

RESEARCH OUTPUTS / RÉSULTATS DE RECHERCHE

The benefits of estetrol addition to drospirenone for contraception

Foidart, Jean Michel; Gemzell-Danielsson, Kristina; Kubba, Ali; Douxfils, Jonathan; Creinin, Mitchell D; Gaspard, Ulysse

Published in:
AJOG global reports

DOI:
[10.1016/j.xagr.2023.100266](https://doi.org/10.1016/j.xagr.2023.100266)

Publication date:
2023

Document Version
Publisher's PDF, also known as Version of record

[Link to publication](#)

Citation for published version (HARVARD):

Foidart, JM, Gemzell-Danielsson, K, Kubba, A, Douxfils, J, Creinin, MD & Gaspard, U 2023, 'The benefits of estetrol addition to drospirenone for contraception', *AJOG global reports*, vol. 3, no. 4, 100266, pp. 100266. <https://doi.org/10.1016/j.xagr.2023.100266>

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal ?

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.



The benefits of estetrol addition to drospirenone for contraception

Jean Michel Foidart, PhD, MD; Kristina Gemzell-Danielsson, MD, PhD; Ali Kubba, MD; Jonathan Douxfils, PharmD, PhD; Mitchell D. Creinin, MD; Ulysse Gaspard, MD, PhD

From the Department of Obstetrics and Gynecology, University of Liège, Liège, Belgium (Prof Foidart and Prof Gaspard); Estetra SRL, an affiliate company of Mithra Pharmaceuticals, Liège, Belgium (Prof Foidart); Department of Women's and Children's Health, Karolinska Institute, and Karolinska University Hospital, Stockholm, Sweden (Prof Gemzell-Danielsson); Department of Gynecological Oncology, Guy's Hospital, London, United Kingdom (Prof Kubba); Department of Pharmacy, Namur Thrombosis and Hemostasis Center, Namur Research Institute for Life Sciences, University of Namur, Namur, Belgium (Prof Douxfils); Quailblood s.a, Namur, Belgium (Prof Douxfils); Department of Obstetrics and Gynecology, University of California, Davis, Sacramento, CA (Prof Creinin).

Prof Jean-Michel Foidart is a member of the board at Mithra Pharmaceuticals, received honoraria from Gedeon Richter, and received financial support for the supervision of these studies.

Prof Kristina Gemzell-Danielsson has served as an ad hoc speaker and/or member of advisory boards for Exelgyn, Campus Pharma and HRA Pharma, Exeltis, Bayer AG, MSD/Merck, MedinCell, Gedeon Richter, Natural Cycles and Myovant, is a member of the former ICCR, Population council and an investigator of ongoing NICDH male contraception trial.

Dr. Ali Kubba has taken part in sponsored educational activity and served on advisory boards for pharmaceutical companies including Bayer, Merck and Exeltis.

Prof Jonathan Douxfils is CEO and founder of QUALblood s.a. and reports personal fees and honorarium from Daiichi-Sankyo, Diagnostica Stago, DOASense, Gedeon Richter, Mithra Pharmaceuticals, Norgine, Portola, Roche and Roche Diagnostics.

Dr. Mitchell D. Creinin has received speaking honoraria from Gedeon Richter, Mayne and Organon. He has served on the Advisory Boards for Evofem, Fuji Pharma, Gedeon Richter, GlaxoSmithKline, Mayne, Merck & Co., OLIC, Organon, and Searchlight. He has been a Consultant for Estetra SRL (an affiliate company of Mithra Pharmaceuticals [includes support for medical and safety oversight of these studies], Libbs, Mayne, and Medicines360, and his university department receives contraceptive research funding for Dr. Creinin from Chemo Research SL, Evofem, HRA Pharma, Medicines360, Merck & Co., and Sebela.

Prof Ulysse Gaspard is a senior consultant member of the Scientific Advisory Board of Mithra Pharmaceuticals.

These listed companies and organizations may have a commercial or financial interest in the results of this research and technology.

Corresponding author: Jean Michel Foidart, PhD, MD. medicalaffairs@mithra.com

2666-5778/\$36.00

© 2023 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>)

<http://dx.doi.org/10.1016/j.xagr.2023.100266>

Ethinylestradiol and drospirenone combined oral contraceptive formulations have been marketed for >20 years. Drospirenone has antimineralocorticoid and anti-androgenic effects that may offer several health benefits. Recently, 2 new drospirenone-containing oral contraceptives entered the market, 1 as a progestin-only pill containing 4 mg drospirenone and the other as a combined oral contraceptive containing 15 mg estetrol and 3 mg drospirenone. Estetrol has a unique differential effect on nuclear and membrane estrogen α -receptors when compared with other estrogens, leading to low impact on the liver, breast, and hemostasis parameters and a beneficial effect on the endometrium, vagina, cardiovascular system, bone, and brain. Phase 3 clinical studies demonstrated that the Pearl Index (pregnancies per 100-woman-years) for drospirenone alone is 4.0 in the United States and 0.93 in the European Union and for the estetrol-drospirenone combination it is 2.65 and 0.44, respectively. Drospirenone alone demonstrates high rates of unscheduled bleeding and low rates of scheduled bleeding, whereas the estetrol-drospirenone combination demonstrates a predictable and regular bleeding profile for most users with a high stable rate of scheduled bleeding and a low rate of unscheduled bleeding, reported primarily as spotting only. The adverse event profiles and discontinuation rates owing to adverse events are comparable, and no clinically significant effects were observed on metabolic parameters with either product. Hemostatic assays for drospirenone do not fully evaluate all parameters although the testing that is available suggests negligible effects, whereas validated hemostatic assays demonstrate that the estetrol-drospirenone combination has limited impact on hemostasis. The introduction of 4 mg drospirenone and 15 mg estetrol with 3 mg drospirenone are valuable additions to the contraceptive market. Adding estetrol to 3 mg drospirenone provides advantages of contraceptive efficacy and a regular, predictable bleeding profile with minimal impact on hemostasis parameters.

Key words: contraception, drospirenone, E4, EE, estetrol, ethinylestradiol

Introduction

Since 1956, combined oral contraceptives (COCs) have undergone several improvements, notably dose reductions, alterations in dosing regimen, use of more selective progestins, and replacement of synthetic by natural estrogens.¹ These developments stem from the recognition that COCs need to not only prevent pregnancies, but also be safe, well tolerated, and offer noncontraceptive health benefits and therapeutic roles in gynecologic conditions.^{2–4}

COCs with ethinylestradiol (EE) and drospirenone (DRSP) were first marketed in 2000. Two new DRSP-

containing contraceptives have been introduced recently, a progestin-only pill (POP) containing 4 mg DRSP and a COC with 15 mg estetrol (E4) and 3 mg DRSP. E4 is a novel estrogen and this COC with E4 and DRSP represents the first COC containing E4. This Clinical Opinion reviews the properties of DRSP and E4, summarizes the 2 new DRSP-containing products, and provides insight on the advantages and disadvantages of both products.

The progestin drospirenone

DRSP is a 17- α -spiro lactone –derived progestogen with some similarities to spironolactone and a

pharmacologic profile more closely related to endogenous progesterone than that of any other synthetic progestogen, especially in terms of its antimineralocorticoid and anti-androgenic effects.^{5,6} The antimineralocorticoid effect of DRSP may compensate for the mineralocorticoid activity of estrogens that enhance the production of angiotensinogen, the substrate of renin. Estrogen activation of the renin-angiotensin-aldosterone system (RAAS), primarily EE, leads to moderate salt and water retention, which can lead to breast fullness and tenderness, abdominal bloating, extremity swelling, and blood pressure (BP) increase, causing moderate hypertension in predisposed users.⁷ DRSP counteracts aldosterone, reduces fluid retention, and prevents BP increases observed with COCs containing EE and other progestins.^{8,9} Its anti-androgenic effects may reduce acne, oily hair, seborrhea and lipid changes.⁹ DRSP has a mostly neutral impact on body weight^{10,11} and BP.^{12,13} Randomized clinical trials (RCTs) evaluating the clinical impact of the antimineralocorticoid activity of the EE-DRSP combination in normotensive healthy young women (<35 years) showed clinically unimportant small decreases in body weight and BP.^{14,15}

However, the clinical impact of DRSP on the RAAS may be important in patients with high normal BP or premenstrual dysphoric disorder (PMDD). Among patients with a baseline systolic BP >130 mm Hg or diastolic BP >85 mm Hg, 4 mg DRSP alone decreased values by 7 mm Hg and 5.5 mm Hg, respectively, whereas no changes occurred among normotensive women.¹⁶ Many progestins in COCs can exacerbate PMDD symptoms.¹⁷ In contrast, the 24/4-day formulation of 20 µg EE with 3 mg DRSP improves PMDD based on pivotal RCTs.¹⁸ In a comparative trial with E4-levonorgestrel (LNG) combination, the E4-DRSP combination conveyed a more predictable bleeding profile, better body weight control, and user acceptability and satisfaction than the combination with LNG.^{19,20}

The estrogen estetrol

E4 is produced naturally in the human fetal liver²¹ and is manufactured for clinical use from commercially available estrone synthesized from plant sources.^{22–24} Extensive studies indicate that in specific cell types, such as breast cancer cells and endothelial cells, E4 presents a profile of estrogen α -receptor (ER α) activation that differs from all other natural synthetic estrogens by inducing only ER α nuclear actions and preventing ER α membrane actions.^{24,25} Preclinical data also suggest that E4 has a differential effect on breast epithelial cells and breast cancer cells when compared with other estrogens.^{24,25} In addition, E4, compared with other estrogens, has a low estrogenic impact on the liver based on differences in sex hormone-binding globulin (SHBG) and angiotensinogen production, hemostasis parameters, and lipid profiles. These differences between E4 and all other estrogens lead to the classification as the only native estrogen with selective tissue activity (NEST).²⁴

With its 4 hydroxyl groups, E4 has a distinct pharmacokinetic and metabolic profile when compared with other estrogens. After oral administration, E4 is rapidly absorbed with high bioavailability (70%) and a long half-life (>24 h),^{26,27} which differs from EE^{28–30} and estradiol (E2) (Table 1).^{29,31} Estetrol metabolism via UDP-glucuronosyltransferases and sulfotransferases lead

to inactive glucuronide and sulfate conjugates that are excreted in urine. In contrast with EE and E2, E4 is not metabolized by cytochrome P450 enzymes (CYP450) and shows minimal impact on the major CYP450 enzymes.^{32–35} Unlike E2, E4 is not converted into estrone (E1) or hydroxylated metabolites that are known precursors of quinone estrogens that can damage DNA and that are linked to breast cancer development.^{36,37} E4 increases SHBG production by hepatic cells much less than other estrogens and minimally binds to SHBG.³⁵

Overall, unlike other estrogens, the unique metabolism of E4 leads to a low impact on the liver and breast and on hemostasis parameters^{38,39} while maintaining beneficial effects on the endometrium, vagina, cardiovascular system, bone, and brain.²⁴

Summary of the 2 new contraceptive products

Drospirenone-alone oral contraceptive

In 2019, 4 mg DRSP (SLYND, SLINDA) was approved for contraceptive use in a cyclic regimen (24 days hormone and 4 days placebo). This regimen was designed with the hope of improving the bleeding profile in comparison with that seen with continuous use of POPs, such as those containing norethindrone or desogestrel (DSG).⁴⁰ When combined with EE, DRSP is given at the

TABLE 1
Pharmacokinetic and metabolic properties of E4, EE, and E2 when used in a combined oral contraceptive

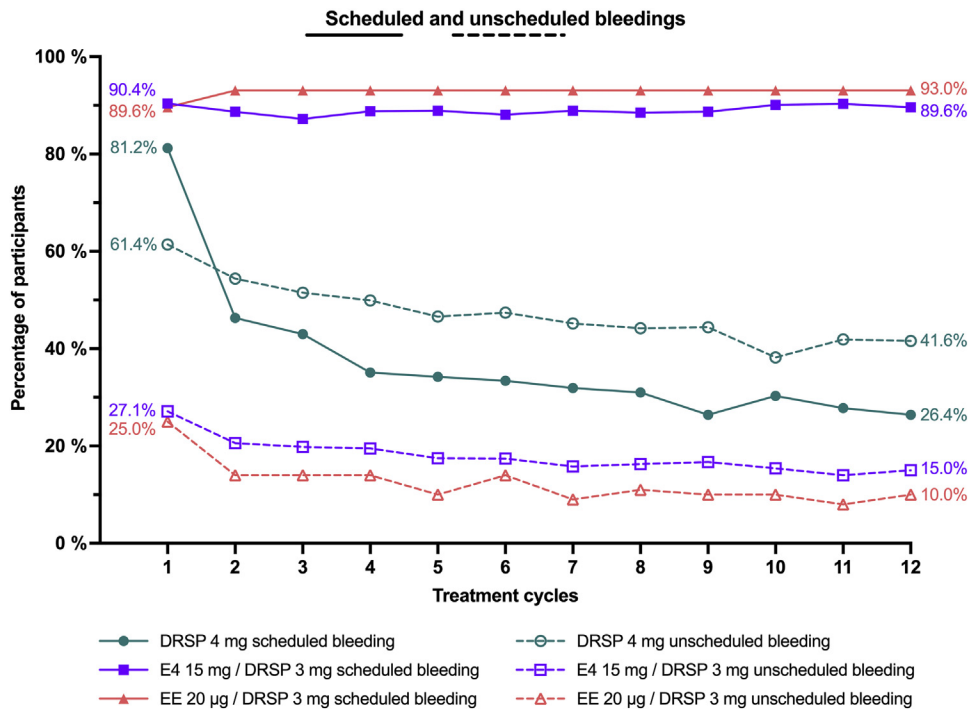
Properties	Estetrol (E4) ^{26,27}	Ethinylestradiol (EE) ^{28–30}	Estradiol (E2) ^{29,31}
Oral bioavailability	70%	45%	<5%
Half-life	>24 h	10–24 h	3.6 h (intravenous) 13–20 h (oral)
Free active fraction	50%	1%–2%	1%–2%
CYP3A4 metabolism	No	Yes	Yes
Active metabolites	No	Yes	Yes ^a

CYP3A4, cytochrome P450 3A4.

^a Metabolites that can react and damage the DNA—linked to breast cancer development.

Foidart. Combination drospirenone and estetrol for contraception. *Am J Obstet Gynecol Glob Rep* 2023.

FIGURE 1
Bleeding with 15mgE4/3mgDRSP, 20 μ gEE/3mgDRSP and 4mgDRSP



E4-DRSP data from Kaunitz et al's⁶⁴ Contraception 2022, EE-DRSP data from the US Food and Drug (FDA) assessment report YAZ 2006⁵² and DRSP alone data from the FDA assessment report SLYND.⁵¹

DRSP, drospirenone; E4, estetrol; EE, ethinylestradiol.

Foidart. Combination drospirenone and estetrol for contraception. *Am J Obstet Gynecol Glob Rep* 2023.

dose of 3 mg, whereas in POP, it is given at the dose of 4 mg despite providing comparable DRSP pharmacokinetic exposure. This difference is explained by the facts that EE inhibits the CYP450 system and because DRSP is micronized when combined with EE, 2 conditions that increase DRSP exposure.⁴¹

Phase 3 clinical trials conducted in the United States and in the European Union demonstrated the contraceptive efficacy of DRSP alone with a Pearl Index (PI) of 4.0 pregnancies per 100 women-years in the United States⁴² and of 0.93 pregnancies per 100 women-years in the European Union or 1.27 in cycles with perfect use.⁴² The consistent observation of higher PIs in all combined hormonal contraceptive studies in populations largely based in the United States when compared with those conducted in Europe is likely related to population differences, some of which are measurable and some that

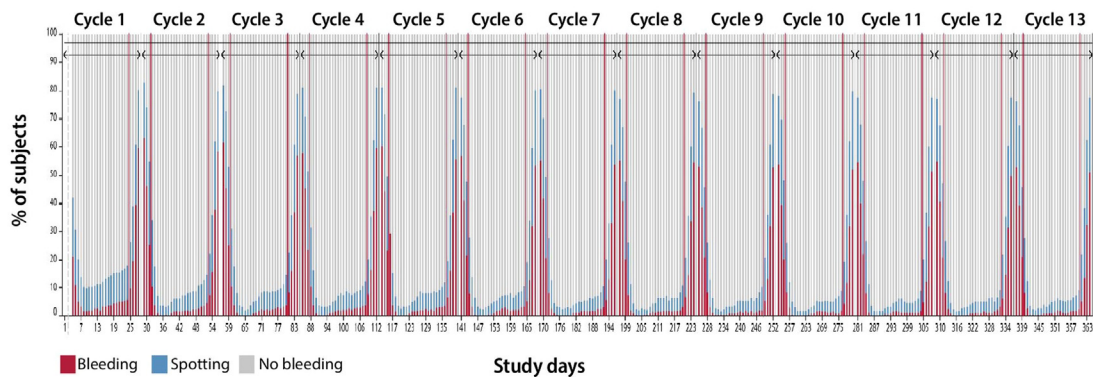
are not. There were, for instance, differences in previous contraceptive use between populations. Differences that are not measured in these studies may include variance in sexual education and health service provision and socioeconomic and education status among study participants. As classically reported with all OCs recently introduced in the United States, the PIs are higher than those approved decades earlier. Trussell and Portman⁴³ coined the term "Creeping Pearl" in a 2013 review of increased rates of contraceptive failures in recent vs older hormonal contraceptive trials. More frequent and sensitive pregnancy testing and less adherent participants are also important contributors to the increased PI in recent trials.⁴³

Combined phase 3 data showed a decline in unscheduled bleeding from 54% in cycle 2 to 42% in cycle 12 and in spotting from 87% in cycle 1 to 63% in

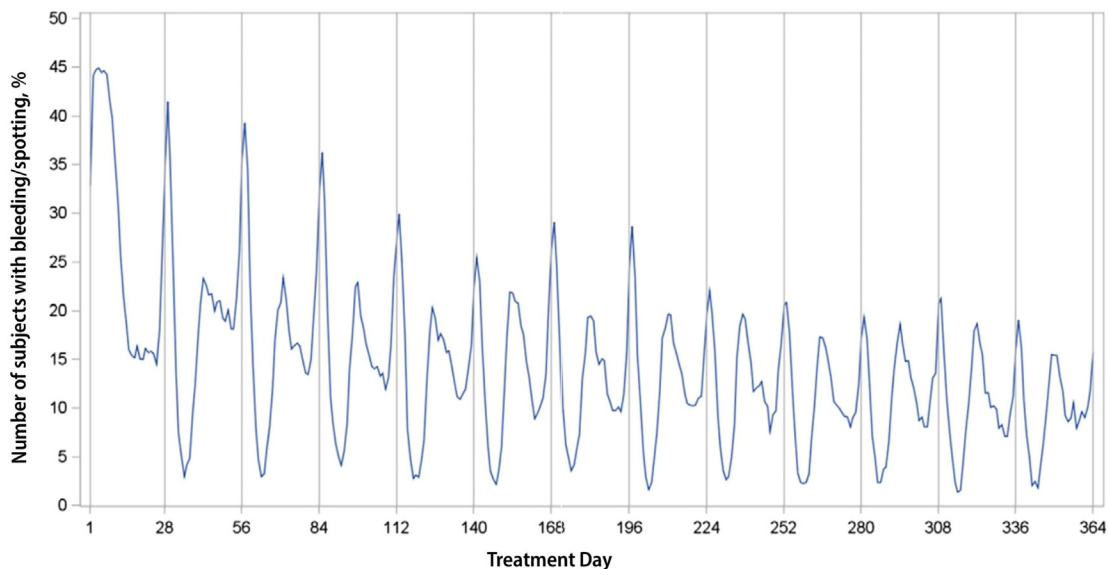
cycle 6 and 45% in cycle 13 (Table 2 and Figures 1 and 2).⁵¹ However, this decline may be facilitated by a substantial dropout rate occurring from 2178 participants in cycle 1 to 726 in cycle 12.⁵¹ A comparative, randomized, 9-month trial with a 75 μ g DSG POP in a continuous 28-day treatment regimen suggested limited differences in the bleeding profiles for the 2 products.⁶⁰ The proportion of users with bleeding and spotting by treatment cycle decreased from 70% in cycle 2 to 56% in cycle 9 with DRSP and from 74% to 45% with DSG. The total mean number of bleeding or spotting days in cycles 2 to 9 was 29 in the DRSP group and 35 in the DSG group ($P < .26$). In cycles 2 to 6, the proportion of women with unscheduled bleeding or spotting was significantly lower in the DRSP group (73%) than in the DSG group (88%) ($P = .0001$). However, these calculations are misleading because all bleeding with

FIGURE 2
Bleeding for 15mgE4/3mgDRSP (A) and for 4mgDRSP (B)

Panel A



Panel B



A, E4-DRSP phase 3 trial European Union and Russia, Gemzell-Danielsson et al⁴⁶ BJOG 2021. **B**, DRSP phase 3 trial European Union, Archer et al Contraception 2015¹².

DRSP, drospirenone; E4, estetrol.

Foidart. Combination drospirenone and estetrol for contraception. *Am J Obstet Gynecol Glob Rep* 2023.

DSG, which is a continuous regimen, is, by definition, unscheduled. More useful, therefore, is the number of women with any bleeding or spotting during days 29 to 252 (cycles 2–9 in the DRSP cyclic regimen), with no difference ($P=.30$) between the 2 preparations.⁶⁰ Still, DRSP use led to a lower discontinuation rate owing to bleeding complaints than DSG use (4% vs 7%; $P<.005$).⁶¹

The most frequently reported adverse events (AEs) during phase 3 DRSP-alone

clinical trials (>2% of patients) were bleeding abnormalities, acne, headache, and breast pain.^{13,42,44,47} Early discontinuation rates owing to AEs were 11% and 12% in the 13-cycle United States and European Union trials, respectively.^{12,13} The discontinuation rate owing to bleeding related AEs was 4% in the European Union trial.¹³ This rate was not reported in the US trial, which had a high overall dropout rate of 65% with 27% of participants lost to follow-up.⁴⁷

DRSP only use showed no clinically relevant effects on carbohydrate metabolism and a nonclinically relevant decrease in cholesterol and triglycerides after 6 months of use (Table 2).⁵⁴ Bone markers measured in a subgroup of 64 participants in the European Union phase 3 trial showed a decrease in bone alkaline phosphatase and a small increase in beta-C terminal telopeptide (CTX), markers that both indicate slight bone degradation.⁵⁴ The impact of

TABLE 2
Efficacy, bleeding, and safety for E4-DRSP, DRSP and EE-DRSP

Parameters	E4 15 mg with DRSP 3 mg	DRSP 4 mg alone	EE 20 µg with DRSP 3 mg
Contraceptive efficacy ^a	Pearl index US: 2.65 (1.73–3.88) ²⁶ Pearl index EU: 0.44 (upper range 1.03)	Pearl index US: 4.00 (2.30–6.40) ⁴² Pearl index EU: 0.93 (upper range 1.84) ⁴⁴	Pearl index US: 1.41 (0.73–2.47) ²⁸ Pearl index EU: 0.80 (upper range 1.30)
Discontinuations			
Overall	Phase 3 trial US/CAN: 45.5% ⁴⁵ Phase 3 trial EU/RUS: 21.6% ⁴⁶	Phase 3 trial US: 65% ⁴⁷ Phase 3 trial EU: 27.8% ¹²	Phase 3 trial global: 28.9% ⁴⁸ Phase 3 trial EU: 12.7% ⁴⁹
Because of adverse events	Phase 3 trial US/CAN: 9.7% ⁴⁵ Phase 3 trial EU/RUS: 10.1% ⁴⁶	Phase 3 trial US: 11.2% ⁴⁷ Phase 3 trial EU: 12.3% ¹²	Phase 3 trial global: 7.5% ⁴⁸ Phase 3 trial EU: 6.3% ⁴⁹
Because of bleeding-related events	Phase 3 trial US/CAN: 2.7% ⁴⁵ Phase 3 trial EU/RUS: 3.4% ⁴⁶	Phase 3 trial US: not reported Phase 3 trial EU: 4.2% ¹²	Not reported
Bleeding profile			
Incidence of scheduled bleeding	Phase 3 trial US/CAN: 82.9% to 87.0% of women per cycle ⁴⁵ Phase 3 trial EU/RUS: 91.9–94.4% of women over cycles 1 to 12 ⁴⁶	46.3% in Cycle 2 declining to 26.4% in Cycle 12 ^{50,51}	89.6% in Cycle 1, ranging between 91.7% and 94.4% at Cycles 2 to 13 ⁵²
Incidence of unscheduled bleeding	Phase 3 trial US/CAN: between 15.5% to 19.2% from Cycle 5 onwards ⁴⁵ Phase 3 trial EU/RUS: <16% from Cycle 6 onwards ⁴⁶	54.4% in Cycle 2 declining to 41.6% in Cycle 12 ^{50,51}	14% in Cycle 2, decreasing to 10% in Cycle 12 ⁵²
Safety profile			
Participants reporting AEs	Phase 3 trial US/CAN: 53.8% ^{45,46} Phase 3 trial EU/RUS: 50.5%	Phase 3 trial US: 61.0% ⁴⁷ Phase 3 trial EU: 48.5% ⁵¹	Phase 3 trial global: not reported Phase 3 trial EU: 47.8% ⁴⁹
Participants reporting ARs	Phase 3 trial US/CAN: 28.9% ^{45,46} Phase 3 trial EU/RUS: 28.5%	Phase 3 trial US: 33.9% ⁴⁷ Phase 3 trial EU: 21.0% ¹²	Phase 3 trial global: 38.5% ⁴⁸ Phase 3 trial EU: 21.2% ⁴⁹
VTE risk	1 case of VTE in the clinical development program (30,289 cycles) ⁴⁶	No cases of VTE in the clinical development program (>20,000 cycles) ⁵³	2 cases of VTE in the clinical development program (both with the 21/7 treatment regimen) (>28,981 cycles) ⁵²
Hemostasis parameters	Effects on individual hemostasis parameters were less or similar to those for EE-LNG. Increase in nAPCs after 6 months of use was 30%. ³⁸ No clinically relevant change in thrombin generation allows to conclude a neutral profile.	No apparent impact on hemostasis parameters but no statistical values (mean ± SD) and inadequate methods to measure the APC resistance preclude definite proof. ⁵⁴	Effects on hemostasis parameters higher compared to those for E4-DRSP. ³⁸ Increase in nAPCs after 6 months of use was 218.5% with EE-DRSP compared to 30% with E4-DRSP.
Endocrine parameters	Decrease in E2 and progesterone levels, indicative for contraceptive efficacy. ⁵⁵	No data available	Decrease in E2 and progesterone levels, indicative for contraceptive efficacy. ⁵⁵
Liver proteins	Limited increase in CBG (+40%) and SHBG (+55%). ⁵⁵ Effects were less compared to EE/LNG (CBG+152%, SHBG +74%)	No data available	Increase in CBG (140%) and SHBG (251%). ⁵⁵ Effects were higher compared to E4/DRSP (CBG+40%, SHBG +55%)
Lipids	Limited changes in lipids: decrease in LDL-C (–2%), increase in HDL-C (+4%), total cholesterol (+4%) and triglycerides (+24%). ⁵⁵	Limited decreases in lipid parameters total cholesterol (–5%), HDL-C (–8%), LDL-C (–3%) and triglycerides (–10%). ⁵⁴	Limited changes in lipids. Decrease in LDL (–5%), increase in HDL-C (+8.5%), total cholesterol (+6.5%) and triglycerides (+65.5%). ⁵⁵

Foidart. Combination drospirenone and estetrol for contraception. *Am J Obstet Gynecol Glob Rep* 2023.

(continued)

TABLE 2

Efficacy, bleeding, and safety for E4-DRSP, DRSP and EE-DRSP (continued)

Parameters	E4 15 mg with DRSP 3 mg	DRSP 4 mg alone	EE 20 µg with DRSP 3 mg
Carbohydrate	No clinically relevant impact on carbohydrate metabolism: glucose (+3%), insulin (+21%), C-peptide (+17%) and HbA1c (0%) ⁵⁵	No relevant impact on glucose (-0.4%), insulin (+33%), and C-peptide (+8%) ⁵⁴	Limited effects on carbohydrate metabolism: glucose (0%), insulin (+42%), C-peptide (+27%) and HbA1c (+2%) ⁵⁵
Cardiovascular safety	No clinically relevant changes in cardiovascular risk parameters such as blood pressure, heart rate, ECG, echocardiography, and coagulation parameters. ^{38,55,56}	No reports of arterial thromboembolism, myocardial infarcts, strokes, or pulmonary embolisms in clinical development program of DRSP-alone. Slight decreases in systolic and diastolic blood pressure. ⁵³	Absolute risk of arterial thrombotic stroke and myocardial infarction is increased by a factor of 0.9 to 1.7 with COCs containing EE at a dose of 20 µg. ⁵⁷
Bone	Positive effect on bone turnover with a dose-related decrease in C-telopeptide (-8.6% with 5 mg E4 and 3 mg DRSP combination and -13.4% with 10 mg E4 combined with 3 mg DRSP) and osteocalcin (-10.4% with 5 mg E4 combined with 3 mg DRSP and -16.3% with 10 mg E4 with 3 mg DRSP) after 3 mg of use. ⁵⁸	The effect on bone mineral density is unknown. Limited decrease in bone AP (-21.7%) and increase in CTX (3.8%) after 6 months of treatment. ⁵⁴ Phase IV trial on bone mineral density at 12 months is ongoing (NCT05303636)	At 12 months, no significant effect on spinal bone mineral density. ⁵⁹

AP, alkaline phosphatase; APC, activated protein C; CAN, Canada; CBG, cortisol binding globulin; COC, combined oral contraceptive; CTX, C terminal telopeptide; DRSP, drospirenone; E2, estradiol; E4, estetrol; ECG, electrocardiogram; EE, ethinylestradiol; EU, Europe; HbA1c, hemoglobin A1c; HDL-C, high density cholesterol; LDL-C, low density cholesterol; LNG, levonorgestrel; nAPCs, normalized APC sensitivity ratio; SD, standard deviation; SHBG, sex hormone binding globulin; RUS, Russia; US, United States; VTE, venous thromboembolism.

^a FDA criteria for Pearl Index: at risk cycles are defined as cycles with no back-up contraception and confirmed vaginal intercourse; pregnancies within 7 days after last use are considered on treatment. EMA criteria for Pearl Index: at risk cycles are defined as cycles with no back-up contraception; pregnancies within 2 days after last use are considered on treatment;

Foidart. Combination drospirenone and estetrol for contraception. *Am J Obstet Gynecol Glob Rep* 2023.

DRSP only on hemostasis is only weakly documented in the literature by studies reporting individual changes of some selected coagulation factors.^{53,54}

Estetrol- drospirenone combined oral contraceptive

Since 2021, E4-DRSP has been approved for pregnancy prevention (NEXTSTELLIS, DROVELIS, ALYSSA, and LYDISILKA).^{1,24} E4-DRSP has a cyclic 24/4-day treatment regimen with 24 active tablets containing 15 mg E4 (as monohydrate [14.2 mg anhydrous]) and 3 mg DRSP followed by 4 hormone-free pills.

Two 13-cycle phase 3 trials with 15 mg E4 and 3 mg DRSP, one conducted in the United States and Canada (US/CAN) and one in Europe and Russia (EU/RUS), demonstrated a PI of 2.65 pregnancies per 100-women years in the US/CAN trial and 0.44 pregnancies per 100-women years in the EU/RUS trial (Table 2).⁶² A recent secondary analysis of the pooled E4-DRSP phase 3 studies

further evaluated the 31 on-treatment pregnancies based simply on adherence to remove other confounders, including study location.⁶³ Pregnancies occurred in 0.09%, 0.25%, 0.83%, and 1.6% of cycles in which participants reported that they took all hormone pills (n=25,613 cycles) or omitted 1 (n=405 cycles), 2 (n=121 cycles), and more than 2 (n=314 cycles) hormone-containing pills ($P<.001$). No pregnancies occurred in 2216 cycles when 1 or more pills were missed and missed-pill instructions were followed. All pregnancies related to not taking pills occurred in the first 3 cycles. Pregnancy rates ranged from 0% to 0.21% per cycle with no significant trend by cycle.⁶³ Similar data for DRSP only contraception are not available.

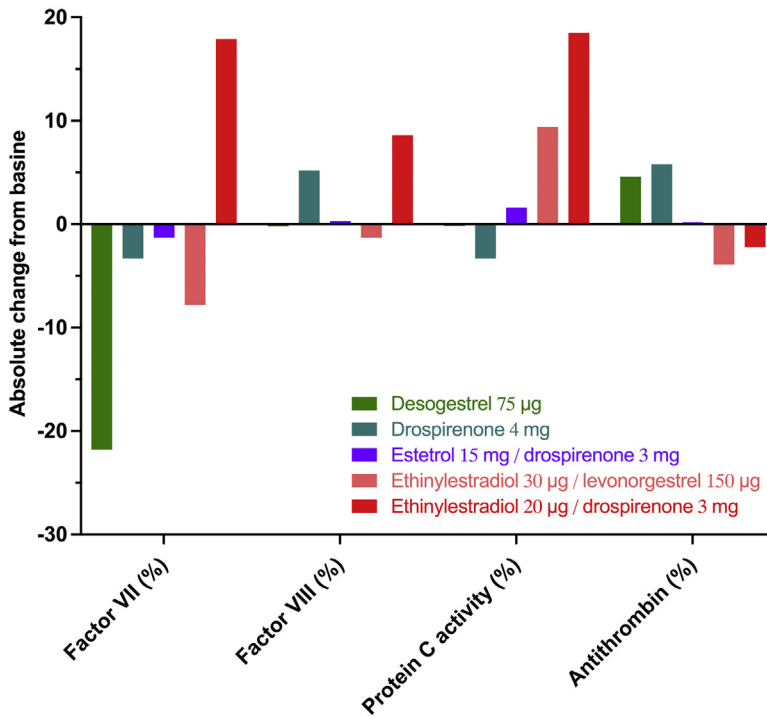
E4-DRSP users experience predictable bleeding episodes with a high stable rate of scheduled bleeding (89% in cycle 2, 90% in cycle 12) and a decreasing rate of unscheduled bleeding (21% in cycle 2 to $\leq 18\%$ from cycle 5 onwards)

(Figures 1 and 2; Table 2); 67% of unscheduled bleeding or spotting episodes included only spotting, 27% included mixed bleeding and spotting, and 6% included only bleeding with a duration of bleeding or spotting of 3 to 4 days.⁶⁴ Most frequently (>2%) reported treatment-related AEs during E4-DRSP use were bleeding complaints, breast pain or tenderness, acne, mood disturbance, headache, dysmenorrhea, and increased weight.⁵⁶ Discontinuation rates owing to AEs were 10% overall and 3% for AEs specifically related to bleeding in both trials.^{45,46}

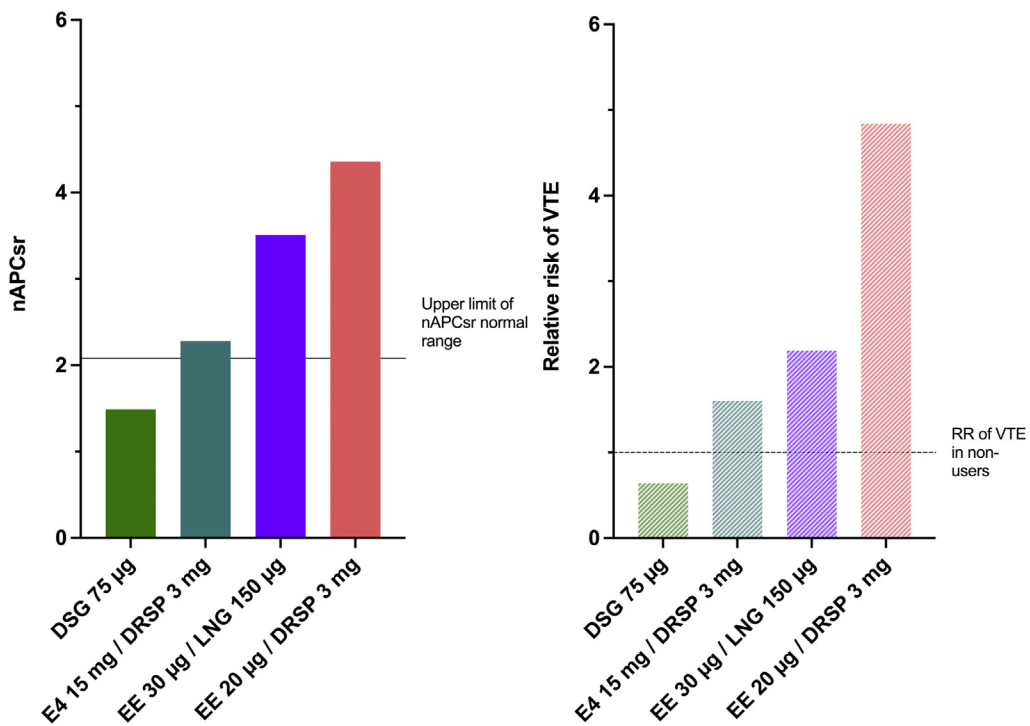
A comparative 6-cycle trial showed that E4-DRSP use had a minimal effect on hemostasis parameters as supported by the impact of E4-DRSP on the endogenous thrombin potential (ETP)-based activated protein C (APC) resistance assay, which was negligible when compared with EE-containing products (Figure 3, B; Table 2).³⁸ E4-DRSP use also led to minimal effects on

FIGURE 3
Impact of POPs and COCs on coagulation factors, nAPCsr and VTE risk

A. Impact of different POPs and COCs on coagulation factors extracted from phase 2 clinical studies



B. Correlation between nAPCsr values obtained in POPs and COC users and the relative risk of VTE



carbohydrate metabolism and on the lipid profile with only a small but statistically significant effect on apolipoprotein A1, apolipoprotein B, and triglycerides (Table 2).⁵⁵

The E4 effects on bone were first studied in an osteoporosis rat model, which showed dose-dependent bone-sparing effects.⁶⁷ In postmenopausal women treated with 15 mg E4, the median osteocalcin and CTX levels decreased respectively by 3.1% and 45.3%.⁶⁸ Similar results were obtained with 5 mg E4 with 3 mg DRSP and with 10 mg E4 with 3 mg DRSP (Table 2).⁵⁸

Discussion Contraceptive efficacy

The progestogen in COCs is primarily responsible for the contraceptive efficacy by suppressing gonadotropin-releasing hormone from the hypothalamus, thus inhibiting follicular development and ovulation.^{69,70} Estrogens attenuate follicular development through a pituitary inhibition of follicle stimulating hormone secretion. Although the PIs for 15 mg E4 combined with 3 mg DRSP and for 20 μ g EE combined with 3 mg DRSP are lower than for 4 mg DRSP alone (Table 2), the PIs for DRSP alone are in the range of combined formulations because of similar ovulation inhibition.¹⁶

Bleeding profile

A common drawback of POPs is their effect on endometrial vasculature. Underdevelopment of spiral arterioles and dilated, thin-walled vessels with increased vascular fragility contribute to irregular bleeding.^{71,72} Although the number of bleeding days over multiple cycles is similar to DSG only POP, DRSP only contraception has a slightly lower discontinuation rate. Estrogens added to the progestin stabilize the endometrium with uniformly

decidualized stroma and only rare, atrophic-appearing glands. The bleeding profile of E4-DRSP demonstrates that 87% to 94% of the cycles had scheduled bleeding vs 26% for DRSP only and lower unscheduled spotting (10%–12%) when compared with 63% for DRSP only users.⁵⁰ The bleeding profile of E4-DRSP seems to be comparable with that of EE-DRSP (Figure 1).

Nonbleeding adverse events

The other most frequent AEs that occur during hormonal contraceptive use include breast tenderness, nausea, headache, abdominal pain, increased vaginal discharge, decreased libido, acne, mood changes, and weight gain.^{73,74} Most of these AEs are also reported with the use of E4-DRSP, EE-DRSP, or DRSP alone with small differences in frequencies. The overall discontinuation rates and the discontinuation rates owing to AEs (as a proxy for the experienced intensity of the AEs) with the use of E4-DRSP and DRSP alone are comparable (Table 2).

Hemostasis parameters and venous thromboembolism

The impact of DRSP alone has only been investigated in a small series of selected coagulation proteins, making it difficult to draw conclusions about its influence on hemostasis.⁵⁴ For example, the effect of DRSP alone on protein C activity and factor VII levels has been reported to be different than that of DSG. Comparatively, the level of factor VII decreases to a similar extent with E4-DRSP use (ie, –3%), and the levels of protein C, factor VIII, and antithrombin are also not influenced by E4-DRSP use (Figure 3).^{38,54} The use of inappropriate methodologies for assessing activated protein C resistance^{53,54,75} precludes conclusions on the impact of DRSP alone on the entire coagulation

process.⁷⁶ Therefore, until the evaluation of hemostasis using appropriate techniques is completed for DRSP alone, it is difficult to infer any differential impacts on hemostasis in comparison with COCs containing DRSP.

The characterization of the hemostatic profile of E4-DRSP is well documented.^{1,38,39,66,77,78} Its impact on the entire coagulation process has been determined using the endogenous thrombin potential–based APC resistance assay, the thrombin generation assay, and several hemostasis markers, suggesting the absence of a clinically relevant impact on hemostasis when compared with EE-containing products (Figures 3 and 4). EE-containing products increase the production of procoagulant factors and decrease the production of anticoagulants to a level that favors clot formation.^{25,38,39,79} E4-DRSP has less impact on thrombin generation than EE-containing OCs associated with LNG or DRSP, which either increase the production of procoagulant factors or decrease the production of anticoagulant ones, shifting the patient to a prothrombotic state. EE-containing OCs thus generate prothrombotic environments, whereas the E4 containing OCs demonstrate a neutral profile on these hemostasis markers.³⁹

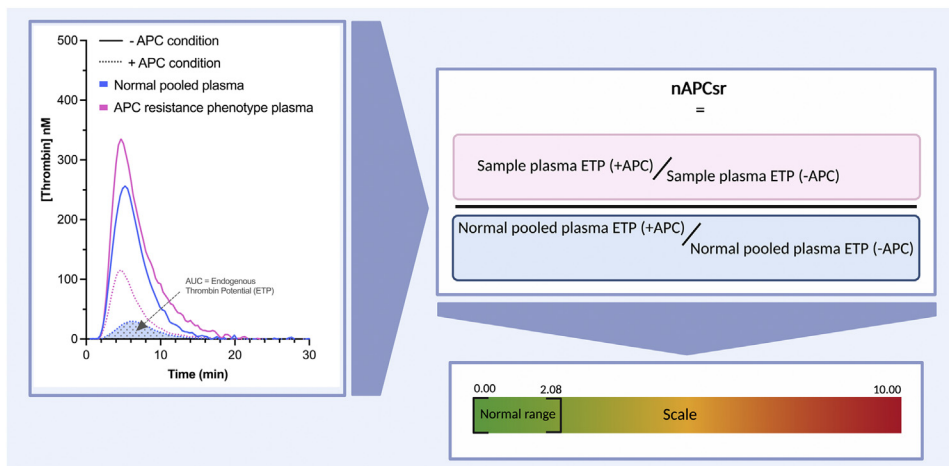
During clinical development with E4-DRSP, 1 venous thromboembolism (VTE) event was reported among 3574 women (35,677 cycles), giving an estimated incidence of 3.7 per 10,000 woman-years, which is in line with rates observed among reproductive-age women who do not use COCs (1–5/10,000 woman-years).^{80,81} For comparison, 2 participants in the 20 μ g EE with 3 mg DRSP clinical trials experienced a VTE in 42,338 treatment cycles (6.1 per 10,000 women-years of use), whereas similar phase 3 clinical studies with other combined hormonal

The impact of POPs and COCs on some individual coagulation factors has been extracted from Palacios et al⁵⁴ and Douxfils et al³⁸ (A). The correlation between nAPCsr results and relative risk for VTE was extracted from Douxfils et al,³⁸ whereas desogestrel data are extracted from QUALblood s.a. (unpublished data). The VTE risk was either extracted from Lidegaard et al⁶⁵ or recovered by the in silico model of Morimont et al.⁶⁶

COCs, combined oral contraceptive; nAPCsr, endogenous thrombin potential-based activated protein C resistance (ETP-based APC), expressed as normalized APC sensitivity ratio; POP, progestin-only pill; VTE, venous thromboembolism.

Foidart. Combination drospirenone and estetrol for contraception. *Am J Obstet Gynecol Glob Rep* 2023.

FIGURE 4
Endogenous thrombin potential(ETP)-based activated protein C(APC) resistance assay



The ETP-based APC resistance assay permits the evaluation of congenital and acquired APC resistance by using data from thrombin generation curves. Thrombin generation curves (thrombograms) reflect the amount of thrombin produced over time in a measurement well. Several parameters can be extracted from this curve but for the sake of the ETP-based APC resistance assay, only the area under the curve of the thrombograms, reflecting the endogenous thrombin potential (ETP), was used.

In the ETP-based APC resistance assay, thrombograms are generated in the absence (— continuous line) and in presence (--- dotted lines) of APC. The resistance towards APC in a subject's plasma, for example, with an APC resistant phenotype (continuous and dotted pink lines), is compared with the resistance obtained in a pool of plasma from normal subjects (continuous and dotted blue lines). This method of calculation permits to express the results in terms of normalized activated protein C sensitivity ratio (nAPCsr).

nAPCsr results scale from 0 to 10, which ease its interpretation. Therefore, the higher the nAPCsr, the higher the resistance toward APC. The normal range in a young and healthy population not taking combined hormonal contraceptives (CHCs) is from 0.00 to 2.08. Women taking EE/LNG COCs usually express nAPCsr results around 3.50.

As stated in by the plasma coagulation inhibitors subcommittee of the International Society on Thrombosis and Haemostasis (ISTH) Scientific and Standardisation Committee (SSC), the ETP-based APC resistance assay⁷⁷ has to be used for assessment of hormone-induced APC resistance since clotting (ie, aPTT-based) APC resistance assays are insensitive to this acquired APC resistance condition.⁷⁵

Foidart. Combination drospirenone and estetrol for contraception. *Am J Obstet Gynecol Glob Rep* 2023.

contraceptives containing EE reported 3 events among 1683 participants for oral 10 µg EE with 1 mg norethisterone acetate,⁸² 4 events among 1188 participants for vaginal 13 µg EE with 150 µg segesterone,⁸³ and 4 events over 2031 participants for transdermal 20 µg EE with 120 µg LNG.⁸⁴

Altogether, the limited comparison of DRSP only vs E4-DRSP and the exhaustive evaluation of E4-DRSP in comparison with other EE-containing products support the observation that E4-DRSP has minimal impact on hemostasis⁶⁶ and confirm that the effect of COCs on hemostasis is mainly driven by the estrogen component of the pill. E4 can thus be viewed as having a minimal effect on hemostasis. The conclusions from the surrogate markers of hemostasis must

be confirmed by a phase 4 postauthorization safety study.

Metabolic effects

Estrogens in a COC typically increase high density lipoprotein cholesterol, decrease low density lipoprotein cholesterol, and increase triglyceride blood concentrations. The magnitude of these effects depends on the potency of the estrogen impact on liver cells. E4 selectivity with relative liver neutrality is reflected in the lack of clinically relevant effects on lipids observed in the clinical trials with E4-DRSP, which comparable with the lack of effects of DRSP alone on plasma lipids levels.^{54,55} Current low-dose COCs rarely impair glucose metabolism in healthy women. DRSP has only a minimal effect on this metabolism.^{9,85,86} No clinically relevant

effects on carbohydrate metabolism were observed with E4-DRSP, DRSP alone, or EE-DRSP.^{54,55}

Drug-drug interaction

E4 is not metabolized by CYP450 and shows minimal impact on this enzyme system,^{32–35} which leads to less interference with the many drugs metabolized by CYP450. The inhibition or induction of CYP450 by EE or E2 alter the metabolism of at least 200 drugs. Reciprocally, these drugs may increase or decrease EE and E2 plasma levels but will not modify E4 levels. However, because DRSP interferes with CYP450, concomitant use of other drugs might reduce contraceptive efficacy.⁸⁷ Finally, unlike E2, E4 is not converted into estrone (E1), which increases thrombin generation.⁸⁸ Interestingly, the VTE risk is increased

30-fold among patients who use oral estrogen and who express the CYP450 3A5*1 allele, a cytochrome mutation that enhances the conversion of E2 into E1.⁸⁹ These observations add weight to the epidemiologic data demonstrating an increased VTE risk among women who use oral E2 treatment.

Bone

Because of the suppression of follicular development, the use of progestin-only contraceptives leads to a decrease in E2 levels, which may affect bone mineral density (BMD).⁹⁰ In a COC, the decrease in endogenous E2 levels is compensated for by the exogenous estrogen that maintains a favorable effect on bone. In the phase 3 trial with DRSP alone, bone alkaline phosphatase, a marker for bone formation, decreased and CTX, a marker for bone resorption, modestly increased after 6 months of use, suggesting a moderate increase in bone turnover.^{4,54} A phase 4 trial is in progress to evaluate the effect of DRSP alone on BMD after 12 months of treatment (ClinicalTrials.gov, NCT05303636). The combination of E4 and DRSP led to an E4 dose-related decrease in bone turnover, which is indicative of a positive influence of E4 on bone turnover in young, postadolescent women.⁵⁸ For EE-DRSP, no changes in BMD were observed after 12 months of use.⁵⁹

Cardiovascular and cardiometabolic thromboembolic safety

Cardiometabolic disorders encompass a cluster of metabolic disorders including insulin resistance, hyperglycemia, hypertriglyceridemia, dyslipidemia, and more.⁹¹ The incidence of these disorders, together with smoking and high blood pressure, predispose users from 35 years of age to a higher risk for cardiovascular disease.⁹² Preclinical studies suggest that COCs containing DRSP are likely safer than those with LNG because of less insulin resistance, pancreatic β -cell dysfunction, glucose deregulation, dyslipidemia, and circulating corticosterone.⁹³ Clinical studies with DRSP alone or with E4-DRSP have

demonstrated a good cardiovascular safety profile.^{53,56} DRSP alone and E4-DRSP also showed limited impact on lipid parameters,^{54,55} whereas with the addition of EE to DRSP, lipid parameters, such as triglycerides, increased by 66% from baseline after 6 cycles of usage.⁵⁵

Conclusion

Many factors determine the preferred individual choice of contraception, including the characteristics of the user, contraindications, the AE profile of different products, costs, availability, and the user's preferences. Healthy users should be free to choose the most acceptable method.

From its introduction to the market in 2000, DRSP held great promise as the progestin that could prevent increases in blood pressure, maintain stable body weight, and have a beneficial impact on health-related quality of life. Unfortunately, DRSP is devoid of anti-estrogenic activity to counteract the estrogenic properties of EE, which leads to a negative impact on hemostasis and VTE risk. The beneficial properties of DRSP may be expressed much better when DRSP is given alone or in combination with a selective estrogen that does have a minimal impact on the breast, liver, and coagulation. The introduction of 4 mg DRSP alone and of 15 mg E4 with 3 mg DRSP are therefore valuable additions to the contraceptive market. Because of the absence of a strong estrogen component, such as EE, DRSP alone offers the advantage of no or a low additional VTE risk like with other POPs.⁵³ However, DRSP alone provides a suboptimal bleeding profile even if somewhat better than other POPs thanks to the 24/4 regimen.⁶⁰ Indeed, it is associated with a high level of discontinuation, a higher rate of unscheduled bleeding, and a lower rate of scheduled bleeding than combined products.^{16,47,50,51,60} Adding 15 mg E4 to 3 mg DRSP concurs with the contraceptive efficacy and stabilizes the endometrium, leading to a COC with a robust contraceptive efficacy and a regular and predictable bleeding profile

with a high rate of scheduled bleeding and lower rates of unwanted, unscheduled bleeding. Because of its unique pharmacologic profile, the impact of E4 on hemostasis remains minimal even when compared with DRSP alone.^{1,38,56} If phase 4 population-based studies confirm the expected low VTE incidence with E4-DRSP, the EE COC may be obsolete in the near future. ■

REFERENCES

- Gemzell-Danielsson K, Cagnacci A, Chabbert-Buffet N, et al. A novel estetrol-containing combined oral contraceptive: European expert panel review. *Eur J Contracept Reprod Health Care* 2022;27:373–83.
- Jensen JT, Speroff L. Health benefits of oral contraceptives. *Obstet Gynecol Clin North Am* 2000;27:705–21.
- Schindler AE. Non-contraceptive benefits of oral hormonal contraceptives. *Int J Endocrinol Metab* 2013;11:41–7.
- Kaunitz AM. Noncontraceptive health benefits of oral contraceptives. *Rev Endocr Metab Disord* 2002;3:277–83.
- Krattenmacher R. Drospirenone: pharmacology and pharmacokinetics of a unique progestogen. *Contraception* 2000;62:29–38.
- Muhn P, Fuhrmann U, Fritzscheier KH, Krattenmacher R, Schillinger E. Drospirenone: a novel progestogen with antiminerocorticoid and antiandrogenic activity. *Ann N Y Acad Sci* 1995;761:311–35.
- Oelkers W. Antiminerocorticoid activity of a novel oral contraceptive containing drospirenone, a unique progestogen resembling natural progesterone. *Eur J Contracept Reprod Health Care* 2002;7(Suppl3):19–26.
- Oelkers W. Drospirenone, a progestogen with antiminerocorticoid properties: a short review. *Mol Cell Endocrinol* 2004;217:255–61.
- Sitruk-Ware R. Pharmacology of different progestogens: the special case of drospirenone. *Climacteric* 2005;8(Suppl3):4–12.
- Foidart JM, Faustmann T. Advances in hormone replacement therapy: weight benefits of drospirenone, a 17 α -spiro-lactone-derived progestogen. *Gynecol Endocrinol* 2007;23:692–9.
- Palacios S, Regidor PA, Colli E, et al. Oestrogen-free oral contraception with a 4 mg drospirenone-only pill: new data and a review of the literature. *Eur J Contracept Reprod Health Care* 2020;25:221–7.
- Archer DF, Ahrendt HJ, Drouin D. Drospirenone-only oral contraceptive: results from a multicenter noncomparative trial of efficacy, safety and tolerability. *Contraception* 2015;92:439–44.
- Palacios S, Colli E, Regidor PA. Multicenter, phase III trials on the contraceptive efficacy, tolerability and safety of a new drospirenone-

only pill. *Acta Obstet Gynecol Scand* 2019;98:1549–57.

14. Oelkers W, Foidart JM, Dombrovicz N, Welter A, Heithecker R. Effects of a new oral contraceptive containing an antimineralocorticoid progestogen, drospirenone, on the renin-aldosterone system, body weight, blood pressure, glucose tolerance, and lipid metabolism. *J Clin Endocrinol Metab* 1995;80:1816–21.

15. Foidart JM, Wuttke W, Bouw GM, Gerlinger C, Heithecker R. A comparative investigation of contraceptive reliability, cycle control and tolerance of two monophasic oral contraceptives containing either drospirenone or desogestrel. *Eur J Contracept Reprod Health Care* 2000;5:124–34.

16. Kubba A, Gemzell-Danielsson K, Palacios S, et al. The drospirenone (DRSP)-only pill: clinical implications in the daily use. *Eur J Contracept Reprod Health Care* 2023;28:36–43.

17. Bäckström T, Andreen L, Birzniece V, et al. The role of hormones and hormonal treatments in premenstrual syndrome. *CNS Drugs* 2003;17:325–42.

18. Rapkin AJ, Sorger SN, Winer SA. Drospirenone/ethinyl estradiol. *Drugs Today (Barc)* 2008;44:133–45.

19. Apter D, Zimmerman Y, Beekman L, et al. Estetrol combined with drospirenone: an oral contraceptive with high acceptability, user satisfaction, well-being and favourable body weight control. *Eur J Contracept Reprod Health Care* 2017;22:260–7.

20. Apter D, Zimmerman Y, Beekman L, et al. Bleeding pattern and cycle control with estetrol-containing combined oral contraceptives: results from a phase II, randomised, dose-finding study (FIESTA). *Contraception* 2016;94:366–73.

21. Hagen AA, Barr M, Diczfalussy E. Metabolism of 17-beta-oestradiol-4-14-C in early infancy. *Acta Endocrinol (Copenh)* 1965;49:207–20.

22. Warmerdam EG, Visser M, Coelingh Bennink HJ, Groen M. A new route of synthesis of estetrol. *Climacteric* 2008;11(Suppl1):59–63.

23. Fruzzetti F, Fidicicchi T, Montt Guevara MM, Simoncini T. Estetrol: a new choice for contraception. *J Clin Med* 2021;10:5625.

24. Gérard C, Arnal JF, Jost M, et al. Profile of estetrol, a promising native estrogen for oral contraception and the relief of climacteric symptoms of menopause. *Expert Rev Clin Pharmacol* 2022;15:121–37.

25. Gérard C, Foidart JM. Estetrol: from pre-clinical to Clinical Pharmacology and advances in the understanding of the molecular mechanism of action. *Drugs R D* 2023;23:77–92.

26. NEXTSTELLIS (drospirenone and estetrol). FDA label, Mayne Pharma. Available at: https://www.accessdata.fda.gov/drugsatfda_docs/label/2021/214154s000lbl.pdf. Accessed November 22, 2022.

27. Drovelis assessment report EMA/212533/2021. European Medicines Agency. Available at: [https://www.ema.europa.eu/en/documents/assessment-report/drovelis-epar-](https://www.ema.europa.eu/en/documents/assessment-report/drovelis-epar-public-assessment-report_en.pdf)

[public-assessment-report_en.pdf](https://www.ema.europa.eu/en/documents/assessment-report_en.pdf). Accessed January 31, 2023.

28. YAZ (drospirenone/ethinyl estradiol). FDA label, Bayer Healthcare Pharmaceuticals Inc. Available at: https://www.accessdata.fda.gov/drugsatfda_docs/label/2012/021676s012lbl.pdf. Accessed November 30, 2022.

29. Stanczyk FZ, Archer DF, Bhavnani BR. Ethinyl estradiol and 17beta-estradiol in combined oral contraceptives: pharmacokinetics, pharmacodynamics and risk assessment. *Contraception* 2013;87:706–27.

30. Hümpel M, Täuber U, Kuhn W, et al. Protein binding of active ingredients and comparison of serum ethinyl estradiol, sex hormone-binding globulin, corticosteroid-binding globulin, and cortisol levels in women using a combination of gestodene/ethinyl estradiol (Femovan) or a combination of desogestrel/ethinyl estradiol (Marvelon) and single-dose ethinyl estradiol bioequivalence from both oral contraceptives. *Am J Obstet Gynecol* 1990;163:329–33.

31. Zoely (estradiol /norgestrel acetate). SmPC, Theramex Ireland Ltd. 2021. Available at: https://www.ema.europa.eu/en/documents/product-information/zoely-epar-product-information_en.pdf. Accessed November 22, 2022.

32. Coelingh Bennink HJ, Holinka CF, Diczfalussy E. Estetrol review: profile and potential clinical applications. *Climacteric* 2008;11(Suppl1):47–58.

33. Pugeat MM, Dunn JF, Nisula BC. Transport of steroid hormones: interaction of 70 drugs with testosterone-binding globulin and corticosteroid-binding globulin in human plasma. *J Clin Endocrinol Metab* 1981;53:69–75.

34. Hodgert Jury H, Zacharewski TR, Hammond GL. Interactions between human plasma sex hormone-binding globulin and xenobiotic ligands. *J Steroid Biochem Mol Biol* 2000;75:167–76.

35. Hammond GL, Hogeveen KN, Visser M, Coelingh Bennink HJ. Estetrol does not bind sex hormone binding globulin or increase its production by human HepG2 cells. *Climacteric* 2008;11(Suppl1):41–6.

36. Santen RJ, Yue W, Wang JP. Estrogen metabolites and breast cancer. *Steroids* 2015;99:61–6.

37. Yager JD. Mechanisms of estrogen carcinogenesis: the role of E2/E1-quinone metabolites suggests new approaches to preventive intervention—a review. *Steroids* 2015;99:56–60.

38. Douxfils J, Klipping C, Duijkers I, et al. Evaluation of the effect of a new oral contraceptive containing estetrol and drospirenone on hemostasis parameters. *Contraception* 2020;102:396–402.

39. Morimont L, Jost M, Gaspard U, Foidart JM, Dogné JM, Douxfils J. Low thrombin generation in users of a contraceptive containing

estetrol and drospirenone. *J Clin Endocrinol Metab* 2022;108:135–43.

40. Chiara Del Savio M, De Fata R, Facchinetti F, Grandi G. Drospirenone 4 mg-only pill (DOP) in 24+4 regimen: a new option for oral contraception. *Expert Rev Clin Pharmacol* 2020;13:685–94.

41. Richter WH, Koytchev R, Kirkov V, Merki G, Colli E, Regidor PA. Comparative pharmacokinetic estimates of drospirenone alone and in combination with ethinyl estradiol after single and repeated oral administration in healthy females. *Contraception* 2020;101:137–43.

42. SLYND (drospirenone). FDA label, Exeltis USA Inc. 2019. Available at: https://www.accessdata.fda.gov/drugsatfda_docs/label/2019/211367s000lbl.pdf. Accessed November 22, 2022.

43. Russell J, Portman D. The creeping Pearl: why has the rate of contraceptive failure increased in clinical trials of combined hormonal contraceptive pills? *Contraception* 2013;88:604–10.

44. Slinda 4 mg film coated tablets. Exeltis Healthcare S.L. 2022. Available at: https://docetp.mpa.se/LMF/Slinda%20film-coated%20tablet%20ENG%20SmPC_09001bee807a7be0.pdf. Accessed November 22, 2022.

45. Creinin MD, Westhoff CL, Bouchard C, et al. Estetrol-drospirenone combination oral contraceptive: North American phase 3 efficacy and safety results. *Contraception* 2021;104:222–8.

46. Gemzell-Danielsson K, Apter D, Zatik J, et al. Estetrol-drospirenone combination oral contraceptive: a clinical study of contraceptive efficacy, bleeding pattern and safety in Europe and Russia. *BJOG* 2022;129:63–71.

47. Kimble T, Burke AE, Barnhart KT, Archer DF, Colli E, Westhoff CL. A 1-year prospective, open-label, single-arm, multicenter, phase 3 trial of the contraceptive efficacy and safety of the oral progestin-only pill drospirenone 4 mg using a 24/4-day regimen. *Contracept X* 2020;2:100020.

48. Bachmann G, Sulak PJ, Sampson-Landers C, Benda N, Marr J. Efficacy and safety of a low-dose 24-day combined oral contraceptive containing 20 micrograms ethinylestradiol and 3 mg drospirenone. *Contraception* 2004;70:191–8.

49. Hernádi L, Marr J, Trummer D, De Leo V, Petraglia F. Efficacy and safety of a low-dose combined oral contraceptive containing drospirenone 3 mg and ethinylestradiol 20 mcg in a 24/4-day regimen. *Contraception* 2009;80:18–24.

50. Archer DF, Mansour D, Foidart JM. Bleeding patterns of oral contraceptives with a cyclic dosing regimen: an overview. *J Clin Med* 2022;11:4634.

51. NDA/BLA Multi-disciplinary review and evaluation. Food and Drug Administration. 2019. Available at: <https://www.fda.gov/media/>

129539/download. Accessed October 14, 2022.

52. Medical review Yaz (NDA 21–676). Food and Drug Administration. 2006. Available at: https://www.accessdata.fda.gov/drugsatfda_docs/nda/2006/021676s000_MEDR_pt1.pdf. Accessed May 25, 2022.

53. Palacios S, Colli E, Regidor PA. Efficacy and cardiovascular safety of the new estrogen-free contraceptive pill containing 4 mg drospirenone alone in a 24/4 regime. *BMC Womens Health* 2020;20:218.

54. Palacios S, Colli E, Regidor PA. Metabolic and laboratory effects of a progestin-only pill containing drospirenone 4 mg in comparison to desogestrel 75 µg: a double-blind, double-dummy, prospective, randomised study. *Eur J Contracept Reprod Health Care* 2021;26:454–61.

55. Klipping C, Duijkers I, Mawet M, et al. Endocrine and metabolic effects of an oral contraceptive containing estetrol and drospirenone. *Contraception* 2021;103:213–21.

56. Chen MJ, Jensen JT, Kaunitz AM, et al. Tolerability and safety of the estetrol/drospirenone combined oral contraceptive: pooled analysis of two multicenter, open-label phase 3 trials. *Contraception* 2022;116:44–50.

57. Lidegaard Ø, Løkkegaard E, Jensen A, Skovlund CW, Keiding N. Thrombotic stroke and myocardial infarction with hormonal contraception. *N Engl J Med* 2012;366:2257–66.

58. Mawet M, Maillard C, Klipping C, Zimmerman Y, Foidart JM, Coelingh Bennink HJ. Unique effects on hepatic function, lipid metabolism, bone and growth endocrine parameters of estetrol in combined oral contraceptives. *Eur J Contracept Reprod Health Care* 2015;20:463–75.

59. Gargano V, Massaro M, Morra I, Formisano C, Di Carlo C, Nappi C. Effects of two low-dose combined oral contraceptives containing drospirenone on bone turnover and bone mineral density in young fertile women: a prospective controlled randomized study. *Contraception* 2008;78:10–5.

60. Palacios S, Colli E, Regidor PA. Bleeding profile of women using a drospirenone-only pill 4 mg over nine cycles in comparison with desogestrel 0.075 mg. *PLoS One* 2020;15:e0231856.

61. Regidor PA, Colli E, Palacios S. Overall and bleeding-related discontinuation rates of a new oral contraceptive containing 4 mg drospirenone only in a 24/4 regimen and comparison to 0.075 mg desogestrel. *Gynecol Endocrinol* 2021;37:1121–7.

62. Jensen JT, Kaunitz AM, Achilles SL, et al. Pooled efficacy results of estetrol/drospirenone combined oral contraception phase 3 trials. *Contraception* 2022;116:37–43.

63. Creinin MD, Jensen JT, Chen MJ, Black A, Costescu D, Foidart JM. Combined oral contraceptive adherence and pregnancy rates. *Obstet Gynecol* 2023;141:989–94.

64. Kaunitz AM, Achilles SL, Zatik J, et al. Pooled analysis of two phase 3 trials evaluating the effects of a novel combined oral contraceptive containing estetrol/drospirenone on bleeding patterns in healthy women. *Contraception* 2022;116:29–36.

65. Lidegaard O, Nielsen LH, Skovlund CW, Løkkegaard E. Venous thrombosis in users of non-oral hormonal contraception: follow-up study, Denmark 2001–10. *BMJ* 2012;344:e2990.

66. Morimont L, Dogné JM, Douxfils J. Letter to the Editors-in-Chief in response to the article of Abou-Ismaïl, et al. entitled “Estrogen and thrombosis: a bench to bedside review” (*Thrombosis Research* 192 (2020) 40–51). *Thromb Res* 2020;193:221–3.

67. Coelingh Bennink HJ, Skouby S, Bouchard P, Holinka CF. Ovulation inhibition by estetrol in an in vivo model. *Contraception* 2008;77:186–90.

68. Douxfils J, Gaspard U, Taziaux M, et al. Impact of estetrol (E4) on hemostasis, metabolism and bone turnover in postmenopausal women. *Climacteric* 2023;26:55–63.

69. Baird DT, Glasier AF. Hormonal contraception. *N Engl J Med* 1993;328:1543–9.

70. Endrikat J, Gerlinger C, Richard S, Rosenbaum P, Düsterberg B. Ovulation inhibition doses of progestins: a systematic review of the available literature and of marketed preparations worldwide. *Contraception* 2011;84:549–57.

71. Dinh A, Sriprasert I, Williams AR, Archer DF. A review of the endometrial histologic effects of progestins and progesterone receptor modulators in reproductive age women. *Contraception* 2015;91:360–7.

72. Smith OP, Critchley HO. Progestogen only contraception and endometrial break through bleeding. *Angiogenesis* 2005;8:117–26.

73. Grossman Barr N. Managing adverse effects of hormonal contraceptives. *Am Fam Physician* 2010;82:1499–506.

74. Cooper DB, Patel P, Mahdy H. Oral contraceptive pills. Treasure Island, FL: StatPearls Publishing; 2023.

75. Moore GW, Castoldi E, Teruya J, Morishita E, Adcock DM. Factor V Leiden-independent activated protein C resistance: communication from the plasma coagulation inhibitors subcommittee of the International Society on Thrombosis and Haemostasis Scientific and Standardisation Committee. *J Thromb Haemost* 2023;21:164–74.

76. Regidor PA, Colli E, Schindler AE. Drospirenone as estrogen-free pill and hemostasis: coagulatory study results comparing a novel 4 mg formulation in a 24 + 4 cycle with desogestrel 75 µg per day. *Gynecol Endocrinol* 2016;32:749–51.

77. Douxfils J, Morimont L, Delvigne AS, et al. Validation and standardization of the ETP-based activated protein C resistance test for the clinical investigation of steroid contraceptives in women:

an unmet clinical and regulatory need. *Clin Chem Lab Med* 2020;58:294–305.

78. Kluff C, Zimmerman Y, Mawet M, et al. Reduced hemostatic effects with drospirenone-based oral contraceptives containing estetrol vs. ethinyl estradiol. *Contraception* 2017;95:140–7.

79. Morimont L, Creinin MD, Gaspard U, Foidart JM, Douxfils J. Hormonal therapies and venous thrombosis: estrogen matters! *Res Pract. Thromb Haemost* 2023;7:100021.

80. Lidegaard Ø, Milsom I, Geirsson RT, Skjeldstad FE. Hormonal contraception and venous thromboembolism. *Acta Obstet Gynecol Scand* 2012;91:769–78.

81. Practice Committee of the American Society for Reproductive Medicine. Combined hormonal contraception and the risk of venous thromboembolism: a guideline. *Fertil Steril* 2017;107:43–51.

82. Archer DF, Nakajima ST, Sawyer AT, et al. Norethindrone acetate 1.0 milligram and ethinyl estradiol 10 micrograms as an ultra low-dose oral contraceptive. *Obstet Gynecol* 2013;122:601–7.

83. Gemzell-Danielsson K, Sitruk-Ware R, Creinin MD, et al. Segesterone acetate/ethinyl estradiol 12-month contraceptive vaginal system safety evaluation. *Contraception* 2019;99:323–8.

84. Nelson AL, Kaunitz AM, Kroll R, et al. Efficacy, safety, and tolerability of a levonorgestrel/ethinyl estradiol transdermal delivery system: Phase 3 clinical trial results. *Contraception* 2021;103:137–43.

85. Gaspard U, Scheen A, Endrikat J, et al. A randomized study over 13 cycles to assess the influence of oral contraceptives containing ethinylestradiol combined with drospirenone or desogestrel on carbohydrate metabolism. *Contraception* 2003;67:423–9.

86. Sitruk-Ware R, Nath A. Characteristics and metabolic effects of estrogen and progestins contained in oral contraceptive pills. *Best Pract Res Clin Endocrinol Metab* 2013;27:13–24.

87. FSRH Clinical Guideline: Combined Hormonal Contraception (January 2019, Amended July 2023). FSRH Clinical Effectiveness Unit. 2023. Available at: <https://www.fsrh.org/standards-and-guidance/documents/combined-hormonal-contraception/>.

88. Bagot CN, Marsh MS, Whitehead M, et al. The effect of estrone on thrombin generation may explain the different thrombotic risk between oral and transdermal hormone replacement therapy. *J Thromb Haemost* 2010;8:1736–44.

89. Canonico M, Bouaziz E, Carcaillon L, et al. Synergism between oral estrogen therapy and cytochrome P450 3A5*1 allele on the risk of venous thromboembolism among postmenopausal women. *J Clin Endocrinol Metab* 2008;93:3082–7.

90. Hadji P, Colli E, Regidor PA. Bone health in estrogen-free contraception. *Osteoporos Int* 2019;30:2391–400.

91. Cameron A. The metabolic syndrome: validity and utility of clinical definitions for cardiovascular disease and diabetes risk prediction. *Maturitas* 2010;65:117–21.

92. Wilson PW, D'Agostino RB, Parise H, Sullivan L, Meigs JB. Metabolic syndrome as a precursor of cardiovascular disease and type 2 diabetes mellitus. *Circulation* 2005;112:3066–72.

93. Adeyanju OA, Olatunji LA. Drospirenone-containing oral contraceptives do not affect glucose regulation and circulating corticosterone. *J Basic Clin Physiol Pharmacol* 2019;30.