Belimumab use during pregnancy: a summary of birth defects and pregnancy loss from belimumab clinical trials, a pregnancy registry and postmarketing reports

Michelle Petri,1 Helain Landy,2,3 Megan E B Cloewe,4 Kim Gemzoe,5 Munther Khamashta,6 Milena Kurtinecz,7 Roger A Levy,8 Andrew Liu,9 Rebecca Marino,10 Paige Meizlik,11 Jeanne M Pimenta,12 Kelsey Sumner,13,14 Hugh Tilson,14 Mary Beth Connolly,15 Keele Wurst,16 Julia Harris,17 Holly Quasny,18 Patricia Juliao,19 David A Roth11

ABSTRACT

Objective Describe available data on birth defects and pregnancy loss in women with systemic lupus erythematosus (SLE) exposed to belimumab.

Methods Data collected from belimumab clinical trials, the Belimumab Pregnancy Registry (BPR), and postmarketing/spontaneous reports up to 8 March 2020 were described. Belimumab exposure timing, concomitant medications and potential confounding factors were summarised descriptively.

Results Among 319 pregnancies with known outcomes (excluding elective terminations), 223 ended in live births from which birth defects were identified in 4/72 (5.6%) in belimumab-exposed pregnancies and 0/9 placebo-exposed pregnancies across 18 clinical trials, 10/46 (21.7%) belimumab-exposed pregnancies in the BPR prospective cohort (enrolled prior to pregnancy outcome) and 0/4 belimumab-exposed pregnancies in the BPR retrospective cohort (enrolled after pregnancy outcome), and 1/92 (1.1%) in belimumab-exposed pregnancies from postmarketing/spontaneous reports. There was no consistent pattern of birth defects across datasets. Out of pregnancies with known outcomes (excluding elective terminations), pregnancy loss occurred in 31.8% (35/110) of belimumab-exposed women and 43.8% (7/16) of placebo-exposed women in clinical trials; 4.2% (2/48) of women in the BPR prospective cohort and 50% (4/8) in the BPR retrospective cohort; and 31.4% (43/137) of belimumab-exposed women from postmarketing/spontaneous reports. All belimumab-exposed women in clinical trials and the BPR received concomitant medications and had confounding factors and/or missing data.

Conclusions Observations reported here add to limited data published on pregnancy outcomes following belimumab exposure. Low numbers of exposed pregnancies, presence of confounding factors/other biases, and incomplete information preclude informed recommendations regarding risk of birth defects and pregnancy loss with belimumab use.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Children of women with systemic lupus erythematosus (SLE) have a higher risk of birth defects than those born to women without SLE, and women with SLE are at increased risk of pregnancy loss. This is due to disease activity, antiphospholipid antibodies and exposure to certain commonly used SLE therapeutic agents. Belimumab is a targeted human IgG1 monoclonal antibody approved in patients ≥5 years of age for the treatment of active, autoantibody-positive SLE in combination with standard therapy.

⇒ Pregnant women are traditionally excluded from enrolling in clinical trials, and as such, there are limited safety data on the use of belimumab in pregnancy and any associated risk of birth defects and pregnancy loss.

WHAT THIS STUDY ADDS

⇒ This is the largest descriptive summary of birth defects and pregnancy losses among women exposed to belimumab during pregnancy. Data sources included belimumab clinical trials, the Belimumab Pregnancy Registry (BPR) and postmarketing/spontaneous reports of belimumab-exposed pregnant women with SLE.

⇒ Overall, among pregnancies ending in live birth, the numbers of birth defects in belimumab-exposed pregnancies were 4/72 (5.6%) in clinical trials, 10/46 (21.7%, ad hoc 95% CI 9.8% to 33.7%) and 0/4 in the BPR prospective and retrospective cohorts, respectively, and 1/92 (1.1%) in the postmarketing/spontaneous reports, with no consistent pattern of malformations. The numbers of pregnancy losses (out of pregnancies with known outcomes excluding elective terminations) were 35/110 (31.8%) in clinical trials, 2/48 (4.2%, ad hoc 95% CI 0.0 to 9.8%) and 4/8 (50.0%) in the BPR prospective and retrospective cohorts, respectively, and 43/137 (31.4%) in the postmarketing/spontaneous reports.
In an animal combined embry–foetal and prenatal study with monkeys that received belimumab by intravenous administration, there was no evidence of foetal harm nor pregnancy loss rates, with exposures approximately 9 times (based on intravenous administration) and 20 times (based on subcutaneous administration) the exposure at the maximum recommended human dose.25 However, there was evidence of reductions of immature and mature B-cell counts; while foetal B-cell counts decreased after in utero exposure to 5 and 150 mg/kg of belimumab every 2 weeks during pregnancy, the B cells of infant monkeys fully recovered by 3 months of age.29 33

Here, we present birth defect and pregnancy loss data from belimumab clinical trials, the Belimumab Pregnancy Registry (BPR), and postmarketing/spontaneous reports in women with SLE exposed to belimumab prior to or during pregnancy.

METHODS

Data on birth defects and pregnancy loss (miscarriage or stillbirth) with belimumab exposures prior to or during pregnancy were collected from belimumab clinical trials, the BPR and postmarketing/spontaneous reports from the Argus database (which included searches of the US Food and Drug Administration Adverse Event Reporting System and EudraVigilance databases) up to 8 March 2020.

Clinical trials

Although pregnant women were excluded from GSK-sponsored belimumab phase III trials, if pregnancy inadvertently occurred, the patient was withdrawn, but outcomes were monitored for the remainder of gestation. The exception was the phase IV Belimumab Assessment of Safety in SLE (BASE) trial (GSK Study BEL 115467, NCT01705977), where pregnant women could continue on-study at the discretion of the investigator. Investigators were required to report pregnancies to GSK within 24 hours–2 weeks of learning of the pregnancy. Adverse pregnancy outcomes, including birth defects, were reported as serious adverse events. However, because the trials were not designed to study pregnancy outcomes, pertinent variables were not routinely collected (eg, confounding information, antiphospholipid antibodies and factors associated with birth defects). Duplicate pregnancy cases, cases in which the sperm or egg donor was exposed to belimumab and cases where the male partner of the pregnant woman was exposed to belimumab preconception or during pregnancy were excluded from clinical trial cumulative counts. Eighteen belimumab trials were included in this summary (online supplemental table 1). Trial data were combined and summarised as one dataset for belimumab and placebo treatment arms, for all pregnancies ending in live birth (for birth defect summaries) or all pregnancies with known outcomes excluding elective terminations (for pregnancy loss summaries).

Belimumab Pregnancy Registry

The BPR (GSK Study BEL114256, NCT01532310) is a global, multicentre observational cohort study collecting data from individuals with SLE exposed to commercially available belimumab up to 4 months before and/or during pregnancy.14 34 Individuals self-enrolled and were categorised into a prospective cohort (if they enrolled before the end of the pregnancy) or a retrospective cohort (if they enrolled after the pregnancy outcome occurred).

The primary objective of the BPR was to evaluate birth defects in women with SLE exposed to belimumab using the Metropolitan Atlanta Congenital Defects Program criteria38 and/or the European Surveillance of Congenital Anomalies criteria.34 35 37
Secondary objectives were to evaluate the number of miscarriages, live births (including preterm birth and births of infants classified as small for gestational age), stillbirths, elective terminations and infant outcomes through 12 months of age. Only birth defects and cases of pregnancy loss that were miscarriages or stillbirths have been included in this summary.

Belimumab exposure timing, SLE disease activity and concomitant medications, where available, were reported at registration, at the end of the second trimester and at the time of pregnancy outcome.

Birth defects were reviewed by the study Birth Defect Evaluator to assess defect classification, exposure timing with outcome and potential confounding factors. With respect to pregnancy loss, the BPR defines miscarriage as foetal death or expulsion of products of conception prior to 20 weeks gestation; stillbirths were defined as foetal death occurring at 20 weeks of gestation or greater or for a fetus weighing ≥500 g if gestational age was unknown. Additionally, the BPR Scientific Advisory Committee, comprising the Birth Defect Evaluator and independent experts in SLE, paediatrics and obstetrics, reviewed and interpreted the cumulative data primarily from the BPR but also across the other datasets included in this report. This summary includes data collected between the start of the BPR on 16 July 2012 and 8 March 2020.

Postmarketing/spontaneous reports

The GSK worldwide clinical safety database Argus, a postmarketing reporting system, was searched for postmarketing/spontaneous reports describing pregnancy or lactation with belimumab on 8 March 2020. Clinical trial and BPR cases, duplicate pregnancy cases, cases in which the sperm or egg donor was exposed to belimumab, and cases where the male partner of the pregnant woman was exposed to belimumab preconception or during pregnancy were excluded from the spontaneous report cumulative counts. The remaining reports were then further assessed for pregnancy outcomes of live birth with a birth defect and for pregnancy losses.

Statistical analysis

Due to small sample sizes, limitations related to capture of complete information, the heterogeneity of the data sources and the presence of confounding factors, only cumulative numbers are reported for each of the individual data sources. Birth defect and pregnancy loss data are presented separately throughout for each data source. Ad hoc 95% CIs for the proportion of BPR cases with birth defects or pregnancy loss were calculated using the Wald method (simple asymptotic) without continuity. No statistical testing was performed; other data were summarised descriptively.

Patient and public involvement

It was not appropriate or possible to involve patients or the public in the design, conduct, reporting or dissemination plans of our research.

RESULTS

Summary of sources

A total of 586 pregnancy reports were identified across 18 clinical trials (n=181 belimumab+ST, n=28 placebo+ST), the BPR (n=57 prospective, n=10 retrospective belimumab+ST) and from postmarketing/spontaneous reports (n=310 belimumab+ST) outside of the BPR (table 1). Pregnancies with known outcomes excluding elective terminations are summarised herein: 126 were identified in clinical trials (n=110 belimumab, n=16 placebo); 56 (n=48 prospective, n=8 retrospective) were identified in the BPR; and 137 were postmarketing/spontaneous reports, with a collective total of 319.

Birth defects and pregnancy losses in belimumab clinical trials

Birth defects: belimumab+ST (n=4/72), placebo+ST (n=0/9)

Of 110 pregnancies with known outcomes excluding elective terminations in women exposed to belimumab during pregnancy in belimumab clinical trials, there were 72 pregnancies ending in live births, and birth defects were identified in four (5.6%) (tables 1 and 2). Two infants from the four pregnancies had more than one birth defect (table 2). In three cases, the investigator was of the opinion that the defect was unlikely to be associated with belimumab exposure; for the case of bilateral enlarged kidneys with severely abnormal function, the investigator indicated that the event was possibly related to belimumab. Investigators are required to mention if they find the association of an adverse event is likely or unlikely to be related to the investigational product. Foetal abnormalities were detected sonographically in two of these cases and abnormalities were not identified in prenatal testing in two cases. Patient characteristic data for the four women from a post hoc summary are shown in table 3. All four patients received prednisone and hydroxychloroquine (table 3).

There were no cases of birth defects reported in women with live births exposed to placebo (n=9).

Pregnancy loss cases: belimumab+ST (n=35/110) and placebo+ST (n=7/16)

Pregnancy loss occurred in 31.8% (n=35) of pregnancies with known outcomes excluding elective terminations in women receiving belimumab and 43.8% (n=7) in those receiving placebo (table 1). None of the pregnancy losses in the belimumab group and one in the placebo group were associated with a birth defect.

Patient characteristic data from a post hoc summary are shown in table 3. For all 27 cases of belimumab exposure in the first trimester only, the pregnancy losses occurred within the first trimester. For the one woman who reported belimumab exposure during the first, second and third trimesters, the pregnancy loss occurred within the third trimester. The most common concomitant medications of interest were corticosteroids, hydroxychloroquine and azathioprine (table 3). In eight cases of belimumab exposure, a concomitant medication (a pregnancy category D or X drug; methotrexate, MMF, azathioprine, enalapril, amlodipine or tretinoin) was thought to be likely causative of the pregnancy loss. For 22 cases of belimumab exposure, an alternative diagnosis or concurrent disease was thought to be the most likely cause of the pregnancy loss.

Birth defects and pregnancy losses in the BPR

Pregnancies with known outcomes excluding elective terminations were protected in 56 women who enrolled in the BPR (table 1); of these, 50 pregnancies ended in live births (46 in the prospective cohort and four in the retrospective cohort).

Birth defects: belimumab+ST, prospective cohort (n=10/46); belimumab+ST, retrospective cohort (n=0/4)

Of the 46 pregnancies ending in live births (including two sets of twins) within the prospective cohort, 10 were associated with a birth defect (21.7%, ad hoc 95% CI 9.8% to 34.5%).
Systemic lupus erythematosus

Table 1 Summary of pregnancies, birth defects and pregnancy loss recorded in clinical trials, the BPR and postmarketing/spontaneous reports to 8 March 2020

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Clinical trials*</th>
<th>BPR</th>
<th>Postmarketing/spontaneous reports</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Belimumab+ST</td>
<td>Placebo+ST</td>
<td>Belimumab+ST, prospective cohort†</td>
</tr>
<tr>
<td>Total number of pregnancies, N</td>
<td>181§</td>
<td>28</td>
<td>57</td>
</tr>
<tr>
<td>Lost to follow-up/unknown, n</td>
<td>13</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Ongoing, n</td>
<td>1</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Known outcome, n</td>
<td>167</td>
<td>25</td>
<td>48</td>
</tr>
<tr>
<td>Pregnancies with known outcomes excluding elective terminations, N</td>
<td>110¶</td>
<td>16</td>
<td>48</td>
</tr>
<tr>
<td>Pregnancy loss, n (%)</td>
<td>35/110 (31.8)</td>
<td>7/16 (43.8)</td>
<td>2/48 (4.2) (95% CI 0.0% to 9.8%)**</td>
</tr>
<tr>
<td>Miscarriage with no apparent birth defect, n††</td>
<td>33</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Miscarriage with birth defect, n††</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Stillbirth with no apparent birth defect, n‡‡</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Stillbirth with birth defect, n‡‡</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total number of pregnancies ending in live births, N§§</td>
<td>72</td>
<td>9</td>
<td>46</td>
</tr>
<tr>
<td>Pregnancies with live infant with birth defect, n (%)</td>
<td>4/72 (5.6)</td>
<td>0/9</td>
<td>10/46 (21.7) (95% CI 9.8% to 33.7%)**</td>
</tr>
<tr>
<td>Pregnancies with live infant with no apparent birth defect, n</td>
<td>68</td>
<td>9</td>
<td>36</td>
</tr>
</tbody>
</table>

*Post hoc summary of double-blind (completed) and open-label (completed/ongoing) phases of clinical studies and NCT03312907, where all arms include belimumab treatment. The following clinical trials were included: NCT01345253, NCT01649765, NCT01597622, NCT01705977, NCT01632241, NCT01894360, NCT03312907, NCT04136145, NCT00410384, NCT00424476, NCT00724867, NCT00712933, NCT01071492, NCT00071487, NCT01639339 and NCT00583362.

†Women who enrolled in the registry before the end of pregnancy regardless of known normal or abnormal prenatal test results.

‡‡Includes two pregnancies in healthy volunteers (one lost to follow-up and one ended in elective termination).

¶‡‡Ectopic and molar pregnancies are included (three in the clinical trials and two in the postmarketing/spontaneous reports); those were not considered pregnancy losses.

**95% CIs were calculated in PASS 2022 V.22.0.2 (ncss.com/software/pass) by ad hoc analysis based on the Wald method (simple asymptotic) without continuity correction.

††Defined as pregnancy loss before the 22nd week of pregnancy; however, this can vary by region and data source. The BPR defines pregnancy loss occurring <20 weeks as miscarriage.

‡‡‡Defined as pregnancy loss from the 22nd week of pregnancy onwards; however, this can vary by region and data source. The BPR defines pregnancy loss ≥20 weeks as stillbirth.

§§There were four twin pregnancies (two BPR and two postmarketing) all ending in live births. Birth defect was diagnosed in one (BPR) of these eight infants. Outcomes reported are per pregnancy and not per infant.

BPR, Belimumab Pregnancy Registry; ST, standard therapy.
The birth defects within the 10 live birth pregnancies ranged in type and severity according to organ system. Three of the 10 live birth pregnancies had more than one birth defect reported (table 2).

Nine women (90%) had prenatal testing prior to enrolment in the BPR; one had an abnormal result (infant with atrial septal defect) and another case where results were not available (Arnold-Chiari type II malformation) (table 2). All 10 pregnancies resulting in birth defects had prenatal testing results post enrolment in the BPR. Among these, two defects were detected prenatally (bilateral clubfoot and congenital heart block), and one defect (hydronephrosis) was suspected by obstetrician after ultrasound or abnormal prenatal screening post enrolment.

---

**Table 2** Cases of birth defects in patients receiving belimumab in clinical trials, the BPR and postmarketing/spontaneous reports

<table>
<thead>
<tr>
<th>Cumulative count of reported cases</th>
<th>Reported defect</th>
<th>The event fulfils MACDP* criteria?</th>
<th>EUROCAT classified defect?†</th>
<th>Additional considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical trials‡</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Microcephaly</td>
<td>NP</td>
<td>NP</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Atrophic ventricular septal defect</td>
<td>NP</td>
<td>NP</td>
<td>There is no reason to predict an IgG antibody would affect interventricular septum development (which completes by 7 weeks in humans) because belimumab is highly specific for B-lymphocyte stimulator which binds to receptors primarily localised to B lymphocytes and because there is very little placentential transfer of IgG antibodies during the first trimester.(55)</td>
</tr>
<tr>
<td>3</td>
<td>Unbalanced translocation, involving chromosomes 11 and 13</td>
<td>NP</td>
<td>NP</td>
<td>Unbalanced translocation involving chromosomes 11/13 is not plausibly linked to belimumab because it is not expected that a monoclonal IgG antibody would interact with DNA or chromosomal material</td>
</tr>
<tr>
<td>BPR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Bilateral clubfoot</td>
<td>Yes</td>
<td>Yes</td>
<td>Can occur due to mechanical factors that take place within the pregnancy</td>
</tr>
<tr>
<td>2</td>
<td>Non-descending testis</td>
<td>Yes</td>
<td>No</td>
<td>May not have involved belimumab exposure during the critical window of development</td>
</tr>
<tr>
<td>3</td>
<td>Very mild Ebstein’s anomaly of the tricuspid</td>
<td>Yes</td>
<td>Yes</td>
<td>–</td>
</tr>
<tr>
<td>4</td>
<td>Congenital heart block</td>
<td>Yes</td>
<td>No</td>
<td>Confounded by neonatal lupus with presence of anti-Ro/SSA and anti-La/SSB antibodies</td>
</tr>
<tr>
<td>5</td>
<td>Small ventricular septal defect</td>
<td>Yes</td>
<td>Yes</td>
<td>Described as tiny atypical ventricular septal defect and muscular</td>
</tr>
<tr>
<td>6</td>
<td>Congenital hydronephrosis</td>
<td>Yes</td>
<td>Yes</td>
<td>–</td>
</tr>
<tr>
<td>7</td>
<td>Low-lying conus medullaris</td>
<td>Yes</td>
<td>Yes</td>
<td>–</td>
</tr>
<tr>
<td>8</td>
<td>Pelviectasis</td>
<td>Yes</td>
<td>No</td>
<td>–</td>
</tr>
<tr>
<td>9</td>
<td>Positional plagioccephaly</td>
<td>Yes</td>
<td>No</td>
<td>Can occur due to mechanical factors that take place within the pregnancy</td>
</tr>
<tr>
<td>10</td>
<td>Positional torticollis</td>
<td>Yes</td>
<td>No</td>
<td>Can occur due to mechanical factors that take place within the pregnancy</td>
</tr>
<tr>
<td>11</td>
<td>Small fenestrated atrial septal defect</td>
<td>ED§</td>
<td>Yes</td>
<td>Prenatal testing prior to enrolment with abnormal results</td>
</tr>
<tr>
<td>12</td>
<td>Severe Arnold-Chiari type II malformation</td>
<td>Yes</td>
<td>Yes</td>
<td>Enrolled in third trimester, prenatal testing done prior to enrolment but results unknown</td>
</tr>
<tr>
<td>13</td>
<td>Ankyloglossia</td>
<td>Yes</td>
<td>No</td>
<td>–</td>
</tr>
<tr>
<td>Postmarketing/spontaneous reports</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Extrarenal pelvis</td>
<td>Yes</td>
<td>Yes</td>
<td>Sibling with a cardiac defect reported separately and included in this report; this presents a potential for a reporting bias and/or an underlying genetic predisposition</td>
</tr>
</tbody>
</table>

*Inclusive of birth defects that are tracked by MACDP via the CDC/BPA 6-digit code defect list. Cases were also considered defects if the infant or foetus had two or more conditional defects. MACDP classification analyses were not performed for the cases from clinical trials and postmarketing/spontaneous reports.
†Inclusive of birth defects classified by EUROCAT (eurocat-network.eu), coded using ICD-10 with a BPA 1-digit extension. EUROCAT classification analyses were not performed for the cases from clinical trials and postmarketing/spontaneous reports.
§Data shown for belimumab treatment arms only.
BPA, British Paediatric Association; BPR, Belimumab Pregnancy Registry; CDC, Centers for Disease Control and Prevention; ED, exclusionary defect; EUROCAT, European Surveillance of Congenital Anomalies; ICD-10, International Statistical Classification of Diseases and Related Health Problems, 10th Revision; MACDP, Metropolitan Atlanta Congenital Defects Program; NP, not performed; SSA, Sjögren’s syndrome-related antigen A; SSB, Sjögren’s syndrome-related antigen B.

---

33.7%), while no birth defects were reported in the retrospective cohort (n = 0/4) (table 1). Patient characteristic and concomitant medications of interest data from an ad hoc summary are shown in table 3.
# Systemic lupus erythematosus

## Table 3  Patient characteristics and concomitant medications of interest from belimumab clinical trials (post hoc summary) and the BPR (ad hoc summary)

<table>
<thead>
<tr>
<th>Clinical trials*</th>
<th>Birth defects</th>
<th>Pregnancy loss</th>
<th>Placebo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belimumab n=4</td>
<td>Belimumab n=35</td>
<td>Belimumab n=7</td>
<td></td>
</tr>
<tr>
<td>Mean (SD) age at enrolment (years)</td>
<td>27.5 (4.51)</td>
<td>28.6 (5.29)†</td>
<td>32.0 (5.48)</td>
</tr>
<tr>
<td>Mean SLEDAI at baseline (SD)</td>
<td>11.0 (7.75)</td>
<td>9.2 (4.80)†</td>
<td>8.4 (1.81)</td>
</tr>
<tr>
<td>Trimesters of exposure, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First trimester only</td>
<td>1 (25)</td>
<td>27 (77)</td>
<td>3 (43)</td>
</tr>
<tr>
<td>First and second trimesters</td>
<td>3 (75)</td>
<td>7 (20)</td>
<td>4 (57)</td>
</tr>
<tr>
<td>First, second and third trimesters</td>
<td>0</td>
<td>1 (3)</td>
<td>0</td>
</tr>
<tr>
<td>Prednisone use &gt;10 mg/day, n (%)</td>
<td>–</td>
<td>12 (34)</td>
<td>2 (29)</td>
</tr>
<tr>
<td>Concomitant medications of interest, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Azathioprine</td>
<td>0</td>
<td>6 (17)</td>
<td>2 (29)</td>
</tr>
<tr>
<td>Enalapril</td>
<td>0</td>
<td>4 (11)</td>
<td>0</td>
</tr>
<tr>
<td>Hydroxychloroquine</td>
<td>4 (100)</td>
<td>18 (51)</td>
<td>2 (29)</td>
</tr>
<tr>
<td>Lisinopril</td>
<td>0</td>
<td>2 (6)</td>
<td>0</td>
</tr>
<tr>
<td>Losartan</td>
<td>0</td>
<td>3 (9)</td>
<td>0</td>
</tr>
<tr>
<td>Methotrexate</td>
<td>0</td>
<td>2 (6)</td>
<td>0</td>
</tr>
<tr>
<td>Methylprednisolone</td>
<td>0</td>
<td>4 (11)</td>
<td>0</td>
</tr>
<tr>
<td>Mycophenolate</td>
<td>0</td>
<td>4 (11)</td>
<td>0</td>
</tr>
<tr>
<td>Corticosteroids: Prednisone/meprednisone/prednisolone</td>
<td>4 (100)</td>
<td>21 (60)</td>
<td>3 (43)</td>
</tr>
<tr>
<td>Tretinoin</td>
<td>0</td>
<td>1 (3)</td>
<td>0</td>
</tr>
<tr>
<td>aCL baseline status, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline status data available</td>
<td>13</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>aCL status positive at baseline</td>
<td>5 (39)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>BPR n=10 n=6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (SD) age at enrolment (years)</td>
<td>34.2 (3.2)</td>
<td>34.0 (3.4)</td>
<td>–</td>
</tr>
<tr>
<td>Earliest belimumab exposure, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preconception</td>
<td>9 (90)</td>
<td>5 (84)</td>
<td>–</td>
</tr>
<tr>
<td>First trimester only</td>
<td>1 (10)</td>
<td>1 (17)</td>
<td>–</td>
</tr>
<tr>
<td>Last belimumab exposure, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First trimester</td>
<td>2 (20)</td>
<td>0</td>
<td>–</td>
</tr>
<tr>
<td>Second trimester</td>
<td>6 (60)</td>
<td>0</td>
<td>–</td>
</tr>
<tr>
<td>Postpartum</td>
<td>2 (20)</td>
<td>6 (100)</td>
<td>–</td>
</tr>
<tr>
<td>Concomitant medications of interest, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antimalarials</td>
<td>9 (90)</td>
<td>3 (50)</td>
<td>–</td>
</tr>
<tr>
<td>Immunosuppressants</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Azathioprine</td>
<td>2 (20)</td>
<td>0</td>
<td>–</td>
</tr>
<tr>
<td>Cyclosporin</td>
<td>1 (10)</td>
<td>1 (17)</td>
<td>–</td>
</tr>
<tr>
<td>Methotrexate</td>
<td>1 (10)</td>
<td>1 (17)</td>
<td>–</td>
</tr>
<tr>
<td>MMF</td>
<td>0</td>
<td>1 (17)</td>
<td>–</td>
</tr>
<tr>
<td>Corticosteroids</td>
<td>6 (60)</td>
<td>3 (50)</td>
<td>–</td>
</tr>
<tr>
<td>Epilepsy medication</td>
<td>1 (10)</td>
<td>0</td>
<td>–</td>
</tr>
<tr>
<td>NSAIDs</td>
<td>2 (20)</td>
<td>1 (17)</td>
<td>–</td>
</tr>
<tr>
<td>Folate</td>
<td>7 (70)</td>
<td>2 (33)</td>
<td>–</td>
</tr>
<tr>
<td>ACE inhibitors</td>
<td>0</td>
<td>0</td>
<td>–</td>
</tr>
<tr>
<td>Heparin</td>
<td>2 (20)</td>
<td>0</td>
<td>–</td>
</tr>
<tr>
<td>Aspirin</td>
<td>3 (30)</td>
<td>1 (17)</td>
<td>–</td>
</tr>
<tr>
<td>Calcium channel blockers</td>
<td>0</td>
<td>1 (17)</td>
<td>–</td>
</tr>
<tr>
<td>Beta blockers</td>
<td>0</td>
<td>1 (17)</td>
<td>–</td>
</tr>
</tbody>
</table>

*Other concomitant medications in the birth defects group include, but are not limited to, prochlorperazine, zolpidem, amlodipine, furosemide and ambrisentan (all n=1). Relevant concomitant medications were teratogens, medications associated with pregnancy loss, medications indicating severe or refractory diagnosis or acetylsalicylic acid/warfarin. †N=34. ‡N=33.

aCL, anticardiolipin; BPR, Belimumab Pregnancy Registry; MMF, mycophenolate mofetil; NSAID, non-steroidal anti-inflammatory drug.
Pregnancy loss cases: belimumab+ST, prospective cohort (n=2/48) and belimumab+ST, retrospective cohort (n=4/8)

Within the prospective cohort, pregnancy loss occurred in 4.2% (n=2 miscarriages, ad hoc 95% CI 0.0 to 9.8%) of the 48 women with known pregnancy outcomes excluding elective terminations (table 1). Of the two women in the prospective cohort who had a miscarriage, one reported not having any prenatal testing prior to enrolment, and no antiphospholipid test, physician global assessment or Systemic Lupus International Collaborating Clinics/ACR Damage Index data were available for both women. None of the pregnancy losses were associated with a birth defect. Half (n=4/8) of the women from the retrospective cohort with a known pregnancy outcome excluding elective terminations had a pregnancy loss (all miscarriages) prior to BPR enrolment (table 1). One patient with known anticardiolipin (aCL) and lupus anticoagulant (LAC) test data was aCL negative and LAC positive; aCL and LAC data were not known for all other cases. None of the pregnancy losses were associated with a birth defect.

Patient characteristic data from an ad hoc summary are shown in table 3. None of the six women with a pregnancy loss from both BPR cohorts had a history of gestational diabetes, pre-eclampsia, eclampsia or haemolysis, elevated liver enzymes and low platelets syndrome. The most common concomitant medications of interest during pregnancy among the six women were corticosteroids (n=3, all retrospective cases) and antimalarials (n=3, two prospective and one retrospective case) (table 3).

Birth defects and pregnancy loss in postmarketing/spontaneous reports

Known outcomes excluding elective terminations were available for 137 postmarketing or spontaneous reports of pregnancies outside of the BPR in women exposed to belimumab.

One stillbirth and one miscarriage case had a birth defect (table 1). A total of 92 pregnancies ended in live births (including two twin pregnancies), of which 1 (1.1%) pregnancy reported a birth defect (table 1). Pregnancy losses were reported in 43 (31.4%) of the 137 pregnancies with known outcomes, excluding elective terminations (table 1). Confounder analysis was not performed for these postmarketing/spontaneous reports due to lack of documentation.

DISCUSSION

This report summarises the available data on birth defects and pregnancy loss (miscarriage or stillbirth) in women exposed to belimumab during pregnancy from three available data sources up to 8 March 2020. However, limitations in the data sources used in the present summaries (discussed further) prevented quantitative comparisons of the prevalence and risk of birth defects and pregnancy loss in the pregnancies of belimumab-exposed women with SLE. Furthermore, differences in study populations and timing, diagnostic capabilities, information on SLE severity, clinical factors, concomitant medications, comorbidities and inconsistent definitions of birth defect preclude comparisons between our data and the limited published literature.

SLE and some SLE therapies are associated with birth defect and pregnancy loss. The risk of birth defects in infants of women with SLE is higher than in the general population. Detailed anatomy ultrasound scans, foetal echocardiography and serial scans are recommended for pregnant individuals with SLE due to increased risks of congenital heart block and foetal growth restriction. Over the past decade, advances in ultrasound technology have enhanced the ability to detect malformations in utero and after birth. Estimates of pregnancy loss among women with SLE are 20% (range across 44 studies: 2.9%–52.6%; see online supplemental file 1), with estimates increasing for those with a longer duration of disease.

Available data on belimumab use in pregnant women are insufficient to determine whether there are drug-associated risks for birth defects. Current prescribing information recommends use during pregnancy only if the potential maternal benefit justifies the potential foetal risk. The European Alliance of Associations for Rheumatology and the British Society for Rheumatology advise caution for belimumab treatment during pregnancy, and discontinuation once pregnancy is confirmed is recommended by the ACR. These recommendations are based on a lack of data on the effect of belimumab on pregnancy outcomes. Small studies have not identified birth defects with belimumab; a recent real-world study of 13 patients exposed to belimumab during pregnancy in Taiwan reported no birth defects among 11 live births. Similarly, a study of 13 pregnancies of women with SLE exposed to belimumab across three Italian centres reported no defects among 12 live births.

The pregnancy loss results of this summary are a continuation of a previous belimumab safety evaluation published in 2013, in which Wallace and colleagues reported 13 pregnancy losses out of 44 pregnancies with known outcomes (29.5%) in patients receiving belimumab and three pregnancy losses out of six pregnancies (50.0%) in those receiving placebo. These data are included within the current summary.

Consistent with SLE treatment recommendations, the most common concomitant medications across data sources were antimalarials and corticosteroids. The use of these medications is generally considered safe during pregnancy. Immunosuppressants were also reported for many pregnancies, of which azathioprine was the most common. This is consistent with evidence that suggests certain immunosuppressant medications should be avoided during pregnancy, including MMF, cyclophosphamide and methotrexate, whereas azathioprine use is considered safe at the minimum effective dose.

There are several limitations to the data used in this summary. The data presented are from various sources with different lengths of belimumab exposure; the clinical trials and postmarketing/spontaneous reports were not specifically designed to assess birth defects nor pregnancy loss and variables potentially impacting pregnancy outcomes were not generally collected in the clinical trials. The impact of SLE disease activity may confound our findings since various adverse pregnancy outcomes are more frequent in SLE pregnancies where disease is more active. This report had insufficient information to determine an association between the timing of belimumab exposure and occurrence of malformations, particularly since some of the observed malformations are associated with other factors (eg, congenital heart block is linked to the presence of maternal anti-Ro/SSA and anti-La/SSB autoantibodies). SLE treatment commonly includes immunosuppressants, which can increase the risk of infection; some infections (eg, maternal rubella virus and cytomegalovirus infections) can be teratogenic, although no infections were captured across these data sources. Furthermore, the use of pregnancies ending in live births as the denominator for birth defects likely overestimated the true defect prevalence.

We cannot provide informed recommendations on the use of belimumab during pregnancy owing to insufficient numbers of observed pregnancies, lack of suitable unexposed groups for comparisons, missing information, presence of confounding factors and insufficient methodology to examine birth defects and pregnancy losses, which prevented full statistical analysis.
Understanding the effects of risk factors associated with foetal loss during pregnancy requires complete data capture from conception; as most data used in this report did not collect Safety of Estrogens in Lupus National Assessment-Systemic Lupus Erythematosus Disease Activity Index (SELENA-SLEDAI) scores at the time of conception and at pregnancy loss, our summaries could not accurately assess the frequency of SLE flares during pregnancy. In the clinical trials and BPR, aCL antibody data were only available for approximately half of pregnancy cases, and LAC data were not available. In addition, women voluntarily enrolled in the BPR, and as such may not be representative of all belimumab-exposed SLE individuals, possibly being more motivated and/or having higher pregnancy risks than those who did not volunteer.32–34 Other limitations include the BPR not having a sufficiently powered control group of pregnant women unexposed to belimumab within the prospective cohort, which may have biased this cohort toward a higher rate of belimumab-related events. Lastly, spontaneous reports are more likely to capture negative rather than positive outcomes, frequently lack the documentation necessary to ascertain causality and are difficult to interpret given the high baseline risk of pregnancy loss in SLE. As such, data should be interpreted with caution.

CONCLUSIONS

We present a summary of data across several sources reporting birth defects and pregnancy loss after maternal exposure to belimumab. Given the limitations of the data, birth defect and pregnancy loss that occurred following belimumab exposure could be presented only descriptively. Increased rates of patient enrolment into pregnancy studies and enhancing quality of data collection in pregnancy studies would allow for better evaluation of birth defects and pregnancy loss risks after maternal exposure to treatment.

Author affiliations
1Rheumatology, Johns Hopkins University School of Medicine, Baltimore, Maryland, USA
2Maternal And Fetal Medicine, Georgetown University Medical Center, Northwest Washington, Washington, DC, USA
3Department of Obstetrics and Gynecology, MedStar Georgetown University Hospital, Northwest Washington, Washington, DC, USA
4Department of Medicine, Duke University School of Medicine, Durham, North Carolina, USA
5Value Evidence and Outcomes, GSK, Stevenage, Hertfordshire, UK
6Medical Affairs, GSK, Dubai, UAE
7Biostatistics, GSK, Collegeville, Pennsylvania, USA
8Specialty Care, Global Medical Affairs, GSK, Collegeville, Pennsylvania, USA
9Global Clinical Safety and Pharmacovigilance, GSK, Brentford, UK
10US Case Management Group, GSK, Research Triangle Park, North Carolina, USA
11Immunoinflammation, GSK, Collegeville, USA
12Epidemiology, GSK, Uxbridge, Middlesex, UK
13Value Evidence Outcomes Epidemiology, GSK, Research Triangle Park, North Carolina, USA
14Department of Epidemiology, University of North Carolina Gillings School of Global Public Health, Chapel Hill, North Carolina, USA
15Safety and Medical Governance, GSK, Research Triangle Park, North Carolina, USA
16Epidemiology, GSK, Research Triangle Park, North Carolina, USA
17Immunology Biostatistics, GSK, Brentford, UK
18Clinical Sciences, GSK, Research Triangle Park, North Carolina, USA
19Vaccines, GSK, Collegeville, Pennsylvania, USA

Acknowledgements

Medical writing support was provided by Liam Campbell, PhD, of Fishawack Indicia, UK, and was funded by GSK. The authors acknowledge the contributions of Marcy Powell (GSK), Damon L Bass (GSK), and Daniela Negrini (GSK) to the summaries contained in this report.

Contributors

KG, MKh, RM, JMP, PJ and DAR contributed to the conception or design of the study. All authors contributed to the data analysis or interpretation. All authors contributed towards the preparation of the manuscript, approved the final submitted version and agreed to be listed as authors.

Funding

This summary (GSK Study BEL2101182) and the BPR (GSK Study BEL114256; NCT0152310) were funded by GSK.

Competing interests

KG, MKh, RAL, AL, RM, MBC, KW, IJNH, HQ, PJ and DAR are employees of GSK and hold shares in the company. KG is a previous employee of Novartis and holds shares in the company. At the time of the study, MKu, PM and JMP were employees of GSK and hold shares in the company. MP received grant support from GSK and is a member of the BPR Scientific Advisory Committee. HT received royalties/licences from UpToDate Inc (Wolters Kluwer Health), has received consulting fees from AMAG Pharmaceuticals and is a member of the BPR Scientific Advisory Committee. KS is employed by the University of North Carolina at Chapel Hill to assist GSK with research. HT is a member of the BPR Scientific Advisory Committee and a GSK retiree. MEBC received grants from GSK and UCB, and acted as a consultant to GSK and UCB. RAL is the guarantor.

Patient and public involvement

Patients and/or the public were not involved in the design, conduct, reporting or dissemination plans of this research.

Patient consent for publication

Not applicable.

Ethics approval

Not applicable.

Provenance and peer review

Not commissioned; externally peer reviewed.

Data availability statement

Data are available upon reasonable request. Anonymised individual participant data and study documents can be requested for further research (www.clinicalstudydatarequest.com).

Supplemental material

This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

Open access

This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: http://creativecommons.org/licenses/by-nc/4.0/.

ORCID iDs

Michelle Petri http://orcid.org/0000-0003-1441-5473
Megan E B Clowse http://orcid.org/0000-0002-8579-3470
Roger A Levy http://orcid.org/0000-0001-6391-6031
Holly Quasny http://orcid.org/0000-0002-1659-0004

REFERENCES

Systemic lupus erythematosus

40 Paspathy D, Denbow ML, Rutherford MA, et al. The combined use of ultrasound and fetal magnetic resonance imaging for a comprehensive fetal neurological assessment in fetal congenital cardiac defects: scientific impact paper No. 60. BJOG 2019;126:e142–51.
Title: Belimumab use during pregnancy: A summary of birth defects and pregnancy loss from belimumab clinical trials, a pregnancy registry, and postmarketing reports

Authors: Michelle Petri¹, Helain Landy²,³, Megan E B Clowse⁴, Kim Gemzoe⁵, Munther Khamashta⁶, Milena Kurtinecz⁷, Roger A Levy⁷, Andrew Liu⁸, Rebecca Marino⁹, Paige Meizlik⁷, Jeanne M Pimenta¹⁰, Kelsey Sumner¹⁰,¹¹, Hugh Tilson¹¹, Mary Beth Connolly⁵, Keele Wurst⁹, Julia Harris⁸, Holly Quasny⁹, Patricia Juliao⁷, David A Roth⁷

Affiliations:
¹Johns Hopkins University School of Medicine, Baltimore, Maryland, USA
²Georgetown University Medical Center, Washington, DC, USA
³MedStar Georgetown University Hospital, Washington, DC, USA
⁴Duke University School of Medicine, Durham, North Carolina, USA
⁵GSK, Stevenage, Hertfordshire, UK
⁶GSK, Dubai, United Arab Emirates
⁷GSK, Collegeville, Pennsylvania, USA
⁸GSK, Brentford, UK
⁹GSK, Research Triangle Park, North Carolina, USA
¹⁰GSK, Uxbridge, Middlesex, UK
¹¹Department of Epidemiology, University of North Carolina Gillings School of Global Public Health, Chapel Hill, North Carolina, USA

*At the time of the study

Corresponding author: Roger A Levy

Target journal: Annals of the Rheumatic Diseases
SUPPLEMENTARY INFORMATION

Published literature on SLE

PubMed was used to identify articles with the keywords “systemic lupus erythematosus” AND “pregnancy” AND “fetal loss” published before 30 July, 2019. Referenced studies within reviews and meta-analysis were also examined. Studies were excluded if the definition of foetal loss was not provided, therapeutic/elective abortions were included in the calculation of loss, neonatal deaths were included in the calculation of loss, or the sample size was <20.

A total of 82 previously published studies were identified, of which 44 met the eligibility criteria, where the majority were prospective clinical studies or medical chart reviews. The mean pregnancy loss rate among the 44 studies was 20% (range: 2.9–52.6%). Across the 44 studies, 12 (27.3%) reported disease activity scores (Supplementary Table 2). The mean age of female patients in the 12 studies ranged from 26.4 to 42.0, and when reported, the mean SLE duration was 4.3–15.0 years.

The Safety of Estrogen in Lupus National Assessment (SELENA)–SLEDAI scores are listed in Supplementary Table 2. The pregnancy loss rate in these 12 studies was 2.9–38.5% and positively correlated with SELENA–SLEDAI scores. For instance, a study in which 78% (191/243) patients had a SLEDAI score ≤4, the pregnancy loss rate was 2.9% (95% confidence interval [CI]: 1.3, 5.6), noting the pregnancy loss rate was recalculated to exclude elective terminations. In contrast, a pregnancy loss rate of 38.5% was reported in a different trial in which the 109 participants had a mean (standard deviation [SD]) SLEDAI 2000 score of 10.1 (7.0).

Several studies included patients with lupus nephritis or antiphospholipid syndrome in addition to SLE, although currently, most belimumab clinical trials excluded patients with severe renal disease. Most studies defined lupus nephritis as presence of proteinuria >0.5 g/day and/or active urinary sediment with or without an elevation in serum creatinine. As expected, pregnancy loss numbers were generally higher in these studies compared to those that excluded these conditions. For instance, a study conducted between 2000 and 2015 in China, which included a total of 195 pregnancies across 163 patients with SLE and antiphospholipid syndrome reported a pregnancy loss rate of 65.6%. Another study, conducted between 1988 and 2002 in Saudi Arabia, which included 19 pregnancies in 8 patients with lupus nephritis, reported a pregnancy loss rate of 52.6%. As shown in Supplementary Table 2, the CIs for pregnancy loss rates were relatively wide; the uncertainty was likely related to low sample sizes (typically N<100).
### Supplementary Table 1

**Belimumab clinical trials included within the summary of belimumab use during pregnancy**

<table>
<thead>
<tr>
<th>Study identifier</th>
<th>Study title</th>
<th>Study phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCT00712933 (HGS1006-C1074)</td>
<td>A continuation trial for subjects with lupus that completed protocol HGS1006-C1056 or HGS1006-C1057</td>
<td>Phase 3</td>
</tr>
<tr>
<td>NCT00071487 (LBSL02)</td>
<td>Safety and efficacy study of lymphoStat-B (belimumab) in subjects with systemic lupus erythematosus (SLE)</td>
<td>Phase 2</td>
</tr>
<tr>
<td>NCT00583362 (LBSL99)</td>
<td>A continuation trial for subjects with systemic lupus erythematosus that have completed protocol LBSL02</td>
<td>Phase 2</td>
</tr>
<tr>
<td>NCT00410384 (HGS1006-C1056)</td>
<td>A study of belimumab in subjects with systemic lupus erythematosus (BLISS-76)</td>
<td>Phase 3</td>
</tr>
<tr>
<td>NCT00724867 (HGS1006-C1066)</td>
<td>A continuation trial for subjects with lupus who completed protocol HGS1006-C1056 in the United States</td>
<td>Phase 3</td>
</tr>
<tr>
<td>NCT00424476 (HGS1006-C1057)</td>
<td>A study of belimumab in subjects with systemic lupus erythematosus (SLE) (BLISS-52)</td>
<td>Phase 3</td>
</tr>
<tr>
<td>NCT00732940 (HGS1006-C1070)</td>
<td>Phase 2 study of belimumab administered subcutaneously to subjects with systemic lupus erythematosus (SLE)</td>
<td>Phase 2</td>
</tr>
<tr>
<td>NCT01345253 (BEL113750)</td>
<td>GSK1550188 A 52 week study of belimumab versus placebo in the treatment of subjects with systemic lupus erythematosus (SLE) located in Northeast Asia</td>
<td>Phase 3</td>
</tr>
<tr>
<td>NCT01597622 (BEL114333)</td>
<td>BEL114333, a continuation study of BEL113750 in subjects with systemic lupus erythematosus (SLE) in Northeast Asia, and in Japan subjects completing the open-label extension of HGS1006-C1115</td>
<td>Phase 3</td>
</tr>
<tr>
<td>NCT01484496 (HGS1006-C1115)</td>
<td>A study of belimumab administered subcutaneously in subjects with systemic lupus erythematosus (SLE) (BLISS-SC)</td>
<td>Phase 3</td>
</tr>
<tr>
<td>NCT01597492 (HGS1006-C1117)</td>
<td>A study to evaluate the effect of belimumab on vaccine responses in subjects with systemic lupus erythematosus (SLE)</td>
<td>Phase 4</td>
</tr>
<tr>
<td>NCT01632241 (BEL115471)</td>
<td>Efficacy and safety of belimumab in black race patients with systemic lupus erythematosus (SLE) (EMBRACE)</td>
<td>Phase 4</td>
</tr>
<tr>
<td>NCT01639339 (BEL114054)</td>
<td>Efficacy and safety of belimumab plus standard of care in subjects with active lupus nephritis (BLISS-LN)</td>
<td>Phase 3</td>
</tr>
<tr>
<td>NCT01649765 (BEL114055)</td>
<td>Pediatric lupus trial of belimumab plus background standard therapy (PLUTO)</td>
<td>Phase 2</td>
</tr>
<tr>
<td>NCT01705977 (BEL115467)</td>
<td>Belimumab Assessment of Safety in SLE (BASE)</td>
<td>Phase 4</td>
</tr>
<tr>
<td>NCT01894360 (BEL117100)</td>
<td>A study to estimate the relative bioavailability, tolerability and safety of a single dose of belimumab self-administered subcutaneously (SC) by healthy subjects</td>
<td>Phase 1</td>
</tr>
<tr>
<td>NCT03312907 (BEL205646)</td>
<td>A study to evaluate the efficacy and safety of belimumab administered in combination with rituximab to adult subjects with systemic lupus erythematosus (SLE) – BLISS-BELIEVE</td>
<td>Phase 3</td>
</tr>
<tr>
<td>NCT04136145 (BEL209629)</td>
<td>Single dose study to investigate the pharmacokinetics (PK) and safety of belimumab 200 milligrams (mg) intravenous and 200 mg subcutaneous via auto-injector in Chinese healthy subjects</td>
<td>Phase 1</td>
</tr>
</tbody>
</table>
**Supplementary Table 2** Pregnancy loss in patients with SLE in published studies that reported SELENA–SLEDAI scores

<table>
<thead>
<tr>
<th>Study</th>
<th>Years</th>
<th>Population (region)</th>
<th>N</th>
<th>SELENA/SLEDAI Mean (SD) (or otherwise specified)</th>
<th>Pregnancy loss rate (95% CI)</th>
</tr>
</thead>
</table>
| Deguchi et al. 2018<sup>5</sup>  
*Clinic-based, prospective study* | 2009–2016  
Asia | 56 | Median: 0.0 (range 0–6)  
Mean 1.14 (1.57) for pregnancy losses (n=7) and 1.35 (1.61) for live births | 12.5 (5.6–23.2) |
| Molad et al. 2005<sup>6</sup>  
*Prospective case series* | 1987–2002  
Europe | 29 | 1.8 (3.2) | 20.7 (8.8–38.2) |
| Xu et al. 2015<sup>7</sup>  
*Retrospective, medical chart review* | 2001–2014  
Asia | 59 | 2.4 (3.9) | 3.4 (0.6–10.8) |
| Buyon et al. 2015<sup>8</sup>  
*Longitudinal study* | 2003–2012  
8 sites in US and 1 in Canada Europe | 385 | 2.8 (3.0) | 4.7 (2.9–7.1) |
| Moroni et al. 2016<sup>9</sup>  
*Prospective, longitudinal study* | 2006–2013  
Europe | 71 | 3.4 (4.0) | 8.4 (3.5–16.7) |
| Chen et al. 2018<sup>1</sup>  
*Retrospective, multicentre study* | 2011–2016  
Asia | 243 | 78% (n=191) SLEDAI 0–4  
18.5% (n=45) SLEDAI 5–9  
2.5% (n=6) SLEDAI 10–14  
0.4% (n=1) SLEDAI >15 | 2.9 (1.3–5.6) |
| Luo et al. 2015<sup>10</sup>  
*Retrospective, medical chart, cohort study* | 1990–2014  
Asia | 93 | Total 3.06 (4.53)  
Among losses 4.14 (4.71)  
Among live births 2.73 (4.45) | 7.5 (3.3–14.3) |
| Tandon et al. 2004<sup>11</sup>  
*Clinic-based, prospective study* | 1970–2001  
Canada | 78 | 6.1 (4.6) | 24.4 (15.8–34.8) |
| Yan Yuen et al. 2008<sup>12</sup>  
*Case–control study* | 1963–2006  
Europe | 108 | 6.7 (0.4) | 18.3 (N/A) |
| Gladman et al. 2010<sup>13</sup>  
*Clinic-based, prospective study* | 1970–2003  
Canada | 112 | 7.3 (5.2) | 24.1 (16.9–32.7) |
| Xu et al. 2015<sup>7</sup>  
*Retrospective, medical chart review* | 2001–2014  
Asia | 18 | 7.9 (6.2) | 22.2 (7.4–45.3) |
| Sittiwangkul et al. 1999<sup>14</sup>  
*Retrospective, medical chart review* | 1991–1998  
Asia | 48 | 8.23 (3.8) to 9.3 (3.05) | 20.5 (10.5–34.2) |
| Ku et al. 2016<sup>2</sup>  
*Retrospective, medical chart review* | 2004–2014  
Asia | 109 | 10.1 (7.0) | 38.5 (29.7–47.9) |
| Gladman et al. 2010<sup>13</sup> | 1970–2003  
Canada | 81 | 10.9 (6.2) | 25.9 (17.3–36.3) |
<table>
<thead>
<tr>
<th>Study</th>
<th>Years</th>
<th>Population (region)</th>
<th>N</th>
<th>SELENA/SLEDAI Mean (SD) (or otherwise specified)</th>
<th>Pregnancy loss rate (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinic-based, prospective study</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CI, confidence interval; N/A, data not available; SD, standard deviation; SELENA–SLEDAI, Safety of Estrogen in Lupus National Assessment-Systemic Lupus Erythematosus Disease Activity Index; US, United States.
SUPPLEMENTARY REFERENCES


