The American College of Obstetricians and Gynecologists
WOMEN'S HEALTH CARE PHYSICIANS

Exposure to Toxic Environmental Agents

The American College of Obstetricians and Gynecologists Committee on Health Care for Underserved Women
American Society for Reproductive Medicine Practice Committee
The University of California, San Francisco Program on Reproductive Health and the Environment

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Reducing exposure to toxic environmental agents is a critical area of intervention for obstetricians, gynecologists, and other reproductive health care professionals. Patient exposure to toxic environmental chemicals and other stressors is ubiquitous, and preconception and prenatal exposure to toxic environmental agents can have a profound and lasting effect on reproductive health across the life course. Although exposure to toxic environmental chemicals is universal, harmful environmental exposure is inequitably and unequally distributed, which leaves some populations, including underserved women, more vulnerable to adverse reproductive health effects than other populations. Because individuals alone can do little about exposure to toxic environmental agents, the authoritative voice of health care professionals in policy arenas is critical to translating emerging scientific findings into prevention-oriented action on a large scale. The evidence that links exposure to toxic environmental agents and adverse reproductive and developmental health outcomes is sufficiently robust, and the American College of Obstetricians and Gynecologists (the College) and the American Society for Reproductive Medicine (ASRM) join leading scientists and other clinical practitioners in calling for timely action to identify and reduce exposure to toxic environmental agents while addressing the consequences of such exposure.

Reproductive Environmental Health

Robust scientific evidence has emerged over the past 15 years, demonstrating that preconception and prenatal exposure to toxic environmental agents can have a profound and lasting effect on reproductive health across the life course (1–9). Exposure to toxic environmental agents also is implicated in increases in adverse reproductive health outcomes that emerged since World War II; these changes have occurred at a relatively rapid rate that cannot be explained by changes in genetics alone, which occur at a slower pace. Current evidence is not sufficient to explain cause and effect, but it can illustrate health outcome patterns over time as outlined in Table 1.

The environmental drivers of reproductive health are many and varied. Of critical concern for reproductive health professionals is the ubiquitous patient exposure to manufactured chemicals and metals. In the past 70 years, the manufacture and use of industrial chemicals has increased more than 15-fold (10). Currently, in the United States, approximately 700 new chemicals are introduced into commerce each year, and more than 84,000 chemical substances are listed by the U.S. Environmental Protection Agency (EPA) for manufacturing, processing, or importing (11–12); overall, approximately 3,000 of these chemicals are used or imported in high volumes (greater than 1 million pounds) (11). Because of deficiencies in the current regulatory structure, unlike pharmaceuticals, most environmental chemicals in commerce have entered the marketplace without comprehensive and standardized research into their reproductive or other long-term toxic effects (13, 14).

Environmental chemicals are pervasive in all aspects of patients' lives, including those found in the air, water, soil, food, and consumer products. As a result, among pregnant women, daily exposure to various toxic chemicals is now the norm. An analysis of National Health and Nutrition Examination Survey data from 2003 to 2004 found that virtually every pregnant woman in the United States was exposed to at least 43 different chemicals (15).

Chemicals in pregnant women can cross the placenta, and in some cases, such as with methyl mercury, can accumulate in the fetus, resulting in higher fetal exposure than maternal exposure (16–18). The 2008–2009 National Cancer Institute's President's Cancer Panel report observed that "to a disturbing extent babies are born 'pre-polluted'" (3). Prenatal exposure to certain environmental chemicals is linked to various health consequences that can manifest across the lifetime of individuals and potentially be transmitted to the next generation (4). Table 2 presents examples of prenatal exposure to environmental contaminants that are associated with reproductive and developmental health outcomes that manifest at birth or are delayed until childhood or adulthood.

Table 1. Adverse Trends in Health in the United States ⇦

Outcome	Time frame	Trend
	Increase	
Impaired fecundity[1, 2]	1982–2002	Increase from 8.4% to 11.8% in women aged 15–44 years
Preterm birth[3]	1981–2010	Increase from 94.4 per 1,000 births to 119.9 per 1,000 births
Low birth weight[3]	1981–2010	Increase from 68.1 per 1,000 births to 81.5 per 1,000 births
Small for gestational age infant[4]	1990–2005	Increase from 72 per 1,000 births to 81 per 1,000 births
Gastroschisis[5]	1987–2003	3.2-fold increase in California
Cryptorchidism[6]	1970–1993	Increase from 19 per 10,000 births to 41 per 10,000 births
Hypospadias[6]	1970–1993	Increase from 20 per 10,000 births to 37 per 10,000
Autism[7]	2002–2008	Increase in prevalence from 6.4 per 1,000 to 11.4 per 1,000
Childhood cancer[8]	1975–2007	Increase from 129 to 167 cases per million children
Obesity[9]	1960–2010	Increase from 15.8% to 36.1% in women aged 20–74 years
	Decrease	
Life expectancy	1990–2008[10]	Decreased by 5 years for white women with less than high school education
	2000–2007[11]	Life expectancy of women in 91% of U.S. counties decreased in standing against the international life expectancy standard
Puberty (onset of menarche)[12]	1970–1994	Decrease of 2.5–4 months
Puberty (breast development)[12]	1948–1994	Decrease in mean age of breast development

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Table 2. Examples of Reproductive Health Effects of Prenatal Exposure to Environmental Contaminants ⇦

Chemicals	Exposure Sources and Pathways	Reproductive or Developmental Health Effects
Pesticides	Pesticides are applied in large quantities in agricultural, community, and household settings. In 2001, more than 1.2 billion pounds of active ingredients were used in the United States. Pesticides can be ingested, inhaled, and absorbed by the skin. The pathways of pesticide exposure include food, water, air, dust, and soil.	Impaired cognitive development[1, 2] Impaired neurodevelopment[3, 4] Impaired fetal growth[5] Increased susceptibility to testicular cancer[6] Childhood cancer[7–9]
Solvents	Examples include benzene, toluene, xylene, styrene, 1-bromopropane, 2-bromopropane, perchloroethylene, and trichloroethylene. Solvents include some of the highest production volume chemicals in the United States. They are used in plastics, resins, nylon, synthetic fibers, rubber, lubricants, dyes, detergents, drugs, pesticides, glues, paints, paint thinners, fingernail polish, lacquers, detergents, printing and leather tanning processes, insulation, fiberglass, food containers, carpet backing, and cleaning products. Solvents are a component of cigarette smoke. Exposure is primarily through breathing contaminated air.	Fetal loss[10–13] Miscarriage[11]
Toluene	Exposure occurs from breathing contaminated air at the workplace, in automobile exhaust, some consumer products, paints, paint thinners, fingernail polish, lacquers, and adhesives.	Decreased fetal and birth weight[14] Congenital malformations[15, 16]
Phthalates	Phthalates are synthetically derived. They are used in a variety of consumer goods, such as medical devices, cleaning and building materials, personal care products, cosmetics, pharmaceuticals, food processing, and toys. Exposure occurs through ingestion, inhalation, and dermal absorption.	Reduced masculine play in boys[17] Reduced anogenital distance[18] Shortened gestational age[19] Impaired neurodevelopment in girls[20]
Lead	Occupational exposure occurs in battery manufacturing and recycling, smelting, car repair, welding, soldering, firearm cleaning and shooting, and stained glass ornament and jewelry production. Nonoccupational exposure occurs in older homes where lead-based paints were used, water pipes, imported ceramics and pottery, herbal remedies, traditional cosmetics, hair dyes, contaminated soil, toys, and costume jewelry.	Alterations in genomic methylation[21] Intellectual impairment[22] Increased likelihood of allergies[23]
Mercury	Mercury from coal-fired power plants is the largest man-made source of mercury pollution in the United States. Primary human exposure is by consumption of contaminated seafood.	Reduced cognitive performance[24, 25] Impaired neurodevelopment[26, 27]
Polychlorinated biphenyls	Polychlorinated biphenyls were used as industrial insulators and lubricants. They were banned in the 1970s but are persistent in the aquatic and terrestrial food chains, resulting in exposure by ingestion.	Development of attention deficit and hyperactivity disorder-associated behavior[28] Increased body mass index[29] Reduced IQ[30]
Air pollutants	Common air pollutants include carbon monoxide, lead, ground-level ozone, particulate matter, nitrogen dioxide, and sulfur dioxide. Air pollution arises from a variety of sources, including motor vehicles, industrial production, energy (coal) production, wood burning, and small local sources, such as dry cleaners.	Low birth weight[31] Birth defects[32]
Cigarette smoke	Cigarette smoke exposure includes active smoking, passive smoking, or both.	Miscarriage[33] Intrauterine growth restriction, low birth weight, and preterm delivery[34] Decreased semen quality[35]

(continued)

Table 2. Examples of Reproductive Health Effects of Prenatal Exposure to Environmental Contaminants *(continued)*

Chemicals	Exposure Sources and Pathways	Reproductive or Developmental Health Effects
Perchlorate	Perchlorate is used to produce rocket fuel, fireworks, flares, and explosives and also can be present in bleach and some fertilizers. Sources of exposure are contaminated drinking water, food, and other nonwater beverages. Infants also may be exposed through breast milk.	Altered thyroid function[36]
Perfluorochemicals	Perfluorochemicals are widely used man-made organofluorine compounds with many diverse industrial and consumer product applications. Examples are perfluorooctane sulfonate and perfluorooctanate, which are used in cookware products with nonstick surfaces and in packaging to provide grease, oil, and water resistance to plates, food containers, bags, and wraps that come into contact with food. They persist in the environment. Occupational exposure and general population exposure occurs by inhalation, ingestion, and dermal contact.	Reduced birth weight[37]
Polybrominated diphenyl ethers	These include flame retardant materials that persist and bioaccumulate in the environment. They are found in furniture, textiles, carpeting, electronics, and plastics that are mixed into but not bound to foam or plastic.	Impaired neurodevelopment[38] Premature delivery, low birth weight, and stillbirth[39]
Bisphenol A	Bisphenol A is a chemical intermediate for polycarbonate plastic and resins. It is found in food, consumer products, and packaging. Exposure occurs through inhalation, ingestion, and dermal absorption.	Recurrent miscarriage[40] Aggression and hyperactivity in female children[41]
Formaldehyde	Formaldehyde is used in the production of wood adhesives, abrasive materials, and other industrial products and in clinical laboratories and embalming. It is found in some germicides, fungicides, insecticides, and personal care products. Routes of exposure are oral, dermal, and inhaled.	Spontaneous abortion[42] Low birth weight[43]
Antineoplastic drugs	This class of chemotherapy drugs presents an occupational exposure for nurses and other health care professionals.	Spontaneous abortion[44] Low birth weight[45]
Anesthetic gases	Anesthetic gases are administered by inhalation in health care settings and veterinary care. Occupational exposure is a risk for nurses, physicians, dentists, veterinarians and, other health care professionals who work in settings where anesthetic gases are used.	Congenital anomalies[46] Spontaneous abortion[47]
Ethylene oxide	Ethylene oxide is used to sterilize heat-sensitive medical items, surgical instruments, and other objects that come into contact with biologic tissues. Occupational exposure is a risk in some health care settings, particularly sterilization units. Exposure is through inhalation.	Spontaneous abortion and pregnancy loss[48] Preterm and postterm birth[49]

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Postnatal maternal exposure to environmental chemicals may continue to expose a newborn through breastfeeding (1, 19–21). Exposure to environmental chemicals during pregnancy is superimposed on the familiar environmental drivers of reproductive health, ie, the social, built (encompasses a range of physical and social characteristics that make up the structure of a community), and nutritional environment (22–25). As illustrated in Figure 1, each of these extrinsic factors interacts with the others and with intrinsic biologic factors, such as age, sex, and genes, to influence individual and population health outcomes (26, 27).

Vulnerable Populations and Environmental Disparities

Although harmful exposure to toxic environmental agents is ubiquitous among all patient populations, many environmental factors harmful to reproductive health disproportionately affect vulnerable and underserved populations and are subsumed in issues of environmental justice. For example, the complex interactions of race, place, and the environment can result in exposure to an increased variety and concentrations of toxic environmental chemicals (24, 28, 29). In the United States, minority populations are likely to live in the counties with the highest levels of outdoor air pollution (28) and to be exposed to a variety of indoor pollutants, including lead, allergens, and pesticides (30). In turn, the effects of exposure to environmental chemicals can be exacerbated by injustice, poverty, neighborhood quality, housing quality, psychosocial stress, and nutritional status (24, 30–43). Importantly, environmental influences, such as good social support networks, access to services, stable income, and good nutrition, can serve as a buffer to stressful influences on health (23, 41–43). For example, resilient individuals and populations, although subject to harm, have community capacity and empowerment, political participation, and many other advantages that can help them to overcome the effects of adverse environmental exposure (44).

Women of reproductive age with occupational exposure to toxic chemicals also are highly vulnerable to adverse reproductive health outcomes (45). For example, levels of organophosphate pesticides and phthalates measured in occupationally exposed populations are far greater than levels measured in the general population (46, 47). Occupational exposure to chemicals of concern for reproductive health includes organic solvents, which are associated with intrauterine growth restriction, small for gestational age infants, and risk of major congenital malformations (48, 49). Other types of work-related chemical exposure of concern for reproductive health include metals, formaldehyde, ethylene oxide, anesthetic gases, antineoplastic drugs, and pesticides (Table 2). Furthermore, low-wage immigrant populations disproportionately work in occupations associated with a hazardous workplace environment (50, 51).

Marginalized groups, often the poor, women, and minorities, are also hit hardest by natural or man-made environmental disasters (52). For example, during

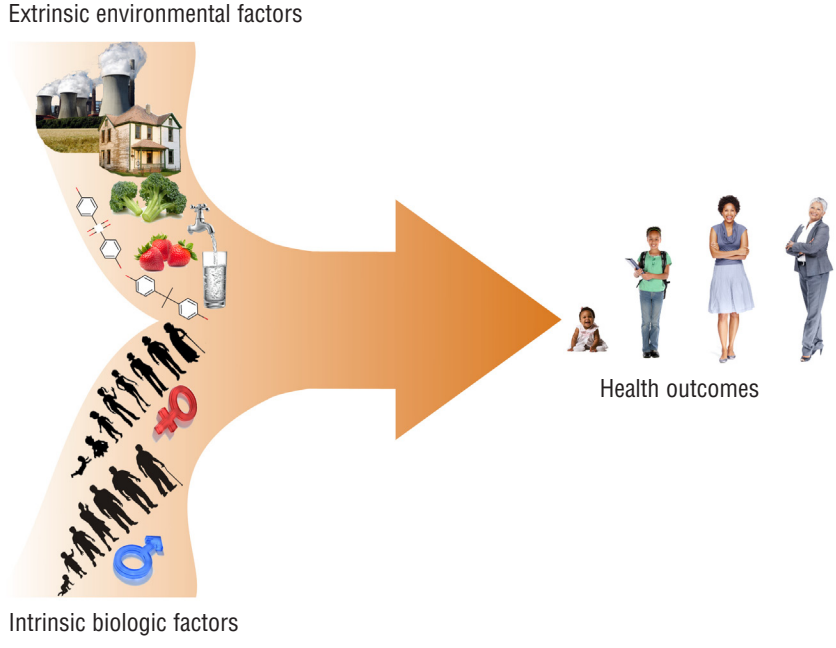

Fig. 1. Environmental Influences on Reproductive and Developmental Health. (University of California, San Francisco Program on Reproductive Health and the Environment.) ⇦

Hurricane Katrina, poor and minority communities were disproportionately unable to evacuate New Orleans and avoid the associated environmental disaster in the wake of the storm (53). Furthermore, great disparities exist in where the effects of climate change will occur (54), with the largest burden likely to befall low-income and minority populations (55). For example, such vulnerable populations are more likely than others to bear the adverse effects of extreme heat events, infectious diseases, and air pollution associated with climate change (55).

Geographic differences also affect the distribution of exposure to toxic environmental agents. For example, California's state policy requirements related to the use of flame retardants in consumer goods underlie why pregnant women in California overall, and the state's low-income communities of color in particular, have some of the world's highest levels of thyroid-disrupting flame retardants in their homes and bodies (56–59). Similarly, disparities in exposure to toxic pesticides among pregnant women in California are attributable to differences in regional agricultural pesticide use (60).

Our industrialized food system also contributes to environmental health disparities. Current practices that underlie how food is produced and distributed involve various and inequitably distributed threats to reproductive and developmental health, including exposure to pesticides; chemical fertilizers; hormones in beef cattle; antimicrobials in beef cattle, swine, and poultry; fossil fuel consumption and climate change; toxic chemicals in food packaging and cookware; and the production and promotion of food that is unhealthy for pregnant women (61). Our industrialized food system produces an abundance of food that is relatively low in cost, high in calories, and low in nutritional value and that is readily available, easy to prepare, and highly marketed (62–64). Healthier food products are more difficult to obtain, can be less convenient, and are frequently more expensive to purchase (65). Policies and practices to advance the availability of healthy food for all can make a difference to patient health. Also these practices and policies can widely influence the food system by sending a signal to the market. This was demonstrated by the burgeoning market in organic food (66), the explosion of the market for alternatives to bisphenol A (BPA) in food contact items, such as baby bottles (67), and in Walmart's banning of a flame retardant found in hundreds of consumer goods from its supply chain (68).

The environment is a critical contributor to reproductive health for all patients, and vulnerable and underserved populations are at high risk of harm. As underscored by a groundbreaking 2009 report by the National Academy of Sciences, the effects of a low-dose exposure to an environmental contaminant may be quite different based on vulnerabilities, such as the underlying health status of the population and the presence of additional or "background" environmental exposure (69). Recognition of environmental disparities is an essential part of developing and implementing successful and efficient strategies for the prevention of exposure to environmental toxic agents and the negative health effects for all.

Critical and Sensitive Windows of Development

Timing of Exposure

Patient exposure to toxic environmental contaminants at any point in time can lead to harmful reproductive health outcomes (25). For example, prenatal exposure to certain pesticides has been documented to increase the risk of cancer in childhood; adult male exposure to pesticides is linked to altered semen quality, sterility, and prostate cancer; and postnatal exposure to some pesticides can interfere with all developmental stages of reproductive function in females, including puberty, menstruation and ovulation, fertility and fecundity, and menopause (70).

However, the human reproductive system is especially vulnerable to environmental chemicals when the exposure occurs during "critical" or "sensitive" windows of development (1, 2, 4, 8, 25, 71–74). Even small amounts of chemical exposure during windows of vulnerability can lead to adverse birth outcomes and increased risks of disease and disability across the entire span of human life (2, 4, 72, 75–79).

A critical window of development is a limited period when exposure to environmental contaminants can disrupt or interfere with the physiology of a cell, tissue, or organ (2); exposure that occurs during this time can lead to permanent and lifelong health effects that may be passed down to future generations. In contrast, during a sensitive window of susceptibility, exposure may still affect development or eventually result in adult disease, but with reduced magnitude compared with the effect of exposure during critical periods (80). A timeline that shows when low-dose developmental exposure to select chemicals in animal models results in altered health outcomes can be found at http://www.criticalwindows.com/go_display.php.

The human reproductive system is vulnerable during critical and sensitive windows in part because these are times of extensive developmental changes, such as cellular proliferation and rapidly changing or undeveloped metabolic, hormonal, and immunologic capabilities (81, 82). Given that development continues after birth, critical and sensitive windows are seen before and after conception, and during pregnancy, infancy, lactation, childhood, and puberty. For example, critical periods of central nervous system development extend from embryogenesis through adolescence, with periods of neuronal proliferation, migration, differentiation, and synaptogenesis especially sensitive to disruption and permanent damage (83). Because these processes are unidirectional, interference at an early stage may result in disruption throughout the further cascade of reactions and interactions that propagate human development (83).

The linkage between fetal and other types of developmental exposure to toxic environmental agents and

increased risk of disease later in life is known as "developmental programming," or "the developmental origins of adult health and disease." Scientific discoveries about developmental programming evolved independently in the fields of environmental health and nutrition (81). In the early 1970s, in utero exposure to diethylstilbestrol, a hormonally active drug prescribed to as many as 10 million pregnant women from 1938 to 1971, erroneously thought to prevent miscarriage, was found to be causally linked to postpubertal benign and malignant reproductive health abnormalities (81, 84–86). In the mid-1980s, reserachers identified strong relationships between maternal undernutrition, low birth weight, and adult risk of metabolic disease (73, 87). In the subsequent decades, these findings of delayed health effects from in utero environmental influences have been further substantiated and refined by a large body of experimental and epidemiologic data (9, 81, 88).

Mechanisms of Action

Important mechanisms related to environmental chemical exposure during critical and sensitive windows of development are mutagenesis and the interrelated mechanisms of epigenetics and hormone disruption. Mutagens affect DNA directly. For example, ionizing radiation-induced cancer results from complex forms of DNA damage (89). In contrast, epigenetic mechanisms modulate gene expression that is integral to orchestrating healthy human development without changing DNA sequences (26). Beckwith–Wiedemann syndrome, Prader–Willi syndrome, and Angelman syndrome are conditions that exemplify the role of epigenetic mechanisms in reproductive health outcomes (90–92). One review explains that for most of our genes, alleles inherited from each parent are equally expressed (91). In contrast, for a small fraction (less than 1%) of genes, alleles are imprinted, meaning that modification of one allele leads to a parent-of-origin specific expression. In such cases, the imprinted allele is repressed by epigenetic factors (DNA and histone methylation). In the case of Prader–Willi syndrome, the absence of normal paternal expression of genes on a section of chromosome 15 causes a total absence of expression because the maternal alleles are silenced by epigenetic factors (imprinted) (91).

Endocrine disrupting chemicals act by interfering with the synthesis, secretion, transport, binding, action, or elimination of natural hormones in the body that are responsible for the maintenance of homeostasis (normal cell metabolism), reproduction, development, or behavior (93). Hormonal regulation is critical to human reproduction; therefore, chemicals that disrupt the endocrine system may cause permanent effects (1, 71, 77, 94–98). Endocrine disrupting chemicals represent a heterogeneous group of agents used in pesticides, plastics, industrial chemicals, and fuel. For example, one study shows that the endocrine disrupting chemical BPA works similar to diethylstilbestrol at the cell and developmental level (79).

Endocrine disrupting chemicals have been implicated in a range of adverse health effects. For example, a 2013 comprehensive review of endocrine disrupting chemicals published by the World Health Organization identified three key concerns: 1) the increasing incidence in some regions of the world of endocrine-related diseases and disorders, ie, low semen quality, genital malformations, adverse pregnancy disorders, neurobehavioral disorders, endocrine-related cancer (breast, endometrial, ovarian, prostate, testicular, and thyroid), early breast development, obesity, and type 2 diabetes mellitus; 2) the existence of almost 800 known or suspected endocrine disrupting chemicals in commercial use, which is likely an underestimate because most chemicals in commerce have not been tested for endocrine disrupting effects; and 3) the high and increasing prevalence of human exposure to endocrine disrupting chemicals through food, water, air, and consumer products (99).

Evidence Available for Decision Making in Environmental Health Science

The type of scientific evidence available for clinical decision making differs in character from the evidence used in environmental health science. The standard practice for obtaining data on which clinical risk–benefit decisions about medical interventions are based is conducting a randomized controlled trial (RCT). However, in environmental health science, ethics virtually precludes the ability of RCTs to discover adverse effects of environmental chemicals on health, and comprehensive comparable weighing of health risks and benefits does not occur in the environmental arena (100) because chemicals are not designed to have a direct health benefit.

Therefore, clinicians must rely on animal and other nonhuman experimental data and human observational studies to shape patient recommendations and prevention strategies in environmental health science. In vitro animal studies of reproductive and developmental toxicity are recognized as reliable predictors of human health effects (101–104). Studies have established the concordance of developmental and reproductive effects between in vitro animal studies and human studies and concluded that humans are as sensitive or more sensitive than even the most sensitive animal species (103, 105).

Although human observational studies of environmental exposure to chemicals provide the most direct evidence of the relationship between chemical exposure and increased risk of adverse health outcomes, human evidence is not prevention oriented because it requires waiting for individuals to develop clearly identified diseases from well-characterized chemical exposure. Although an experimental animal carcinogenic study typically lasts 2 years, it can take 20 years to get a result from a comparable human study (106). Thus, sole reliance on epidemiologic studies squanders the option of preventing chemical exposure before such harm has occurred.

To bridge the gap between evidence streams in clinical and environmental health sciences, a methodology

called the Navigation Guide has been developed to evaluate the quality of evidence and strength of recommendations about the relationship between the environment and reproductive health in uniform, simple, and transparent summaries that integrate best practices of evaluation in environmental and clinical health sciences (107). Efforts are currently underway to establish the "proof of concept" of the Navigation Guide methodology.

The evidence of adverse health outcomes caused by environmental chemicals often cannot be identified on an individual level because exposure to individual chemicals at levels commonly experienced in the population have a relatively small effect, and disentangling the environmental chemical signal from other risk factors is challenging. For example, on an individual level, Full Scale IQ losses for an increase in blood lead from 10 micrograms per deciliter to 20 micrograms per deciliter in children aged 1–5 years was associated with an additional decrement of 1.9 Full Scale IQ points (108), a deficit largely invisible to clinicians. However, small individual-level effects can produce large adverse societywide health effects because exposure to chemicals is so prevalent (108). Population-level Full Scale IQ losses associated with exposure to lead, organophosphate pesticides, and methyl mercury—23,000,000, 17,000,000 and 285,000 points, respectively—are comparatively large or larger than other population level disease-specific risk factors for IQ loss (108).

Recommendations for Prevention

The evidence that links exposure to toxic environmental agents and adverse reproductive and developmental health outcomes is sufficiently robust, and the College and the ASRM join leading scientists and other clinical practitioners in calling for timely action to identify and reduce exposure to environmental toxic agents while addressing the consequences of such exposure (1–4, 8, 109). Reproductive care providers can be effective in preventing developmental exposure to environmental threats to health because they are uniquely poised to intervene during preconception and pregnancy, a critical window of human development. An important outcome of pregnancy is no longer just a healthy newborn but a human being biologically predisposed to be healthy from birth to old age (9, 81, 110, 111). By taking steps to address the environmental drivers of health, reproductive care professionals can have a large and enduring beneficial effect on patient health.

It is important for health care providers to become knowledgeable about toxic environmental agents that are endemic to their specific geographic areas. Intervention as early as possible during the preconception period is advised to alert patients regarding avoidance of toxic exposure and to ensure beneficial environmental exposure (eg, fresh fruit and vegetables, unprocessed food, outdoor activities, and a safe and nurturing physical and social environment). By the first prenatal care visit, exposure to toxic environmental agents and disruptions of organogenesis may have already occurred. Interactions between reproductive care providers and patients occur at an opportune time for effecting change. Individuals who desire to bear children are intensely interested in the effect of the environment on their pregnancies and the health of their future children, and they look to their health care providers for guidance regarding avoidance of potentially harmful exposure to toxic agents. Health care providers can serve a critical role as a science-based source of such guidance (112, 113).

Obtaining a history during a preconception visit and at the first prenatal visit to identify specific types of exposure that may be harmful to a developing fetus is a key step. Maternal and paternal exposure to chemicals in the workplace is a reproductive health concern and also should be queried (114). A list of key chemical categories, sources of exposure, and clinical implications are provided in Table 2, and a link to examples of an exposure history can be found in the section "Resources." As in other areas of clinical practice, communicating the science and areas of uncertainties concerning environmental exposure to chemicals can provide patients with the information they need to make informed choices based on the evidence and their values and preferences. Studies related to communicating the results regarding levels of environmental chemicals in breast milk and other biomarkers lend empirical support to this approach (115–118).

Anticipatory guidance should include information regarding avoidance of toxic environmental exposure at home, in the community, and at work (119) with possible referrals to occupational medicine programs or United States Pediatric Environmental Health Specialty Units, if serious exposure to toxic environmental agents is found. Legal exposure limits for most workplace chemicals are not designed to protect against harm to a pregnant woman or the developing fetus, and risks that are considered acceptable for workers are greater than risk levels established for the public (120).

Reproductive care professionals do not need to be experts in environmental health science to provide useful information to patients and refer patients to appropriate specialists when hazardous chemical exposure is identified. Existing clinical experience and expertise in communicating risks of treatment are largely transferable to environmental health. Physician contact time with a patient does not need to be the primary point of intervention; information and resources about environmental hazards can be successfully incorporated into a childbirth class curriculum or provided in written materials to help parents make optimal choices for themselves and their children (121).

Reporting identified hazards is critical to prevention. A patient with a hazardous exposure to chemicals or an adverse health outcome can be sentinel for an unrecognized health hazard, large public health hazard, or both. Astute practitioners have played vital roles in the identification of environmental hazards (122). For example, the reproductive toxicity of a common solvent used in

many consumer products was first described in a case report of a stillbirth (123). Physicians in the United States are required to report illnesses or injuries that may be work related, and reporting requirements vary by state. No authoritative national list of physician-reporting requirements by state exists. Resources for information about how to report occupational and environmental illnesses include local and state health agencies and the Association of Occupational ad Environmental Clinics (http://www.aoec.org/about.htm). Illnesses include both acute and chronic conditions, such as a skin disease (eg, contact dermatitis), respiratory disorder (eg, occupational asthma), or poisoning (eg, lead poisoning or pesticide intoxication) (124).

Advancing policies and practices in support of a healthy food system should be pursued as a primary prevention strategy to ensure healthy pregnancies, children, and future generations. Patient-centered actions can reduce body burdens of toxic chemicals (ie, the total amount of chemicals present in the human body at any one time). For example, research results document that when children's diets change from conventional to organic, the levels of pesticides in their bodies decrease (125, 126). Likewise, study results document that avoiding canned food and other dietary sources of BPA can reduce measured levels of the chemical in children and adult family members (127), and that short-term changes in dietary behavior may significantly decrease exposure to phthalates (128).

Clinicians should encourage women in the preconception period and women who are pregnant and lactating to eat fruit, vegetables, beans, legumes, and whole grains every day, to avoid fast food and other processed foods whenever possible, and to limit foods high in animal fat, while providing information about how certain types of food affect health and how individuals can make changes. Also, patients should be advised that some large fish, such as shark, swordfish, king mackerel, and tilefish, are known to contain high levels of methylmercury, which is known to be teratogenic. As such, women in the preconception period and women who are pregnant or lactating should avoid these fish. To gain the benefits of consuming fish, while avoiding the risks of methylmercury consumption, pregnant women should be encouraged to enjoy a variety of other types of fish, including up to 12 ounces a week (two average meals) of a variety of fish and shellfish that are low in mercury. Five of the most commonly eaten seafood items that are low in mercury are shrimp, canned light tuna, salmon, pollock, and catfish. White (albacore) tuna has more mercury than canned light tuna and should be limited to no more than 6 ounces per week. Pregnant women and breastfeeding women also should check local advisories regarding the safety of fish caught in local lakes, rivers, and coastal areas. If no advice is available, they should consume no more than 6 ounces per week (one average meal) of fish caught in local waters and no other fish during that week (129).

Advance Prevention-Oriented Policy

Decisions on the individual level regarding avoidance of toxic exposure are complex and often affected by external factors that limit making healthy lifestyle choices (130, 131) and, thus, need to be part of a multifaceted approach to prevention that does not assume a patient can shop her way out of societal-level problems (61). A successful strategy encompasses mutually reinforcing interventions on the individual patient (as previously discussed), health care, institutional, and societal levels.

Institutional-level interventions in support of a healthy food system include the development of urban agricultural programs, farmer's markets, and local food sourcing outlets to increase access to healthy food products and undertaking procurement policies that support a sustainable and healthy food service model (132, 133). In the United States, approximately $12 billion is pent annually to purchase food for health care systems (134). Changing procurement patterns in a hospital could leverage food system change more broadly. An evaluation of institutional-level interventions at four hospitals also shows that reduced purchasing of meat can result in significant savings in the cost of food and greenhouse gas emissions (135). Nearly 350 hospitals have taken the Healthy Food in Healthcare Pledge in support of these efforts (136).

Society-wide policy actions are essential in creating a healthy food system because many of the adverse health effects of the industrialized food system are not actionable by individuals but are determined by federal policy decisions (eg, food, air, and water pollution; disparities in access to healthy food and in toxic exposure associated with pesticides; and public research that guides the food system (60, 137–140). Examples of federal policies that influence environmental exposure from the food system include the Federal Farm Bill, responsible for approximately $60 billion of annual spending and passed by Congress every 5–7 years and the regulation of toxic releases from nonagricultural processes under the Clean Air Act, which regulates the levels of mercury emissions emitted by coal-fired power plants because, ultimately, the mercury ends up in the fish consumed by pregnant women and children (61). The Toxic Substances Control Act, which regulates chemicals in commerce, also is a food-related policy because food is an important pathway of patient exposure to many industrial chemicals. The inadequacies of the Toxic Substances Control Act are recognized by the EPA (141), the American Medical Association (142), various coalitions of nongovernmental organizations, eg, the Safer Chemical Healthy Families Coalition, and industry, eg, the American Chemistry Council. The clinical voice in these and related policy arenas can be a powerful force for lasting and systemic change.

Ultimately, evidence-based recommendations for preventing harmful environmental exposure must involve policy change (143). Although action at the individual

level can reduce exposure to some toxic chemicals (125, 127, 128) and informed consumer-purchasing patterns can send a signal to the marketplace to help drive societal change (67, 68), individuals alone can do little about exposure to toxic environmental agents, such as from air and water pollution, and exposure perpetrated by poverty. Thus, the role of clinicians extends well beyond the clinic (144–146). The incorporation of the authoritative voice of health care professionals in policy arenas is critical to translating emerging scientific findings into prevention-oriented action on a large scale (147). Accordingly, many medical associations have taken steps in that direction (109). For example, in 2009, the Endocrine Society called for improved public policy to identify and regulate endocrine disrupting chemicals and recommended that "until such time as conclusive scientific evidence exists to either prove or disprove harmful effects of substances, a precautionary approach should be taken in the formulation of EDC [endocrine disrupting chemical] policy" (1). Consistent with the clinical imperative to "do no harm," the precautionary principle states, "When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically" (148). An ethical rationale for preventing toxic environmental exposure also has been advanced (149).

The College and ASRM join these associations and call on their members to advocate for policies to identify and reduce exposure to toxic environmental agents while addressing the consequences of such exposure. The College and ASRM urge EPA and other federal and state agencies to take all necessary actions when reviewing substances to guarantee health and safety. In addition, the College and ASRM fully support rigorous scientific investigation into the causes and prevention of birth defects, including linkages between environmental hazards and adverse reproductive and developmental health outcomes. Timely and effective steps must be taken to ensure the safety of all mothers and infants from toxic environmental agents. Because data are lacking on the safety of most chemicals, careful consideration of the risks posed must be given while the potential immediate and long-term health and genetic risks are evaluated. A chemical should never be released if a concern exists regarding its effect on health.

Resources ⇦

The following list is for information purposes only. Referral to these sources and web sites does not imply endorsement. This list is not meant to be comprehensive. The exclusion of a source or web site does not reflect the quality of that source of web site. Please note that web sites are subject to change without notice.

- *All That Matters* is a compendium of patient centered, low literacy educational materials for patients and their families that address exposure to toxic chemicals in the workplace, at home, and in the community and provides information on how to avoid potentially harmful exposure. Each brochure contains links to detailed resources and information available online. Brochures can be requested in hard copy or downloaded for free in a printable format at: http://prhe.ucsf.edu/prhe/families.html.
  - — *Toxic Matters* and *Cuestiones de Salud* provide information about common sources of chemical exposure in our everyday lives and how to avoid exposure to chemicals that can affect reproduction. Also, they include information about becoming a more informed consumer and engaging with government representatives to improve the overall health of the community. *Cuestiones de Salud* is the low-literacy Spanish version of *Toxic Matters*.
  - — *Work Matters* provides information and resources for avoiding workplace chemicals that can affect reproduction. Also it provides resources, links, and information about organizations that can help workers understand their legal rights.
  - — *Food Matters: What to Eat* provides instructions regarding selecting the best types of food and avoiding exposure to chemicals that are found in some food products.
  - — *Pesticides Matter* provides tips about avoiding exposure to pesticides and insecticides at work, at home, and in the community.

  These clinical education materials were developed and vetted by members of the From Advancing Science to Ensuring Prevention (FASTEP) Alliance—a collaboration of University of California San Francisco, Program on Reproductive Health and the Environment (http://prhe.ucsf.edu/prhe). The FASTEP Alliance is a diverse alliance of leaders in the reproductive and environmental health care fields who share a commitment to the primary prevention of exposure to environmental contaminants. Using a highly collaborative model, the mission of the FASTEP Alliance is to secure each individual's right to optimal reproductive health by fostering an environment that prevents exposure to potential reproductive toxicants and provides the nutritive and social sustenance necessary for healthy pregnancies, healthy children, and healthy future generations.
- Multiple examples regarding obtaining an exposure history exist and can be found at: http://prhe.ucsf.edu/prhe/clinical_resources.html.
- Association of Occupational and Environmental Clinics, Pediatric Environmental Health Specialty Units are a network of investigators across the United States who support clinical capacity related to environmental health. The Pediatric Environmental Health Specialty Units respond to requests

for information throughout North America regarding prevention, diagnosis, management, and treatment of environmentally-related health effects in children and, as such, are poised to serve as a resource for obstetricians and gynecologists in recognition of the inextricable relationship between reproductive and pediatric health. The Pediatric Environmental Health Specialty Units network can be contacted at: http://www.aoec.org/PEHSU.htm.

- Occupational Medicine Programs at regional academic centers can serve as a resource for evaluating occupational exposure to chemicals.
- Health professional organizations have been active in calling for regulatory and other efforts to address exposure to toxic chemicals and many other environmental threats to human health. A compilation of professional society policy statements can be found at: http://prhe.ucsf.edu/prhe/professional-statements.html.

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