastfeeding published between 2001 and 2011.

Conclusions: TNF inhibitors do not appear to be associated with a high risk of teratogenicity or intrauterine death. However, a small magnitude increase in risk cannot be ruled out given the paucity of data on the subject. Although TNF inhibitor use may be associated with a higher rate of preterm delivery, this may in fact be due to an active, underlying disease. Therefore, the decision to use these medications should be made on a case-by-case basis. If the disease cannot be managed with first line agents, TNF inhibitors may be helpful in reducing the number of disease exacerbations. Nevertheless, when using TNF inhibitors, it is prudent to discontinue treatment around the third trimester when transfer across the placenta is greatest and to restart postpartum.

Introduction

Commerically available tumor necrosis factor (TNF) inhibitors (e.g., adalimumab, certolizumab, etanercept, golimumab, and infliximab) have been found to be useful in the treatment of noninfectious inflammatory diseases, including inflammatory bowel disease (IBD),1 rheumatoid arthritis (RA),2,3 and psoriatic arthritis (PsA).4 Their use is especially valuable in refractory disease, when first line agents have failed or caused intolerable side effects. In these cases, TNF inhibitors may be highly effective in reducing the number of disease exacerbations.1–4 For a few indications, including the management of moderate to severe RA, anti-TNF agents are also Food and Drug Administration (FDA) approved as initial therapy. Given the increasing use of these drugs in managing immunologic disorders, many of which occur in women of childbearing age, safety during pregnancy is of concern. This is a review of the literature on the subject of safety of TNF inhibitors during pregnancy and breastfeeding published within the last 10 years. Particular attention is paid to adalimumab, infliximab, and etanercept, as these drugs have been the subject of the majority of published research in this area to date.

Methods

Literature Review

To accomplish as current a review of the literature as possible, we limited our search to articles published in peer-reviewed journals within the last 10 years (2001–2011). Articles were identified between September 1, 2011, and October 1, 2011, by performing a series of PubMed searches using the following Boolean search terms: “TNF inhibitors...
AND pregnancy,” “adalimumab AND pregnancy,”
“certolizumab AND pregnancy,” “etanercept AND
pregnancy,” “golimumab AND pregnancy,” “inflix-
imab AND pregnancy” “TNF inhibitors AND
breastfeeding” and “TNF inhibitors AND placental
transfer.” Original studies and case presentations,
which reported the use of one or more TNF
inhibitors in pregnancy or during breastfeeding,
including outcomes, were included in our review.

Tumor Necrosis Factor-Alpha and
Lymphotoxin

TNF-α is an inflammatory cytokine released by
many cell types, including macrophages, in the setting
of an immune response. As an endogenous pyrogen,
TNF-α has multiple activities that contribute to the
initiation and perpetuation of inflammation. Al-
though its role in gestation has yet to be completely
elucidated, TNF-α may serve two apparently com-
peting roles. On one hand, it mediates a stress
response within the embryo, triggering inflammatory
loss of pregnancy if the embryo sustains structural
damage. On the other hand, TNF-α is also believed to
play a role in protecting the embryo against toxins
during development. By disrupting the protective
effects of TNF-α, TNF blockers could be associated
with an increased risk of congenital anomalies.

Lymphotoxin, previously known as TNF-β, exerts
a similar downstream effect by binding the same
receptors as TNF-α. Lymphotoxin activates neutro-
phils and macrophages and alters expression of
vascular endothelial adhesion molecules to help
mobilize inflammatory cells. Although not a principal
target of TNF blockers, lymphotoxin is targeted by
etanercept, a soluble form of the TNF receptor that
binds and inactivates both TNF-α and TNF-β.

TNF Inhibitors

As a whole, TNF inhibitors are classified as
Pregnancy Category B drugs by the FDA. According
to this classification system, Category B comprises
those drugs that reproductive studies in animals have
failed to demonstrate risk to the fetus and that no
well-controlled studies exist in pregnant women, or
that reproductive studies in animals have demonstrat-
ed risk to the fetus, but that well-controlled studies in
pregnant women have failed to substantiate this risk.
Of note, infliximab has not been studied in animal
reproductive models because this chimeric murine-
human immunoglobulin G (IgG) 1 monoclonal
antibody cross-reacts only with TNF-α in humans
and chimpanzees. However, no embryotoxicity, tera-
togenicity, or maternal toxicity was detected in
developmental toxicology studies performed in mice
using a functionally similar antibody directed at
mouse TNF-α. Table 1 provides a summary of the
various TNF inhibitors as adapted from Micromedex
Healthcare Series.

Given the obvious ethical limits to conducting a
double-blind, controlled study to accurately assess the
risks of the TNF blockers in pregnancy, there is a
paucity of data on the safety of these drugs during
pregnancy and breastfeeding. Since much of the data
we have comes from case reports and case series with
small sample sizes, the findings cannot be easily
extrapolated. Some recent publications have present-
ed data collected by voluntary reporting about
adverse events associated with TNF inhibitors by
patients and health care providers. Such methodology
is confounded by recall and reporting bias, and often
provides incomplete details about disease severity,
comorbidities and/or concomitant medication use.

Transfer of TNF Inhibitors across the
Placenta and into Breast Milk

The TNF inhibitors vary considerably in the
degree that they cross the placental barrier from
mother to fetus and enter breast milk during
lactation. Infliximab, the most extensively studied
TNF inhibitor in this regard, is a chimeric murine-
human IgG1 monoclonal antibody against TNF-α. In
studies designed to measure the degree of placental
transfer of infliximab, drug levels in cord blood were
between 2- and 3-fold higher than in maternal serum
in three out of four infants from an IBD-complicated
pregnancy.

However, findings pertaining to postpartum levels
of infliximab were less clear. One case report showed
that infliximab levels are low, but detectable, up to 6
months postpartum in the blood of infants exposed to
infiximab during pregnancy. Yet, in apparent
conflict with these findings, another case series
reported undetectable levels of infliximab in infants
born to mothers treated with the drug prior to
conception through approximately 30 weeks gesta-
tion.

The detection of infliximab in neonates and the
observation that placental transfer of IgG is greatest
during the third trimester have led to the general
recommendation that treatment with infliximab
should be concluded prior to the third trimester.
On the other hand, studies consistently show no
Table 1. Summary of TNF Inhibitors as Adapted from Micromedex Healthcare Series (Internet Database), (Updated Periodically)

<table>
<thead>
<tr>
<th>Drug</th>
<th>Structure</th>
<th>Active Against TNF-α</th>
<th>Active Against Lymphotoxin?</th>
<th>Mechanism(s) of Action</th>
<th>FDA Approved Indications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adalimumab</td>
<td>Human monoclonal TNF-α antibody</td>
<td>Yes</td>
<td>No</td>
<td>Lyses cells expressing surface TNF-α in vitro. Modulates TNF regulation of vascular endothelial adhesion molecules. Increases CRP, ESR, IL6, and MMP-1 and MMP-3</td>
<td>AS CD (moderate to severe) if conventional therapy is insufficient. JIA CPP (moderate to severe) PA RA (moderate to severe)</td>
</tr>
<tr>
<td>Certolizumab Pegol</td>
<td>PEGylated Fab fragment of humanized TNF-α monoclonal antibody</td>
<td>Yes</td>
<td>No</td>
<td>Interferes with prostaglandin, inflammatory mediators, IL1, PAF, and NO</td>
<td>CD RA (moderate to severe)</td>
</tr>
<tr>
<td>Etanercept</td>
<td>Dimeric soluble form of TNF receptor</td>
<td>Yes</td>
<td>Yes</td>
<td>Modulates TNF regulation of serum cytokine levels, serum MMP levels, and vascular endothelial adhesion molecule expression</td>
<td>AS JIA (moderate to severe) CPP (moderate to severe) in patients who may warrant systemic therapy or phototherapy PsA RA (moderate to severe)</td>
</tr>
<tr>
<td>Golimumab</td>
<td>Human monoclonal TNF-α monoclonal antibody</td>
<td>Yes (soluble and transmembrane forms)</td>
<td>No</td>
<td></td>
<td>AS RA (moderate to severe)</td>
</tr>
<tr>
<td>Infliximab</td>
<td>Chimeric human-mouse immunoglobulin IgG1-kappa</td>
<td>Yes (soluble and transmembrane forms)</td>
<td>No</td>
<td></td>
<td>AS CD Fistulizing CD (moderate to severe) if conventional therapy is insufficient CPP PsA RA (moderate to severe) in combination with MTX</td>
</tr>
</tbody>
</table>

http://tvstjournal.org/doi/full/10.1167/tvst.1.2.6
passage of infliximab to the infant during breastfeeding as evidenced by stable serum levels in the breastfeeding infant and undetectable levels of infliximab in breast milk.11,12,14

Like infliximab, adalimumab is a monoclonal IgG1 antibody against TNF-α. However, unlike infliximab, it is a fully humanized antibody. Because of similarities in their structure, adalimumab is presumed to have a comparable degree of transfer across the placental barrier as infliximab.15 However, at this time, serum levels of adalimumab cannot be measured commercially, so data on adalimumab levels in maternal and infant serum are lacking.16 According to an assessment of the safety and efficacy of various biologic therapies used in pregnant women with Crohn’s disease (CD) by the World Congress of Gastroenterology, use of adalimumab in pregnancy is challenging due to its frequent dosing schedule. Discontinuing treatment with adalimumab early in the third trimester before immunoglobulin transfer across the placenta is at its greatest is also particularly difficult without potentiating a flare. For that reason, it was recommended that adalimumab be stopped approximately 8 to 10 weeks prior to the delivery date. No safety information is available on the subject of adalimumab and lactation.16

In contrast to infliximab and adalimumab, certolizumab is a PEGylated Fab fragment of the anti-TNF-α antibody. As a result of this structural difference, certolizumab crosses the placenta slowly, through the process of diffusion rather than by active transport across a membrane receptor as occurs with whole antibodies.17 In a study performed in rats, levels of anti-TNF agent in breast milk and pup serum were lower if mothers received the Fab antibody fragment rather than whole antibody.18 These findings were supported by a report of a 22-year-old woman with IBD initiated on subcutaneous certolizumab in the second trimester, in whom maternal serum levels of certolizumab far exceeded the concentration in cord blood, suggesting minimal in utero transfer of certolizumab.19

Similarly, cord blood levels of etanercept have been shown to be lower than maternal serum levels in women exposed to the drug during pregnancy.20 Although etanercept may be detected in breast milk at a low concentration, serum levels in the nursing infant were reported to decline rapidly (i.e., undetectable at 12 weeks) despite regular breastfeeding in the case of a 40-year-old woman with RA treated with etanercept, indicating that little, if any, drug passes to the infant during lactation.21 Slightly higher, but still minimal, levels of etanercept were noted in breast milk in another patient after pulsed treatment with the drug postpartum.22 See Table 2 for a summary of original papers describing the use of TNF inhibitors during breastfeeding.

### Adverse Effects of TNF Inhibitors during Pregnancy

A number of studies have suggested that the use of TNF inhibitors during pregnancy is not associated with teratogenic effects. A registry study reported on pregnancy outcomes of 33 women with RA who were treated with TNF antagonists and followed prospectively during pregnancy in comparison to nonexposed disease matched women and otherwise healthy women, and found no clear difference in the rate of major malformations between the three groups.23 However, neonates born to mothers in the group exposed to TNF antagonists and in the disease matched control group were significantly more likely to be born preterm. These findings have been recapitulated by an ongoing registry study by the same group, which prospectively followed pregnant women with RA treated with adalimumab adding comparison groups.24

In a second study of pregnancy outcomes in 10 women treated with infliximab, all pregnancies resulted in live births without congenital malformations, intrauterine growth retardation (IUGR), or infants small for gestational age (SGA).25 While there were three preterm deliveries and two cases of neonatal illness, no association with infliximab use could be made due to concomitant use of other biologic agents in several of the women. Numerous case reports and other small case series have documented the use of anti-TNF agents during pregnancy without complication (Table 3).
With regard to the potential abortifacient effects of TNF inhibitors, two studies suggest no significant difference in the rates of miscarriage between infliximab-exposed and infliximab-naïve women.\textsuperscript{28,29} Additionally, a recent observational study including 212 subjects implied that overall abortion rates in women treated for IBD did not differ significantly regardless of exposure history to TNF inhibitors.\textsuperscript{26}

Furthermore, regardless of whether the women received anti-TNF therapy, abortion rates did not differ from rates amongst healthy controls. There was, however, an increased risk of preterm delivery in women treated with anti-TNF agents compared with healthy controls due either to the underlying disease, the use of TNF blockers, or a combination thereof. In contrast to these reports, a recent study

### Table 2. Original Articles on TNF Inhibitors and Breastfeeding and Transfer across the Placenta

<table>
<thead>
<tr>
<th>Reference</th>
<th>Drug</th>
<th>Study Size</th>
<th>Timing of Drug Administration</th>
<th>Main Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>Certolizumab</td>
<td>22-year-old with IBD</td>
<td>T2–postpartum</td>
<td>Healthy delivery with low cord blood levels.</td>
</tr>
<tr>
<td>20</td>
<td>Etanercept</td>
<td>34-year-old with AS</td>
<td>4 years before conception–postpartum</td>
<td>Healthy delivery with low cord blood levels and undetectable infant serum levels despite breastfeeding.</td>
</tr>
<tr>
<td>22</td>
<td></td>
<td>34-year-old with RA</td>
<td>Postpartum</td>
<td>Low breast milk levels after treatment with etanercept.</td>
</tr>
<tr>
<td>21</td>
<td></td>
<td>40-year-old with RA</td>
<td>Shortly before conception–postpartum</td>
<td>Healthy delivery with low cord blood levels and decline in infant serum levels despite breastfeeding.</td>
</tr>
<tr>
<td>12</td>
<td>Infliximab</td>
<td>3 patients, ages 24–32 years with CD</td>
<td>Maintenance therapy through 25–30 weeks gestation and restarted postpartum</td>
<td>3 healthy pregnancies (1 preterm) with undetectable levels in breast milk and infant serum.</td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>1 patient: 22-year-old with CD</td>
<td>12 weeks gestation–postpartum</td>
<td>Healthy delivery with undetectable levels in breast milk.</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>32-year-old with CD</td>
<td>5 doses throughout pregnancy</td>
<td>Healthy delivery with undetectable levels in breast milk and steady decline in infant serum levels during the first 6 months postpartum despite breastfeeding.</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>4 patients, ages 19–31 years, with IBD</td>
<td>Before pregnancy–30 weeks gestation</td>
<td>Healthy deliveries with variable cord blood levels in 3 of 4 infants and undetectable levels in 1 infant. 1 infant with detectable levels of infliximab in the cord blood was born with polydactyly. At 3–6 month follow up postpartum, there was no increased risk of infection and an appropriate antibody response to nonliving vaccines.</td>
</tr>
</tbody>
</table>

ELISA, Enzyme-Linked Immunosorbent Assay; T2, second trimester.
### Table 3. Original Articles and Case Presentations on the Safety of TNF Inhibitors during Pregnancy

<table>
<thead>
<tr>
<th>Reference</th>
<th>Study Type</th>
<th>Study Size</th>
<th>Drug</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td>OTIS Registry Study prospectively following pregnant RA patients, adding controls</td>
<td>33 patients with RA receiving anti-TNF therapy compared with disease matched controls (n = 77) and healthy controls (n = 50)</td>
<td>Etanercept (n = 29) Infliximab (n = 4)</td>
</tr>
<tr>
<td>26</td>
<td>Observational study with IBD patients</td>
<td>42 pregnancies with IBD exposed to TNF antagonist compared with 23 nonexposed pregnancies prior to IBD diagnosis, 78 pregnancies after diagnosis of IBD but before starting a TNF antagonist, 53 pregnancies with indirect exposure to a TNF antagonist, and 56 healthy controls.</td>
<td>Adalimumab Infliximab</td>
</tr>
<tr>
<td>27</td>
<td>Review of pregnancy outcomes from the BSRBR</td>
<td>140 pregnancies, 130 of which were exposed to anti-TNF therapy at or before conception</td>
<td>Not specified</td>
</tr>
<tr>
<td>28</td>
<td>Retrospective review of BSRBR data</td>
<td>32 total pregnancies. 23 pregnancies in patients mostly with RA, directly exposed to an anti-TNF agent at time of conception. The other 9 patients discontinued anti-TNF therapy at a mean length of 5 months before conception</td>
<td>Adalimumab (n = 3) Etanercept (n = 17) Infliximab (n = 3)</td>
</tr>
<tr>
<td>29</td>
<td>Retrospective chart review of infliximab safety database (US and Europe)</td>
<td>96 pregnancies complicated by CD, UC, or RA, exposed to infliximab with known outcomes compared with historic healthy controls and disease matched controls not receiving infliximab</td>
<td>Infliximab</td>
</tr>
<tr>
<td>25</td>
<td>Retrospective chart review</td>
<td>10 patients with CD</td>
<td>Infliximab</td>
</tr>
<tr>
<td>Reference</td>
<td>Timing of Drug Administration</td>
<td>Main Findings</td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>-------------------------------</td>
<td>---------------</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>T1</td>
<td>Significant increase in the rate of preterm delivery in the anti-TNF and non exposed disease matched groups relative to healthy controls. No clear difference in the rate of malformations between all 3 groups.</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Direct exposure = within 3 months of conception and/or during pregnancy until T2. Indirect exposure = before, but not during, pregnancy</td>
<td>Increased risk of preterm delivery in the direct exposure group compared with healthy controls. No significant difference in spontaneous abortion rates between IBD pregnancies regardless of TNF exposure and healthy controls.</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>At conception (+/- methotrexate or leflunomide), before conception, or not at all</td>
<td>Rate of spontaneous abortion was highest in the group exposed at conception followed by exposure prior to conception, and no exposure. Cases of premature delivery, neonatal death, and intrauterine death were also reported.</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>All but 2 patients stopped taking medications during T1.</td>
<td>6 of 23 pregnancies resulted in miscarriage in women directly exposed to a TNF inhibitor at conception. No major malformations, 1 premature delivery, 1 low birth weight infant, and 1 C-section for fetal distress were reported. In the group of women who discontinued anti-TNF therapy before conception, 1 case of fetal demise in utero was reported in a patient who discontinued MTX 4 months before conception.</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>Variable</td>
<td>Rates of live births, miscarriages, and therapeutic terminations were similar between all 3 groups. Cardiac malformation, preterm delivery, complicated neonatal course, intestinal malrotation, and an infant with hypothyroidism and developmental delay, were reported. Some of these cases occurred in pregnancies complicated by known teratogenic medication use, maternal infection, etc.</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Unclear</td>
<td>61 reported congenital anomalies in 41 children born to women taking a TNF inhibitor. 24 of 41 infants had 1 or more VACTERL-associated malformations. Miscarriages were also reported in women exposed to etanercept.</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>8 patients treated throughout pregnancy, 1 treated in T3, and 1 treated in T1.</td>
<td>No malformations, IUGR, or SGA neonates. Preterm delivery, low birth weight infancy, and neonatal illness were reported.</td>
<td></td>
</tr>
<tr>
<td>Reference</td>
<td>Study Type</td>
<td>Study Size</td>
<td>Drug</td>
</tr>
<tr>
<td>-----------</td>
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<td>------------</td>
<td>------</td>
</tr>
<tr>
<td>30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41</td>
<td>Multiple case reports and 1 case series, compiled</td>
<td>15 total patients, ages 22–36 years, with CD, PsA, RA, or TA</td>
<td>Adalimumab, Certolizumab, Etanercept and/or Infliximab</td>
</tr>
<tr>
<td>42</td>
<td>Case Report</td>
<td>29-year-old with CD</td>
<td>Infliximab</td>
</tr>
<tr>
<td>43</td>
<td>Case Series</td>
<td>4 patients, ages 27–40 years, with seronegative erosive JIA, RA, or polyarthritis consistent with lupus</td>
<td>Etanercept ((n = 1)) Infliximab ((n = 3))</td>
</tr>
<tr>
<td>44</td>
<td>Case Report</td>
<td>26-year-old with CD</td>
<td>Infliximab</td>
</tr>
<tr>
<td>45</td>
<td>Case Report</td>
<td>30-year-old with CD</td>
<td>Infliximab</td>
</tr>
<tr>
<td>46</td>
<td>Case Report</td>
<td>36-years-old with UC</td>
<td>Infliximab</td>
</tr>
<tr>
<td>47</td>
<td>Case Report</td>
<td>28-year-old with psoriasis</td>
<td>Etanercept</td>
</tr>
<tr>
<td>48</td>
<td>Case Report</td>
<td>28-years-old with CD</td>
<td>Infliximab</td>
</tr>
<tr>
<td>49</td>
<td>Case Report</td>
<td>2 patients, ages 23- and 31-year-old, with CD</td>
<td>Infliximab</td>
</tr>
<tr>
<td>50</td>
<td>Prospective case series</td>
<td>3 patients, ages 21, 37, and unspecified years</td>
<td>Adalimumab ((n = 1)) Etanercept ((n = 2))</td>
</tr>
<tr>
<td>51</td>
<td>Case report</td>
<td>26-year-old with CD</td>
<td>Infliximab</td>
</tr>
<tr>
<td>52</td>
<td>Case report</td>
<td>24-year-old with SLE</td>
<td>Etanercept</td>
</tr>
<tr>
<td>53</td>
<td>Case series</td>
<td>15 pregnancies in patients 22- to 42-years-old, with JIA, PsA, RA, or SpA</td>
<td>Adalimumab ((n = 2)) Etanercept ((n = 10)) Infliximab ((n = 3))</td>
</tr>
<tr>
<td>54</td>
<td>Case report</td>
<td>29-years-old with RA</td>
<td>Infliximab</td>
</tr>
</tbody>
</table>

CAH, congenital adrenal hyperplasia; c/b, complicated by; ICU, Intensive Care Unit; PFO, Patent Foramen Oval; SLE, Systemic Lupus Erythematosus; SpA, Spondyloarthritis; T1, first trimester; T3, third trimester; TA, Takayasu’s Arteritis; UTI, urinary tract infection.
following outcomes of 130 pregnancies in 118 women with RA concluded that the rate of spontaneous abortion was higher in women exposed to anti-TNF therapy at conception than those exposed before conception or not at all. It is unclear if these findings were statistically significant.

Finally, in a recent paper observing patterns of medication use in 393 pregnancies complicated with RA, 281 pregnancies ended in live births versus 75 that ended in spontaneous abortions. Of these 281 live births, 35 of 281 (12.5%) were exposed to biologic disease-modifying antirheumatic drugs (DMARDs) during pregnancy, and of the 75 spontaneous abortions, a similar proportion (9/75 [12%]) was exposed to biologic DMARDs. The disparity in exposure rate was considerably different with regard to the use of category D and X nonbiologic DMARDs in the group resulting in live delivery

<table>
<thead>
<tr>
<th>Reference</th>
<th>Timing of Drug Administration</th>
<th>Main Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>42</td>
<td>3 months before pregnancy</td>
<td>Healthy preterm delivery</td>
</tr>
<tr>
<td>43</td>
<td>Before conception– birth</td>
<td>2 preterm and 2 full term healthy pregnancies</td>
</tr>
<tr>
<td>44</td>
<td>Before pregnancy– postpartum</td>
<td>Healthy preterm delivery</td>
</tr>
<tr>
<td>45</td>
<td>Before conception– birth</td>
<td>Premature delivery c/b low birth weight</td>
</tr>
<tr>
<td>46</td>
<td>T2</td>
<td>Pregnancy c/b growth retardation, depressed fetal heart rate and SGA diagnosis in patient with active disease</td>
</tr>
<tr>
<td>47</td>
<td>Years before conception– birth. Pregnancy followed dosage increase.</td>
<td>Preterm delivery c/b tracheal atresia and tracheoesophageal fistula, esophageal atresia, imperforate anus, PFO, hypospadias, and thoracic vertebral anomaly.</td>
</tr>
<tr>
<td>48</td>
<td>Before conception– birth</td>
<td>Healthy preterm delivery. Vaccinated with BCG vaccine at 3 months and died from complications at 4.5 months.</td>
</tr>
<tr>
<td>49</td>
<td>Before conception– birth</td>
<td>1 premature delivery c/b low birth weight, acute respiratory distress, and prolonged ICU stay. Normal development at 8 months.</td>
</tr>
<tr>
<td>50</td>
<td>Before conception</td>
<td>Preterm delivery in 1 pregnancy exposed to adalimumab, and neonatal jaundice, UTI and CAH (also in father) in 1 pregnancy exposed to etanercept.</td>
</tr>
<tr>
<td>51</td>
<td>At conception</td>
<td>Preterm delivery c/b intracerebral and intrapulmonary bleeding and neonatal death</td>
</tr>
<tr>
<td>52</td>
<td>Before conception and T2–birth</td>
<td>Healthy delivery at 36 weeks; pregnancy complicated by pre-eclampsia at 26 weeks.</td>
</tr>
<tr>
<td>53</td>
<td>Variable</td>
<td>12 full term deliveries and 2 miscarriages</td>
</tr>
<tr>
<td>54</td>
<td>Before conception–5 weeks</td>
<td>T1 miscarriage. Concomitant MTX, folic acid, and diclofenac before pregnancy.</td>
</tr>
</tbody>
</table>
(3.9%) compared with the group resulting in spontaneous abortion (8%) (Table 4). Furthermore, the authors showed that use of biologic DMARDs tend to decrease over the course of the pregnancy because of a lack of data on the safety of TNF inhibitors.30

One of the largest studies reviewed more than 120,000 adverse events reported to the US FDA between 1999 and 2005 in relation to the use of etanercept, infliximab, and adalimumab.5 Conducting a search of the database for adverse outcomes associated with pregnancy, the authors identified reports of 61 congenital anomalies in 41 children born to mothers taking a TNF inhibitor. The most common anomalies were referring to the non random grouping of congenital malformations including vertebral, anal, cardiac, tracheo-esophageal, renal, and limb defects (VACTERL). However, 41% of women were also taking concomitant medications, including methotrexate (MTX), a Pregnancy Category X drug with known teratogenic potential.

The authors acknowledged several limitations of their study. Foremost, since this database cataloged only adverse events in patients treated with a TNF blocker and was reliant on patient or provider reporting, it is unknown how many women were ultimately treated to generate this number of adverse events. Additionally, since the data relied on voluntary reporting, there was potential for reporting bias. The lack of information concerning the patients’ other comorbidities was an additional limitation. Findings consistent with an increased rate of vertebral, anal, tracheo-esophageal, and renal anomalies (VATER) and VACTERL-associated defects in women treated with TNF blockers was previously reported by the same authors in a patient with psoriasis treated with etanercept.47

Complications have also been reported in the postnatal period following the use of TNF inhibitors during pregnancy. One case report describes a 28-year-old woman with IBD treated with infliximab whose infant was born without complication and, at 3 months of age, was immunized with the bacille Calmette-Guerin (BCG) vaccine. The infant died from clinically diagnosed disseminated BCG, a rare complication of the live, attenuated vaccine thought to relate to maternal use of infliximab during pregnancy, which has an unknown effect on immune system development and function in infants.48

Another publication reported on an infant born prematurely at 24 weeks gestation to a 26-year-old woman with IBD treated with infliximab, as well as azathioprine, metronidazole, and mesalamine, during pregnancy.33 The neonate developed intracerebral and intrapulmonary bleeding and died 3 days after birth. This case illustrates the difficulty in identifying potential drug side effects in the presence of concomitant medication use. Additional cases affirm the difficulty in identifying potential drug side effects when patients are taking multiple medications, some of which are known to have teratogenic effects54 or when pregnancy is complicated by an active underlying disease.46,49 Table 3 provides a summary of the key studies summarized in our review.

### Conclusion

In conclusion, TNF inhibitors are risk category B drugs in pregnancy that, based on our evaluation of the available literature, do not pose high risk of teratogenicity or intrauterine death. A small magnitude increase in risk cannot be ruled out given the paucity of data on the subject. Although TNF inhibitor use may be associated with a higher rate of preterm delivery, this may in fact be due to the active underlying disease. The decision to use these drugs should, therefore, be made on a case-by-case basis, taking into account severity of disease and the potential benefits and harms of using immunomodulators versus contending with the inherent risks to the pregnancy caused by the inflammatory disease. Questions regarding activity of the disease, the potential for organ- or life-threatening complications, and available alternative medications must be ad-

<table>
<thead>
<tr>
<th>No. exposed to nonbiologic DMARDs (category D or X)</th>
<th>Pregnancies Resulting in Live Delivery (281)</th>
<th>Pregnancies Resulting in Spontaneous Abortion (75)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. exposed to biologic DMARDs</td>
<td>11 (3.9%)</td>
<td>6 (8%)</td>
</tr>
<tr>
<td></td>
<td>35 (12.5)</td>
<td>9 (12%)</td>
</tr>
</tbody>
</table>

*Based on a Study by Kuriya, et al.55*
dressed when a patient desires to become pregnant or has become pregnant while taking a TNF inhibitor. If the disease is quiescent or can be managed with low dose prednisone and a medication such as azathioprine or sulfasalazine, the treating physician may recommend against continuation of the anti-TNF agent. On the other hand, if the disease is active and an anti-TNF agent is the best therapeutic alternative for the patient, continuing the medication may be the best option. If TNF inhibitors are used during pregnancy, discontinuing use at the beginning of the third trimester is prudent, as transplacental transfer of IgG is greatest after this time. If treatment with TNF inhibitors must be continued in the long term, it appears safe to do so after delivery. It is important to emphasize that an assessment of the risks and benefits of these medications during pregnancy should be carefully discussed with the patient.

Acknowledgments

The authors would like to thank Douglas Jabs, Department of Ophthalmology, Mount Sinai School of Medicine, and Russell Van Gelder, Department of Ophthalmology, University of Washington, for their insights during the preparation of this manuscript.

Disclosure: H. Raja, None; E.L. Matteson, None; C.J. Michet, None; J.R. Smith, None; J.S. Pulido, None

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