EURAP

An International Antiepileptic Drugs and Pregnancy Registry

Interim Report – **NOVEMBER 2024**

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BACKGROUND

A number of independent groups with experience and interest in maternal and foetal well-being in association with maternal use of antiseizure medications (ASMs) have agreed on a prospective international multi-centre study of pregnancies with ASMs. Data from all participating groups are shared in a Central Registry of Antiepileptic Drugs and Pregnancy (EURAP). EURAP was established in the first centres in some European countries and has since then gradually expanded to include more centres and countries now involving also Asia, Oceania, Latin America and Africa. The EURAP Study protocol has been updated in June 2021 and can be found on www.eurapinternational.org

OBJECTIVE OF EURAP

The primary objective of EURAP is to evaluate and determine the comparative risk of major foetal malformations following intake of ASMs and their combinations during pregnancy.

METHODS

EURAP is an observational study. Women taking ASMs at the time of conception, irrespective of the indication, may be included. To avoid selection bias, only pregnancies recorded before foetal outcome is known and within week 16 of gestation are included in the prospective risk assessment. Cases ascertained later in pregnancy are recorded as retrospective cases, as they may provide signals, but are not included in the comparative risk evaluation.

Information on patient's demographics, type of epilepsy, seizure frequency, family history of malformations, drug therapy and of other potential risk factors is obtained, and follow-up data are collected once at each trimester, at birth and at one year after delivery.

Networks of reporting physicians have been established in countries taking part in the collaboration. During the course of the pregnancy, and the follow-up time after delivery, the participating physician enters data into five Subforms (Subforms A-E) for each patient.

Subform A is completed on enrolment of the patient, Subform B after the first trimester, Subform C after the second trimester, Subform D within three months after delivery, and Subform E within 14 months after birth. Immediately after completion, each Subform is submitted to the national coordinator for review. The national coordinator transfers the reviewed and accepted Subform to the Central EURAP Registry in Milan, Italy.

EVALUATION OF OUTCOME

The physician records descriptively abnormalities observed in the offspring. The final assessment and classification of the type of malformation is the responsibility of the Central Project Commission (CPC). In order to facilitate a uniform and objective assessment, reports of malformations are assessed regularly by an outcome assessment committee, which is kept blinded with respect to the type of exposure.

INTERIM REPORT

EURAP was implemented in the first two countries in Europe in 1999 and has since then grown to include countries from Europe, Oceania, Asia, Latin America and Africa. This development is reflected by increasing numbers of enrolled pregnancies. The development since 1999 is illustrated in Figure 1.

<u>Figure 1</u>. Number of Participating Countries and Pregnancies Reported to the Central Registry by November, 2024.

The present report is **based on data available in the Central Registry by November 15th, 2024**.
At that time more than 1,500 reporting physicians from 47 countries had contributed cases to the Central Registry. Countries that have contributed at least 10 pregnancies in the current report are listed in Table 1.

Table 1. Countries that have contributed at least 10 pregnancies in the current report (n=38).

COUNTRY	National Coordinator (or referring physician*)	Date of joining the Registry
Argentina	Silvia Kochen	2002
Australia	Frank Vajda	2000
Austria	vacant	2000
Belarus	Halina Navumava*	2008
Belgium	vacant	2002
Chile	Alejandro De Marinis	2002
China	Lei Chen	2006
Croatia	Dinko Vitezic	2002
Czech Republic	Jana Zarubova	2001
Denmark	Anne Sabers	2000
El Salvador	Ovidio Solano Cabrera*	2017
Estonia	Aleksei Rakitin	2019
Finland	Reetta Kälviäinen	2003
France	Marion Quirins*	2000
Georgia	Sofia Kasradze; Nino Gogatishvili*	2000
Germany	Bettina Schmitz	2000
Hong Kong	vacant	2002
India	Ramshekhar N. Menon	2001
Iran	Nasim Tabrizi	2018
Israel	Lilach Goldstein	2000
Italy	Barbara Mostacci	2000
Japan	Hideyuki Ohtani	2001
Lithuania	Ruta Mameniskiene	2002
Macedonia	Gordana Kiteva Trencevska	2001
Netherlands	vacant	2002
Norway	Silje Alvestad	2000
Philippines	Leonor Cabral-Lim	2003
Poland	Joanna Jedrzejczak	2001
Portugal	Isabel Pires*; Joana Parra*; Ines Cunha*; Elia Baeta*; Carla Bentes*; Catarina Cruto*; Inês Menezes Cordeiro*	2001
Serbia & Montenegro	Maja Milovanovic	2002
Slovakia	Vladimír Safcák	2002
Slovenia	Boštjan Čebular & Gal Granda	2002
Spain	Meritxell Martinez Ferri	2001
Sweden	Torbjörn Tomson	2000
Switzerland	Elisabeth Sellitto, Dominique Flügel*	2001
Taiwan	Hsiang-Yu Yu	2004
Turkey	Demet Ilhan Algın	2000
United Kingdom	John Craig & Craig Heath	2001

NB: *Some of the countries listed in this table are currently inactive, not contributing pregnancies the last few years*.

By the cut-off date for this report (November 15th, 2024), **30,594 pregnancies had been entered into the central database**. Of these, **12,404 pregnancies are excluded** from the present interim report for reasons explained here below:

1. Pregnancies that failed to meet inclusion criteria (n=223).
2. Lost to follow-up, including those failing to submit sub-forms within preset deadlines (n=4,334).
3. Pending pregnancies, awaiting updates or corrections of different sub-forms (n=708).
4. Ongoing pregnancies, updated and corrected (n=570).
5. Retrospective, but completed and corrected (n=4,790). Among these, there are true retrospective pregnancies (n=4,420) and a further three hundred and seventy pregnancies (n=370) that otherwise met our criteria for prospective pregnancies since they were recruited within 16th week, but for which patients had an ultrasound examination performed before enrolment.
6. Retrospective*, i.e.* initially classified as prospective pregnancies but re-classified as retrospective cases because one or more CRF subforms were submitted after the set deadlines (n=413).
7. Unclassifiable *i.e.* cases for which it was impossible to determine if there was a malformation or not (n=95). *This includes 1 stillbirth with unknown fetal status, induced abortions with insufficient information on fetus (n=6), anomalies in livebirths where the information was insufficient to determine if qualifying for malformation diagnosis (n=83), 1 incomplete spontaneous abortion with unclear results of biopsy, and 4 perinatal deaths in premature births (<35 gestational weeks) with anomalies difficult to classify as congenital or due to prematurity.*
8. Not yet classified, *i.e.* pregnancies where classification is pending as well as pregnancies which became completed after the last time we sent the database to the Outcome Assessment Committee (OAC), regardless if they resulted in malformations or not (n=0).
9. Treatment changes between different ASMs or mono- to polytherapy or vice versa during the first trimester (n=1,271).

Thus, in total **18,190 prospective pregnancies** (enrolled at the latest during the 16th gestational week and before outcome was known) **are included** in this report.

The indication for treatment and the classification of the epilepsy among the prospective pregnancies are reported in table 2. Epilepsy was the indication for treatment in all but 128 (0.7%) of the pregnancies.

Table 2. Classification of the epilepsy in 18,190 prospective pregnancies.

Epilepsy	**N**	**%**
Localisation-related*	9,421	51.8
Generalized	7,655	42.1
Undetermined	618	3.4
Missing information	368	2.0
No epilepsy	128	0.7
Total	**18,190**	**100**

**Focal, according to current ILAE terminology.*

The women were of Caucasian **ethnicity** in 86% and Asian in 10%.

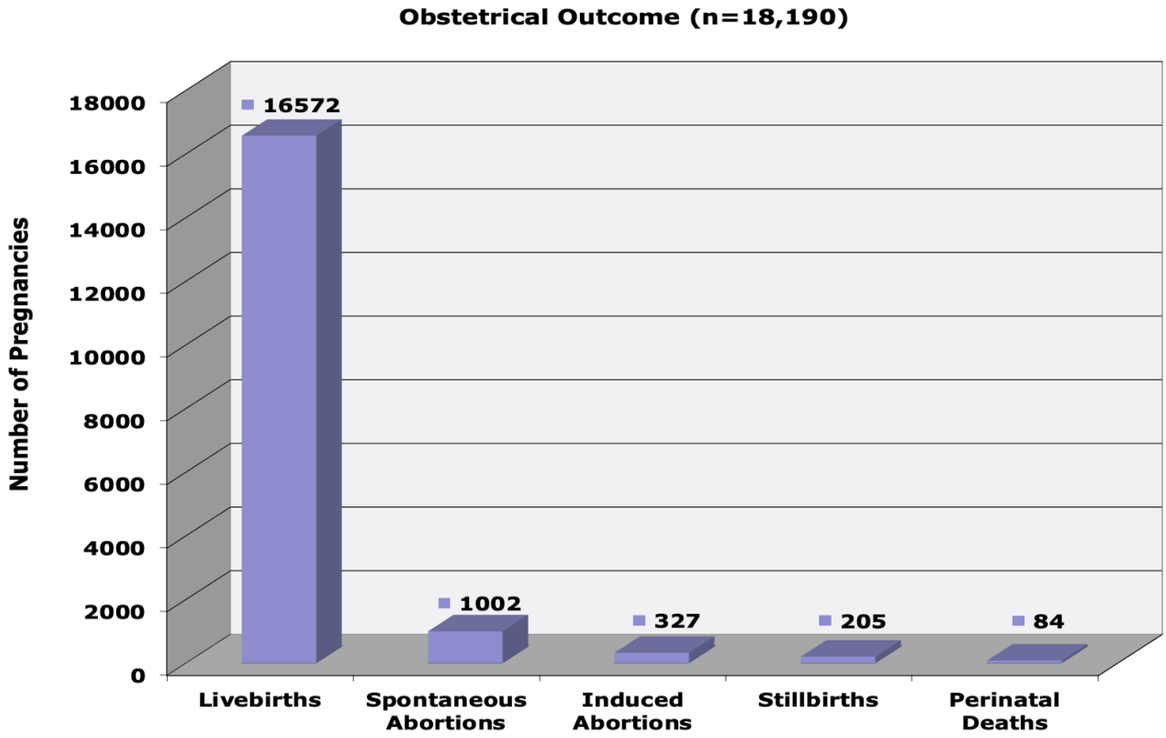
Gravida for each pregnancy is reported in Table 3.

Table 3. Number of the pregnancy in 18,190 prospective cases.

Gravida	N	%
1st pregnancy	8,277	45.5
2nd pregnancy	5,728	31.5
3rd pregnancy	2,523	13.9
4th pregnancy	1,023	5.6
5th pregnancy	391	2.1
> 5th pregnancy	245	1.4
Missing information	3	0.0
Total	**18,190**	**100**

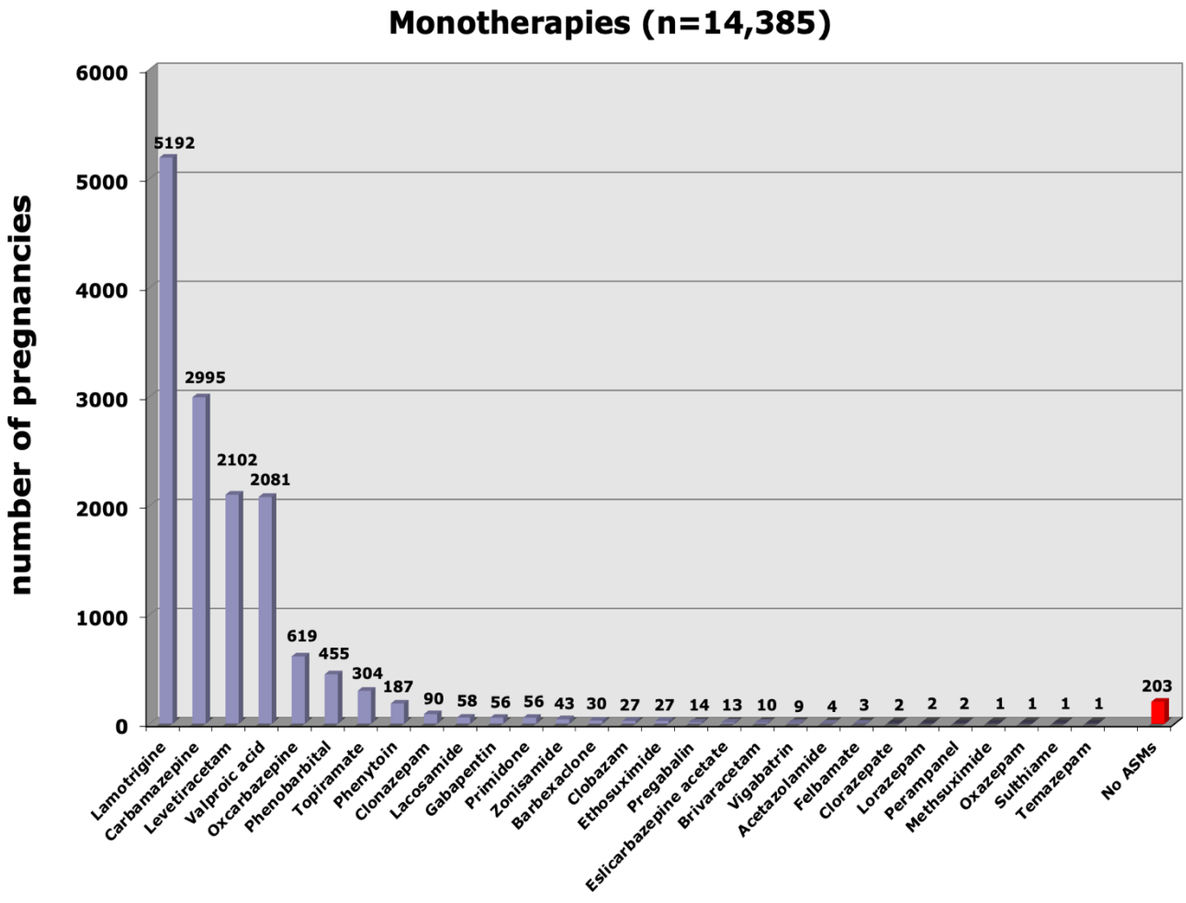
The outcomes of the prospective completed pregnancies are illustrated in Figure 2. Out of the **327 induced abortions**, 60 were for chromosomal abnormalities and/or syndromes and 86 were for other fetal indications detected by prenatal screening (*out of these 86 cases, 73 were confirmed as major malformations and the remaining 13 cases were classified as other abnormalities such as hydrops fetalis, molar pregnancies, blighted ovum, fetal placental transfusion syndromes, fetal growth retardation, fetus papyraceus, fetal death for unspecified causes, balanced translocation and insertion in normal individual).*

Figure 2. Obstetrical outcome of prospective pregnancies.



Of the 18,190 pregnancies, **14,385 (79.1%) involved women on a single ASM**, 3,077 (16.9%) women on two ASMs, whereas 525 (2.9%) occurred in women who took three ASMs or more. Two hundred and three women (1.1%) were not on ASM treatment during the 1st trimester. The exposure to the different ASMs in monotherapy among the prospective pregnancies is illustrated in Figure 3.

Figure 3. Number of prospective pregnancies exposed to different ASMs in monotherapy during the first trimester of pregnancy.



There were 383 different ASM combinations. The most frequently used combinations were lamotrigine and levetiracetam (n=582), lamotrigine and valproic acid (n=314), carbamazepine and levetiracetam (n=194), carbamazepine and clobazam (n=137), carbamazepine and lamotrigine (n=131), lamotrigine and topiramate (n=111), carbamazepine and phenobarbital (n=86), carbamazepine and valproic acid (n=85), levetiracetam and oxcarbazepine (n=75), clobazam and lamotrigine (n=74), levetiracetam and valproic acid (n=69) and carbamazepine and topiramate (n=62) (Table 4).

Table 4. Most common ASM combinations recorded in prospective pregnancies.

Most common polytherapies during the first trimester of pregnancy	N
Lamotrigine + levetiracetam	582
Lamotrigine + valproic acid	314
Carbamazepine + levetiracetam	194
Carbamazepine + clobazam	137
Carbamazepine + lamotrigine	131
Lamotrigine + topiramate	111
Carbamazepine + phenobarbital	86
Carbamazepine + valproic acid	85
Levetiracetam + oxcarbazepine	75
Clobazam + lamotrigine	74
Levetiracetam + valproic acid	69
Carbamazepine + topiramate	62
Clonazepam + lamotrigine	60
Lacosamide + levetiracetam	60
Lamotrigine + oxcarbazepine	50
Levetiracetam + topiramate	43
Phenobarbital + valproic acid	41
Topiramate + valproic acid	41
Clonazepam + valproic acid	40
Carbamazepine + clonazepam	38
Clobazam + oxcarbazepine	38
Phenobarbital + phenytoin	33
Lamotrigine + phenobarbital	27
Lamotrigine + zonisamide	26
Levetiracetam + zonisamide	26
Clobazam + levetiracetam	25

The number of pregnancies exposed to different second-generation ASMs taken in combination with other ASMs are listed in Table 5.

Table 5. Number of pregnancies exposed to second-generation ASMs in a polytherapy regimen.

Lamotrigine	1,723
Levetiracetam	1,394
Topiramate	439
Oxcarbazepine	314
Lacosamide	155
Zonisamide	134
Gabapentin	67
Pregabalin	42
Perampanel	40
Vigabatrin	37
Eslicarbazepine acetate	31
Brivaracetam	26
Tiagabine	11
Rufinamide	4
Stiripentol	2
Cenobamate	1
Retigabine	1

TERATOGENIC OUTCOME

There were 778 cases of major congenital malformations (MCMs), 36 syndromic and/or genetic cases and 105 chromosomal abnormalities (CHR) in the prospective cohort of 17,188 pregnancies for which follow-up has been completed, as shown in Table 6 (*1,002 spontaneous abortions are excluded*).

Table 6. Pathological outcomes.

Outcome	Outcome Classification	N
MCMs	Multiple major	65
	Isolated major	713
MCMs		778
Syndromes or genetic conditions		36
CHR		105
Total		**919**

The 36 syndromic and/or genetic cases include Marfan's syndrome (3), Noonan syndrome (3), inherited tuberous sclerosis (7), Goldenhar syndrome (1), incontinentia pigmenti n.o.s (1), incontinentia pigmenti (Bloch-Sulzberger syndrome) (1), inherited congenital glaucoma (1), inherited congenital cataract (1), inherited craniosynostosis (1), Di George's syndrome (1), bilateral hearing loss (1), X-linked lissencephaly (1), skeletal dysplasia/dwarfism (1), X-linked ichthyosis (1), Freeman Sheldon syndrome (1), Zellweger syndrome (1), achondroplasia (2), blepharophimosis-ptosis-epicanthus syndrome (BPES) (1), Dravet syndrome (2), developmental and epileptic encephalopathy2 (Gene *CDKL5* mutation) (1), developmental and epileptic encephalopathy7 (Gene *KCNQ2* mutation) (1), congenital lactase deficiency (Gene *LPH* alteration) (1), Cornelia de Lange syndrome (1) and autosomal dominant temporal lobe epilepsy (Gene *LGI1* mutation) (1).

In this report we confine our analysis to the 778 MCMs, including those identified in 73 induced abortions, eight stillbirths and 19 neonatal deaths. Of the 678 live births, 98 cases of malformations were ascertained prenatally, 398 were first reported at birth, and a further 182 not detected at birth were identified within one year after birth.

Among the 778 cases with MCMs, 184 were detected by ultrasound examination. Out of these 184 cases, there were 73 induced abortions, six stillbirths, seven perinatal deaths and 98 live births.

The 778 cases represent a **MCM prevalence of 4.5%** of all prospective pregnancies for which follow-up has been completed (778/17,188). **The type of MCMs is described in Table 7a**, while CHR, genetic conditions, and other syndromes are listed in Table 7b.

Table 7a. Type of MCMs and other pathological outcomes.

PATHOLOGICAL OUTCOMES	DESCRIPTION	N
MCM	Multiple major	65
	Nervous system	
MCM	Spina Bifida	43
MCM	Anencephalus and similar	6
MCM	Hydrocephaly	8
MCM	Microcephaly	2
MCM	Nervous system (other malformations)	18
	all	77
	Cardiovascular system	
MCM	Atrial septal defect	38
MCM	Ventricular septal defect	71
MCM	Atrioventricular septal defect	3
MCM	Congenital heart disease	62
MCM	Tetralogy of Fallot	5
MCM	Transposition of great vessels (complete)	4
MCM	Pulmonary valve stenosis or atresia	12
MCM	Hypoplastic left heart	8
	all	203
	Urinary system	
MCM	Urinary system (other malformations)	58
MCM	Renal Dysplasia	8
	all	66
	Digestive system	
MCM	Diaphragmatic hernia	9
MCM	Ano-rectal atresia and stenosis	2
MCM	Digestive system (other malformations)	13
MCM	Duodenal atresia or stenosis	3
MCM	Gastroschisis	3
MCM	Omphalocele	4
MCM	Atresia of oesophagus without fistula	3
	all	37
	Limbs	
MCM	Upper limb reduction	8
MCM	Lower limb reduction	1
MCM	Syndactyly	9
MCM	Polydactyly	29
MCM	Club foot - talipes equinovarus	23
MCM	Limbs (other malformations)	2
	all	72
	Musculoskeletal	
MCM	Musculo-skeletal (other malformations)	14
MCM	Hip dislocation and/or dysplasia	76
	all	90
	Genital system	
MCM	Hypospadias	81
MCM	Developmental ovarian cyst	6
MCM	Genital (other malformations)	1
	all	88
	Eye, ear, face and neck	
MCM	Congenital cataract	5
MCM	Eye (other malformations)	3
MCM	Ear, face and neck	5
MCM	Choanal atresia	1
MCM	Atresia of nasopharynx	1
	all	15
	Oro facial clefts	
MCM	Cleft lip with or without palate	15
MCM	Cleft palate	18
	all	33
MCM	**Other specified malformations** (including sacral teratoma, cystic hygroma, haemangiomas, accessory skin tags, aberrant subclavian artery, congenital malformation of spleen, sequences, genetic syndromes, congenital malformation of renal artery, congenital malformation of adrenal gland, congenital malformations of integument, congenital malformations of the lung, congenital bronchomalacia, congenital malformations of thyroid gland, Tracheal cartilage anomaly *(CHAOS syndrome)*).	32
MCM	**all MCMs**	**778**
CHR	**all CHR**	**105**
Syndromes	**all Syndromes**	**36**
Total	**all cases with pathological outcomes**	**919**

Table 7b. Type of chromosomal abnormalities (CHR), genetic conditions and other syndromes.

PATHOLOGICAL OUTCOMES	DESCRIPTION	N
MCM	all MCMs	778
	Chromosomal	
CHR	Chromosomal	26
CHR	Down's syndrome	51
CHR	Edward syndrome/trisomy 18	12
CHR	Klinefelter's syndrome	2
CHR	Patau syndrome/trisomy 13	7
CHR	Turner's syndrome	5
CHR	Wolff-Hirschorn syndrome	2
CHR	all CHR	105
	Syndromes or genetic conditions	
Syndrome	Marfan's syndrome	3
Syndrome	incontinentia pigmenti, n.o.s	1
Syndrome	incontinentia pigmenti (Bloch-Sulzberger syndrome)	1
Syndrome	Noonan's syndrome	3
Syndrome	Goldenhar syndrome (oculo-auriculo-vertebral syndrome)	1
Syndrome	Di George's syndrome	1
Syndrome	tuberous sclerosis	7
Syndrome	craniosynostosis, inherited	1
Syndrome	congenital cataract, inherited	1
Syndrome	congenital glaucoma, inherited	1
Syndrome	X-linked ichthyosis	1
Syndrome	X-linked lissencephaly	1
Syndrome	hearing loss, bilateral, inherited	1
Syndrome	skeletal dysplasia (achondroplastic dwarfism)	1
Syndrome	Freeman Sheldon Syndrome (distal arthrogryposis type 2A)	1
Syndrome	Zellweger syndrome	1
Syndrome	achondroplasia	2
Syndrome	blepharophimosis-ptosis-epicanthus syndrome (BPES syndrome)	1
Syndrome	Dravet syndrome	2
Syndrome	developmental and epileptic encephalopathy2 (Gene CDKL5 mutation)	1
Syndrome	developmental and epileptic encephalopathy7 (Gene KCNQ2 mutation)	1
Syndrome	congenital lactase deficiency (Gene LPH alteration)	1
Syndrome	Cornelia de lange syndrome	1
Syndrome	autosomal dominant temporal lobe epilepsy (Gene LGI1 mutation)	1
Syndromes	all Syndromes	36
Total	all cases with pathological outcomes	919

One or more MCMs were recorded in 569 out of 13,631 (4.2%) pregnancies exposed to ASM monotherapy, as opposed to 203 out of 3,361 (6.0%) pregnancies exposed to ASM polytherapy (Table 8).

Table 8. Pathological outcomes by ASM treatment categories.
(In this table, 1,002 spontaneous abortions have been excluded from the denominator).

	No ASM	%	Monotherapy	%	Polytherapy	%	Total
MCM	**6**	3.1	**569**	4.2	**203**	6.0	**778** (4.5%)
CHR	**2**	1.0	**85**	0.6	**18**	0.5	**105** (0.6%)
Syndromes	**0**	0.0	**27**	0.2	**9**	0.3	**36** (0.2%)
No pathological outcome	**188**	95.9	**12,950**	95.0	**3,131**	93.2	**16,269** (94.7%)
Total	**196**	100	**13,631**	100	**3,361**	100	**17,188** (100%)

SELECTED PUBLICATIONS

1. EURAP study group. (2006) Seizure control and treatment in pregnancy. Observations from the EURAP Epilepsy Pregnancy Registry. Neurology 2006; 66:354–360.
2. Tomson T, Battino D, Bonizzoni E, et al; EURAP study group. Dose-dependent risk of malformations with antiepileptic drugs: an analysis of data from the EURAP epilepsy and pregnancy registry. Lancet Neurol 2011;10(7):609-17.
3. Battino D, Tomson T, Bonizzoni E, et al; EURAP Study Group. Seizure control and treatment changes in pregnancy: observations from the EURAP epilepsy pregnancy registry. Epilepsia. 2013;54(9):1621-7.
4. Tomson T, Battino D, Bonizzoni E, et al; EURAP Study Group. Withdrawal of valproic acid treatment during pregnancy and seizure outcome: Observations from EURAP. Epilepsia 2016;57(8):e173-7.
5. Tomson T, Battino D, Bonizzoni E, et al; EURAP Study Group. Comparative risk of major congenital malformations with eight different antiepileptic drugs: a prospective cohort study of the EURAP registry. Lancet Neurol 2018;17(6):530-538.
6. Tomson T, Battino D, Bonizzoni E, et al; EURAP Study Group. Declining malformation rates with changed antiepileptic drug prescribing: An observational study. Neurology 2019 27;93(9):e831-e840.
7. Battino D, Tomson T, Bonizzoni E., et al., Risk of major congenital malformations and exposure to antiseizure medication monotherapy. JAMA Neurol 2024;81(5):481-489.
8. Stjerna S, Huber-Mollema Y, Tomson T, Perucca E, Battino D, Craig J, Sabers A, Thomas S, Vajda F, Gaily E. Cognitive outcomes after fetal exposure to carbamazepine, lamotrigine, valproate or levetiracetam monotherapy: Data from the EURAP neurocognitive extension protocol. Epilepsy Behav. 2024 Oct;159:110024. doi: 10.1016/j.yebeh.2024.110024. Epub 2024 Aug 31.

Outcome in relation to exposure to individual drugs or specific drug combinations is not included in the present report.

ORGANISATION, FUNDING AND SUPPORT

EURAP is a consortium of independent research groups working on a non-profit basis. The project is administratively organised by the Central Project Commission (CPC) with members representing different geographical areas and disciplines. The project has been supported over the years by donations to EURAP from Accord Healthcare Ltd, Angelini Pharma, Betapharm Arzneimittel GmbH, Bial, Ecupharma srl, Eisai Pharmaceuticals, GlaxoSmithKline, Glenmark Pharmaceuticals, GW/Jazz Pharmaceuticals, Janssen-Cilag, Johnson & Johnson, Krka, Novartis, Pfizer, Sanofi, S.F Group, Teva, UCB biopharma and Zentiva. In addition, national and regional networks may receive support from the same or other pharmaceutical companies.

APPENDIX

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