

Review of hazards to female reproductive health in veterinary practice

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OBJECTIVE

To review publications that address female reproductive health hazards in veterinary practice, summarize best practices to mitigate reproductive risks, and identify current knowledge gaps.

DESIGN

Systematized review.

SAMPLE

English-language articles describing chemical, biological, and physical hazards present in the veterinary workplace and associations with adverse reproductive outcomes or recommendations for minimizing risks to female reproductive health.

PROCEDURES

Searches of the CAB abstracts database were performed in July 2012 and in May 2015 with the following search terms: veterinarians AND occupational hazards and vets.id AND occupational hazards.sh. Searches of the PubMed database were conducted in November 2012 and in May 2015 with the following medical subject heading terms: occupational exposure AND veterinarians; anesthetics, inhalation/adverse effects AND veterinarians; risk factors AND pregnancy AND veterinarians; pregnancy outcome AND veterinarians; and animal technicians AND occupational exposure. Two additional PubMed searches were completed in January 2016 with the terms disinfectants/toxicity AND female AND fertility/drug effects and veterinarians/psychology AND stress, psychological. No date limits were applied to searches.

RESULTS

4 sources supporting demographic trends in veterinary medicine and 118 resources reporting potential hazards to female reproductive health were identified. Reported hazards included exposure to anesthetic gases, radiation, antineoplastic drugs, and reproductive hormones; physically demanding work; prolonged standing; and zoonoses.

CONCLUSIONS AND CLINICAL RELEVANCE

Demographic information suggested that an increasing number of women of reproductive age will be exposed to chemical, biological, and physical hazards in veterinary practice. Information on reproductive health hazards and minimizing risk, with emphasis on developing a safety-focused work culture for all personnel, should be discussed starting in veterinary and veterinary technical schools and integrated into employee training. (*J Am Vet Med Assoc* 2017;250:862–872)

Most veterinary personnel engaged in clinical practice are generalists who, during a routine work day, may be exposed to ionizing radiation, anesthetic gases, zoonotic diseases, and trauma from fractious animals—both large and small. No other medical profession is required to assess and manage such a wide range of workplace exposures to chemical, biological, and physical hazards.^{1–8}

Reproductive hazards are those hazards that may negatively impact fertility or pregnancy. The review reported here focused on pregnant women and wom-

en of childbearing age working in veterinary practice. Reproductive hazards common in the veterinary workplace can be categorized as chemical, biological, and physical hazards. Chemical hazards include contact with antineoplastic drugs, hormones, pesticides, and anesthetic gases; biological hazards include zoonotic and other infectious agents; and physical hazards include animal-related injuries, radiation exposure, demanding work conditions and physical work load, needle sticks, and psychosocial hazards from workplace stress, long work hours, and other factors that affect mental well-being.

The proportion of women in the veterinary profession in the United States has increased in recent years. More than 90% of veterinary technicians are, and historically have been, female.⁹ Of 105,000 US

ABBREVIATIONS

| | |
|-------|---|
| NIOSH | National Institute for Occupational Safety and Health |
| OSHA | Occupational Safety and Health Administration |

veterinarians actively practicing in 2015, 58% were women, and more than 80% of new graduates were women.^{10,11} This represents a dramatic shift from the demographic 50 years ago, when almost 90% of US veterinary students were male.¹² As older male veterinarians retire from practice and are replaced by new female graduates, an increasing number of women of reproductive age will encounter workplace hazards that may pose undefined risks to fertility as well as to an embryo or fetus during pregnancy.

Comprehensive guidance to prevent or mitigate exposures to occupational reproductive health hazards for female veterinary personnel is greatly needed.¹³ In recognition of this, the NIOSH, in partnership with the National Occupational Research Agenda and other stakeholders, finalized a series of goals including raising awareness of reproductive hazards, formulating recommendations to mitigate them, and developing fact sheets and other outreach materials for veterinary personnel.¹³

The objectives of the study reported here were to conduct a systematized review of retrievable publications addressing hazards to female reproductive health in the veterinary workplace, to evaluate and summarize recommendations to minimize reproductive risks in veterinary practice, and to identify gaps in current knowledge related to these risks. This report is intended to provide a framework for education, research, and future development of materials in this area.

Materials and Methods

Searches of the CAB abstracts database were conducted in July 2012 and in May 2015. Two sets of search terms, veterinarians AND occupational hazards and vets.id AND occupational hazards.sh, were used without date limits, and both searches yielded the same results. Searches of PubMed without date limits were conducted in November 2012 and in May 2015, with the following MeSH search terms used: occupational exposure AND veterinarians; anesthetics, inhalation/adverse effects AND veterinarians; risk factors AND pregnancy AND veterinarians; pregnancy outcome AND veterinarians; and animal technicians AND occupational exposure. Two alternate MeSH search terms for the last string, veterinary nurse AND occupational exposure and risk factors AND pregnancy AND animal technicians, produced the same results. Two additional PubMed searches without date limits were completed in January 2016 to discover reproductive hazards related to disinfectants and hazards posed by psychosocial factors. These included MeSH search terms of disinfectants/toxicity AND female AND fertility/drug effects and veterinarians/psychology AND stress, psychological. Additional articles and recommendations were identified on US government and AVMA websites pertaining to reproductive health and by manually searching article reference lists.

The articles were divided among all 4 authors for review, and results were recorded on a shared spread-

sheet. We determined relevance to veterinary occupational health and reproductive health and whether the article included best practices for prevention, control, and mitigation of reproductive hazards. References that were not written in English language were excluded. Articles that did not relate to occupational health or reproductive health or were not available were excluded. Excluded articles underwent a second evaluation by 2 reviewers (JMS and BLE).

Information recorded from the literature search included authorship information; title, journal, and year of publication; study type or design; resource type (eg, peer-reviewed journal article, non-peer-reviewed journal article, or meeting proceedings); reproductive hazard; reviewer comments; reviewer; and date. A spreadsheet template was used to organize relevant articles according to hazard (chemical, biological, physical, or general [for resources covering multiple hazards]) and strength of evidence. Strength of evidence was classified as primary, supportive, or anecdotal. Anecdotal publications were those that contained opinions or observations by experts but did not include objective safety data. Publications such as reviews, in which hazards and practices were described but lacked original data to support recommendations, were considered to have supportive evidence. Original studies that included statistically significant associations in reporting risk or contained quantitative or descriptive data to support recommendations were considered primary resources. Except for hazards such as zoonotic diseases with rare outcomes, reproductive risks reported here were supported by primary resources that reported statistically significant associations.

Results

Evaluation of 521 unique articles led to identification of 99 references that described chemical, biological, and physical hazards present in the veterinary workplace and their association with adverse reproductive outcomes, or contained recommendations for minimizing risk from exposure to reproductive hazards (**Figure 1**). These were categorized as primary (n = 57), supportive (41), or anecdotal (1). Thirty-four of 66 (52%) published papers pertaining specifically to veterinary occupational health focused predominantly on veterinarians, and 32 (48%) included all veterinary personnel, including veterinarians. In addition, 4 sources identifying demographic trends and 19 US government documents, US government websites, or AVMA websites containing information about reproductive health hazards and their mitigation were identified and included without categorization.

Chemical hazards

Chemical hazards in veterinary medical settings, including those from antineoplastic drugs and other pharmaceuticals, are often similar to those in human health care¹⁴ and have been identified and listed by the NIOSH.¹⁵ Safety data sheets for disinfectants and

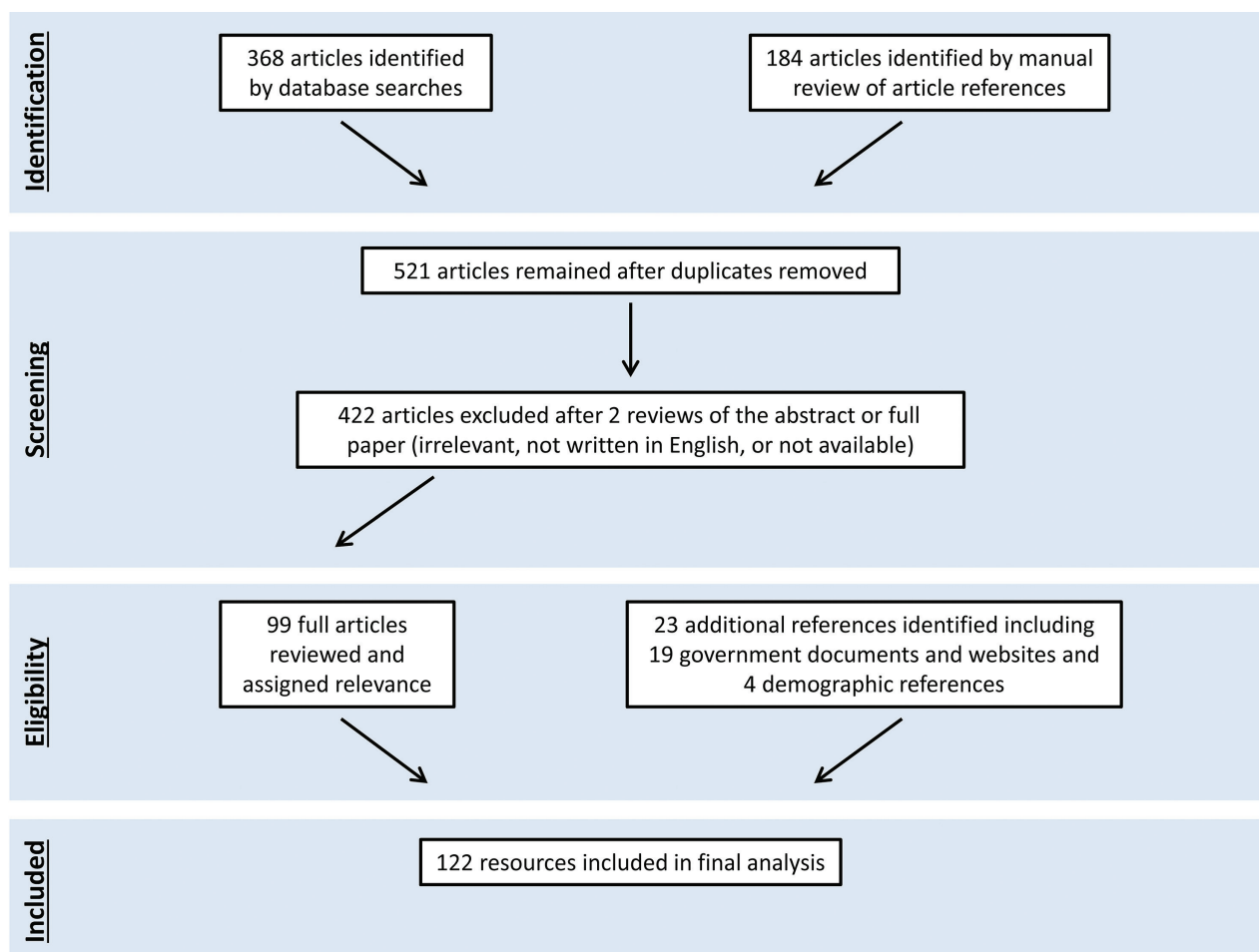


Figure 1—Diagram depicting resource selection process and outcome for a systematized review of hazards to female reproductive health in veterinary practice.

other chemicals are readily available both from the manufacturer and online. However, these documents do not always provide all necessary information for assessing health risks, and it is often necessary to consult other sources of information to fully assess health hazards from chemicals. The OSHA has published standards and the NIOSH has published guidelines addressing chemical hazards, including how these hazards should be communicated to workers who may be exposed occupationally.^{16–18} Similar to other health-care and industry settings, veterinary practices are subject to the OSHA Hazard Communication Standard¹⁸; information specific to veterinary medicine can be found on the AVMA website.¹⁹ Chemical exposures identified through the literature search that could present a risk to female reproductive health, and best practices to prevent or mitigate such exposures, were summarized (**Table 1**).^{6,15–17,20–45}

Antineoplastic pharmaceuticals, primarily used to treat cancer in dogs and cats, are important reproductive hazards found in the veterinary setting.⁴⁶ Many antineoplastic drugs have been reported to be carcinogenic, mutagenic, or teratogenic and have been associated with reduced fertility, spontaneous

abortion, and fetal loss.^{30–32,46–49} Usage and exposure estimates have been reported for veterinary personnel in Canada⁴⁶ and the Netherlands,⁵⁰ where concerning exposures during preparation and administration of antineoplastic drugs were documented. No such antineoplastic pharmaceutical usage or exposure data for US veterinary personnel were identified in the literature search.

Reproductive hormones used in contemporary veterinary practice are especially hazardous to pregnant women. Prostaglandins, in particular, should be avoided during pregnancy; these and other reproductive hormones warrant meticulous care and training in their use.²³

Beginning in the 1960s and 1970s, there was substantial concern about the effects of inhaled anesthetic gases on reproduction in health-care workers.^{51–56} In response, the NIOSH published recommendations for reducing exposure and risk.⁵⁷ Importantly, most of the early epidemiological reports linking waste anesthetic gas exposure to adverse health events have since been critically reviewed and faulted for inappropriate design or improper statistical analysis.^{58–61} Thus, a direct cause-and-effect relationship between long-term exposure to waste anesthetic gas and ad-

Table 1—Chemical hazards present in veterinary workplaces and recommendations for mitigation of risks to female reproductive health identified in the literature.

| Hazard | Reproductive risk | Best practices to mitigate risk |
|---|---|--|
| Anesthetic gases | Spontaneous abortions ²⁰ and preterm birth ²¹ | <p>Install scavenging and ventilation systems^{6,20–26}</p> <ul style="list-style-type: none"> •Operating rooms: 15 air changes/h, with a minimum of 3 air changes of fresh air/h •Recovery rooms: 6 air changes/h, with a minimum of 2 air changes of fresh air/h²⁵ <p>Properly inspect and maintain anesthesia machines, breathing circuits, and waste-gas scavenging systems^{6,22,25,26}</p> <ul style="list-style-type: none"> •Inspect the anesthetic delivery system before each use for irregularities or breaks •Fill vaporizers before or after (not during) the anesthetic procedure •Fill vaporizers under a ceiling-mounted hood with an active evacuation system, if available •Check the patient's breathing circuit for negative pressure and positive pressure relief •Turn on the room or local ventilation system •Make sure the scavenging equipment is properly connected •Start the gas flow only after anesthesia is induced and the endotracheal tube is placed with the cuff properly inflated •Confirm that the endotracheal tube creates a completely sealed airway •If a mask is used, make sure it fits the patient well •Use an appropriate oxygen flow rate for the animal's size •Occlude the Y-piece if the breathing circuit must be disconnected during surgery •Turn off the anesthetic gas before turning off the breathing system and flush the patient's airway with oxygen before disconnecting •Eliminate residual gases through the scavenging system before disconnecting a patient from the breathing system; empty the breathing bag into the scavenging system <p>Perform a comprehensive maintenance inspection annually</p> <p>Train all workers in hazard awareness, prevention, and control of exposures to waste anesthetic gases²⁵</p> <p>Inform female veterinary personnel of the risks^{27–29}</p> |
| Carbon monoxide | Fetal anoxia leading to fetal death ²³ | <p>Do not enter a poorly ventilated, artificially heated area where animals may be ill or dying, because of a potential for carbon monoxide exposure²³</p> |
| Antineoplastic drugs and other hazardous pharmaceuticals | Reduced fertility, fetal loss, spontaneous abortion, preterm birth, and low birth weight ^{30–32} | <p>Read and follow recommendations in the following publications:</p> <ul style="list-style-type: none"> •DHHS (NIOSH) 2010–150¹⁷ and other publications^{33–36} providing guidelines for safe handling of hazardous drugs in veterinary medicine, including receipt and storage, drug preparation, drug administration, waste cleaning and disinfection, drug transportation, spill control, and medical surveillance •DHHS (NIOSH) 2004–165,¹⁶ which includes protection recommendations for health-care workers potentially exposed to hazardous drugs including chemotherapeutic drugs used in cancer treatment, antiviral drugs, hormones, and some bioengineered drugs •DHHS (NIOSH) 2014–138,¹⁵ which provides a list of antineoplastic and other hazardous drugs <p>Other prevention practices for handling antineoplastic and other hazardous pharmaceuticals include the following:</p> <ul style="list-style-type: none"> •Minimum precautions include use of gloves, mask, goggles, and a long-sleeved, water-resistant gown³⁷ •Pregnancy intention status is an important determinant regarding prevention behaviors in handling cytotoxic drugs and should be considered in training programs³⁸ <p>Practice institution-wide prevention strategies,³⁷ develop written chemotherapy safety protocols,³³ and communicate risk and prevention strategies to employees^{32,33}</p> |
| Ethylene oxide (gas sterilization) | Spontaneous abortion ²⁶ | <p>Ethylene oxide gas sterilization procedures should be avoided in general veterinary practice because of the challenges involved with safe use²⁶</p> <p>If ethylene oxide is to be used, consult OSHA guidance documents³⁹ and OSHA standards document 29 CFR 1910.1047,⁴⁰ and observe the following:</p> <ul style="list-style-type: none"> •Wear proper personal protective equipment when working with ethylene oxide; protective outerwear, chemically resistant gloves, and goggles or face shields should be worn²⁶ •Worker exposure to ethylene oxide should be limited to 1 ppm in air measured as an 8-hour time-weighted average. •Worker exposure to the agent may not exceed the short-term excursion limit of 5 ppm averaged over any 15-minute sampling period •Leave the sterilizer area during the exhaust cycle²⁶ •Use engineering controls and good work practices to reduce exposure •Implement a written compliance program |
| Insecticides and other pesticides | Birth defects ⁴¹ and spontaneous abortion ²⁹ | <p>Consult safety data sheets for the compounds^{42,43}</p> <p>Use appropriate protective measures to prevent or minimize exposure⁴²</p> <p>Avoid extralabel use⁴²</p> <p>Be aware that pesticide concentrates that require dilution pose a higher risk of exposure</p> <p>Avoid using materials that may absorb the compound and release it later⁴³</p> <p>Inform female veterinary personnel of possible reproductive effects of pesticide exposure^{29,44}</p> <p>Use extreme caution and biological monitoring to regulate occupational exposure to organophosphates^{41,43}</p> |
| Prostaglandins and other reproductive hormones (eg, GnRH analog, human chorionic gonadotropin, estrogen, progesterone, synthetic progesterin, testosterone, and oxytocin) | Spontaneous abortion, fetal death (PGF2 α and its analog), prolongation of pregnancy (synthetic progesterin), disruption of menstrual cycle (GnRH analog, synthetic progesterin), and increased or decreased uterine bleeding (synthetic progesterin) ^{23,45} | <p>Pregnant women should not handle or administer prostaglandin products^{23,45}</p> <p>Avoid direct skin contact by wearing impervious gloves during drug handling; wash hands immediately after removing gloves; adhere to manufacturers' safety warnings⁴⁵</p> <p>When specific warnings and guidelines are not provided, follow NIOSH guidelines^{15–17}</p> <p>If contact with skin occurs, wash the affected area immediately and seek medical attention⁴⁵</p> |

DHHS = US Department of Health and Human Services. GnRH = Gonadotropin-releasing hormone. PG = Prostaglandin.

verse reproductive health events has not been firmly established. However, Boivin²⁰ performed a meta-analysis of epidemiological studies and found that data obtained prior to the routine use of scavenging systems (exhaust systems to remove excess anesthetic gases) indicated an increased risk of spontaneous abortion, and Shirangi et al²¹ found an increased risk of preterm delivery in women exposed to unscavenged waste anesthetic gas for ≥ 1 h/wk, compared with that for an unexposed group. At the present time, owing to the almost universal adoption of scavenging systems, reproductive risk from occupational exposure to inhalation anesthetics in veterinary personnel appears to be minimal.^{27,58,59,61–65} Nevertheless, it remains prudent to recommend control measures that reduce occupational exposure.^{51,58–60,24,25,66}

Awareness of potential health hazards from chemicals and pharmaceuticals, along with adoption

of measures to reduce potential for exposure, are essential to prevent or reduce adverse health events.⁶⁷ This can be accomplished through elimination or substitution of the chemical, changes to work practices, and use of personal protective equipment.⁴⁶

Biological hazards

Exposure to biological hazards is inevitable when working closely with animals.^{68–72} A subset of these hazards may pose a particular risk for maternal and fetal health, including some zoonotic bacterial and viral pathogens and certain infectious agents that pose an increased risk of illness to immunocompromised individuals (including pregnant women); the most common of these were tabulated with recommendations for prevention (**Table 2**).^{23,26,68,70,72–84} The many zoonoses (eg, rabies virus, *Salmonella* spp, or herpesvirus B) that can adversely impact human health

Table 2—Biological hazards present in veterinary workplaces and recommendations for mitigation of risks to female reproductive health identified in the literature.

| Hazard | Reproductive risk | Best practices to mitigate risk |
|--|--|--|
| Brucellosis (<i>Brucella</i> spp) | Preterm delivery and low birth weight ⁷⁰ | Use standard precautions ⁷² Be aware of risk and attain prompt diagnosis ⁷⁰ Consult an infectious disease specialist if symptoms develop ⁷⁰ Report infection to animal and public health authorities ⁷² |
| Leptospirosis (<i>Leptospira interrogans</i>) | Infection of the embryo or fetus with outcomes ranging from midgestational fetal death to birth of a healthy infant; maternal death can also occur ^{73,74} | Use standard precautions ⁷² Consult an infectious disease specialist if symptoms develop ⁷³ Contact local or state health departments for guidance following potential exposure ⁷² Wear gloves when handling pet rats ⁷⁵ |
| Listeriosis (<i>Listeria monocytogenes</i>) | Preterm labor, fetal death, stillbirth, and <i>Listeria</i> septicemia and meningitis of the neonate ²⁶ | Wear gloves, facial protection, and protective clothing while working with aborted fetuses and tissues or fluids expelled by the dam ^{23,72} Use extra caution when working with sheep, goats, and cattle during pregnancy ²⁶ |
| Lymphocytic choriomeningitis virus infection | Spontaneous abortion and severe birth defects (eg, chorioretinitis, hydrocephalus, and mental retardation) ⁷⁶ | Wear gloves and facial protection when handling rodents while pregnant ⁷² Avoid sweeping or vacuuming rodent urine, droppings, and nesting materials ⁷² Report infection to public health authorities ⁷² |
| Gestational psittacosis (<i>Chlamydia psittaci</i>) | Adverse pregnancy outcomes are very rare, but stillbirth has been reported ⁷⁷ | Wear gloves and N95 respirator when handling ill psittacine birds ⁷² Consider all ill birds to be a potential source of infection ^{68,72} Avoid sweeping or vacuuming bird urine, droppings, and nesting materials; use gloves, N95 respirator, goggles, and surgical cap when cleaning contaminated areas ^{72,77} Report infection to public health authorities ⁷² |
| Gestational chlamydiosis (<i>Chlamydia abortus</i>) | Spontaneous abortion, severe chlamydiosis (coagulopathy, intense placentitis), and maternal death ⁷⁸ | Wear gloves, N95 respirator, and protective clothing while working with aborted sheep or goat fetuses or tissues and fluids expelled by the dam ^{78,79} Pregnant women should avoid contact with aborting sheep and goats, if possible ⁷⁸ Report infection to public health authorities ⁷² |
| Q Fever (<i>Coxiella burnetii</i>) | Spontaneous abortion, stillbirth, preterm birth, intrauterine growth retardation, and low birth weight ⁸⁰ | Consult an infectious disease specialist if symptoms develop ⁸⁰ Wear gloves, N95 respirator, and protective clothing when working with aborted sheep or goat fetuses or tissues and fluids expelled by the dam ^{23,72} Use extra caution when working with sheep, goats, and cattle during pregnancy ⁸¹ Report infection to public health authorities ⁷² |
| Toxoplasmosis (<i>Toxoplasma gondii</i>) | Spontaneous abortion, preterm birth, stillbirth, fetal neurological damage, congenital chorioretinitis, hydrocephalus, encephalitis, and mental retardation ^{23,26} | Avoid exposure to cat feces and litter while pregnant ⁸² Consult a health-care provider when considering pregnancy or in early pregnancy about advisability of baseline antibody titer determination (authors' recommendation on the basis of Weese et al ⁸²) Maintain a clinic practice of daily litter pan cleaning by nonpregnant staff members ⁷⁶ Use gloves when conducting feline fecal examinations and wash hands afterward ⁸³ |
| Infections from animal licks, bites, or scratches (eg, <i>Pasturella multocida</i> , <i>Bartonella henselae</i> , <i>Capnocytophaga canimorsus</i>) | Maternal pyrexia, premature labor, chorioamnionitis, and maternal and neonatal death ⁷⁶ | Counsel pregnant personnel likely to be exposed to animal flora ⁸⁴ Educate physicians to consider systemic infection with <i>P multocida</i> and other animal flora in symptomatic female veterinary personnel ⁸⁴ |

regardless of pregnancy status were not included in the summary.

Emerging zoonotic diseases pose a risk to people who work at the human-animal interface. It is likely that reproductive health as well as fetal health may be acutely susceptible to adverse outcomes from emerging infectious diseases, particularly before the risk has been identified. Thus, when an emerging zoonotic disease is not yet well characterized, veterinary personnel are advised to strictly adhere to standard precautions.^{72,76}

The proportion and magnitude of biological exposures that result in disease transmission to the veterinary workforce is poorly understood because of a lack of integrated surveillance systems for occupationally related infections. Ultimately, the advent of surveillance systems to consistently and uniformly record injuries and illnesses among veterinary personnel will better characterize the hazards so that attention and resources can be prioritized for most effective risk reduction.^{4,26,74,85}

At present, best practices to mitigate these risks include environmental controls, written infection control policies that are consistently applied, staff training in the use of procedures and equipment to reduce risk, and use of appropriate personal protective equipment (eg, gloves, protective outerwear, and facial protection), with emphasis on groups that may be particularly vulnerable, such as pregnant women.^{72,82,86,87}

Physical hazards

Physical hazards that can pose a risk to female reproductive health and recommended measures to prevent or mitigate injury were reviewed (**Table 3**).^{7,8,21,23,28,29,44,49,72,88–106} Prevention of physical workplace hazards in a veterinary setting is best accomplished through consistent application of safe workplace practices, such as routine use of personal dosimetry and lead apparel when performing radiography.^{28,92–95,97} During much of the first 7 weeks after conception,

Table 3—Physical hazards present in veterinary workplaces and recommendations for mitigation of risks to female reproductive health identified in the literature.

| Hazard | Reproductive risk | Best practices to mitigate risk |
|--|---|---|
| Radiography | Risks depend on stage of embryonic or fetal development and level of radiation exposure. Outcomes range from death of the embryo to congenital malformations and mental retardation ⁸⁸ | Occupational exposure limit for ionizing radiation to the fetus is 5 mSv (0.5 rem) cumulative during pregnancy, with a 0.5 mSv limit for each month of pregnancy ⁸⁹ Keep radiation exposure as low as reasonably achievable or as low as reasonably practicable ^{90–93} Avoid radiographic evaluation unless it is justified ⁹⁰ Perform yearly safety verification of gloves and aprons, and check the tube device for leakage ⁹³ Increase distance of the individual performing radiography from the radiation source, reduce the duration and amount of exposure, and use protective barriers between the individual and the source ²³ Perform radiography only in controlled areas ⁹⁰ ; wear radioprotective clothing (eg, lead aprons, thyroid shields, glasses, and gloves) and use personal dosimetry badges worn on the trunk under the lead gown ^{23,28,90,94,95} ; gloves and thyroid shields should have a minimum lead equivalent of 0.5 mm ⁹⁰ Prohibit manual restraint of animals by pregnant women during radiography ⁹⁰ Use tube stands or a pole with a cassette holder, rather than holding with hands, for radiography of large animals ^{90–92} Emphasize the importance of adequate radiation protection and knowledge in schools of veterinary medicine and professional associations ⁹⁶ Include written policies in a practice infection control plan requiring staff members to notify hospital leadership of pregnancy as soon as the staff member becomes aware of it ⁹⁷ Fully inform female veterinary personnel of the risks from ionizing radiation ^{29,44} Work with employers to reduce exposures during pregnancy and lactation ^{23,49,90} |
| Standing at work | Preterm delivery ^{98–100} and low birth weight ¹⁰¹ | Pregnant personnel should not stand > 6 h/d ⁹⁸ Limit standing and walking at work, especially standing in 1 position, to 4 to 5 hours during the second and third trimesters ^{99,101} |
| Long working hours | Preterm delivery ^{21,98} | Limit work to < 42–45 h/wk ^{21,98} |
| Physically demanding work, including lifting | Preterm delivery, maternal hypertension, ¹⁰⁰ and low birth weight ¹⁰² | Reduce or eliminate physically demanding work from job duties of pregnant personnel ^{100,103} Consult MacDonald et al (2013) ¹⁰² for specific guidelines for occupational lifting during pregnancy; guidelines are given for infrequent lifting, repetitive short-duration lifting, and repetitive long-duration lifting in multiple body positions at < 20 wk of gestation and ≥ 20 wk of gestation. Reductions in recommended weight limits may need to be made for veterinary personnel, considering the unpredictability of sudden animal movement or pushing and pulling of animals during lifting that may influence recommended weight limits ¹⁰² Minimize or eliminate demanding levels of physical work for women with previous complications of pregnancy that are likely to recur, such as low birth weight of infants and premature labor ²³ |
| Shift and night work | Preterm delivery ¹⁰⁰ | Limit shift or night work ¹⁰⁰ |
| Needle sticks | Spontaneous abortion ¹⁰⁴ | Establish a needle-stick prevention program ^{7,8} Provide information and training on needle-stick prevention and establish written infection control policies that include needle-stick prevention ^{72,105} Practice standard precautions when using anthelmintic, euthanasia, and anesthetic agents ¹⁰⁴ Avoid recapping needles or use a I-handed scooping technique to recap ^{37,72,106} Perform worksite analyses for tasks causing needle sticks ¹⁰⁶ |

when the embryo is most susceptible to the effects of radiation, a woman may not be aware that she is pregnant. Therefore, any female veterinary personnel with the potential to be pregnant should use all available precautions when radiographic equipment is in use.^{23,88,96,107} Needle sticks and other traumatic physical injuries from animal bites, lifts, trips, slips, falls, and automobile accidents can be largely prevented by habitual safety practices.^{7,8,28,37,72,104,106} Most veterinary settings are small, and personnel are often cross-trained to perform multiple tasks, making workplace safety culture especially important in preventing accidents and injury.⁷²

Several studies^{21,98-100,102} identified an association between long work hours, prolonged standing at work, or physically demanding work including manual lifting, and preterm delivery or low birth weight for gestational age. Measures to mitigate certain physical hazards become more important as a pregnancy progresses, including adoption of recommended weight limits for lifting and adjusting work practices to address concerns associated with fatigue, prolonged standing or walking, and working long hours.^{21,23,98-103} The importance of physical work limits during pregnancy should be discussed starting in veterinary and veterinary technical schools and carried through to employee health practices in clinical settings.¹⁰³ Organizational policies regarding reproductive hazards and pregnancy should be documented and clearly communicated to female employees.^{29,44,105}

The association between serious life events and workplace stress on preterm delivery and low birth weight has been established.¹⁰⁸⁻¹¹¹ Specific to veterinary medicine, the literature review identified articles pertaining to stress and work-related exhaustion in the veterinary workplace^{98,103,112,113} and substantial and deeply concerning psychological work stress and suicidal ideation among veterinarians.¹¹⁴⁻¹¹⁶ Given what is known about the detrimental effects of stress on gestation, it is clear that more research in this area, focused on the veterinary community, is needed.

Available guidance resources

Guidance documents regarding veterinary workplace safety and health are available from varied sources, including the NIOSH, OSHA, and AVMA. The NIOSH provides health and safety recommendations to protect workers in workplace settings, including resources specific to workplace hazards and reproductive health^{117,118}; the organization's website also directly addresses veterinary safety and health.¹¹⁹

In the United States, the OSHA is the federal agency charged with enforcing laws regarding workplace safety and health. Exposures that occur in human as well as animal medical facilities are addressed in a variety of OSHA publications.¹²⁰ Although some of the information reflects employer legal obligations, much of the guidance is intended as advisory, so that medical facility managers can optimize prevention practices. The AVMA is a member

organization representing > 88,000 veterinarians.¹²¹ The AVMA's website¹²² and the *JAVMA* frequently publish articles addressing veterinary workplace hazards and prevention guidance.

Discussion

Most veterinarians presently in practice are women, and most veterinary technician and veterinary assistant positions are, and historically have been, filled by women. The present review was performed to summarize the available information on veterinary workplace exposures that can negatively impact a woman's reproductive health, to raise awareness of established risks, and to explore knowledge gaps related to this subject. In addition, the review identified current best practices that veterinary personnel can institute to mitigate risks associated with workplace reproductive hazards.

Exposure to anesthetic gases and ionizing radiation are reproductive hazards that are generally well recognized and addressed in most veterinary workplaces.⁴⁶ Other hazards are perhaps less well understood. For example, our literature review revealed associations between long work hours, physically demanding work, or standing at work for > 4 to 6 hours at a time and preterm delivery.^{21,98-100,102} Historically, the veterinary profession has been a demanding, physically difficult profession often requiring long work hours. Culturally, workplace dispensations for pregnancy (or other conditions requiring special consideration) have not been the norm. Changes in workplace culture regarding perceptions of work ethic could be the most difficult adjustment that must occur to accommodate increasing numbers of women in the veterinary workplace.

We attempted to identify all publications that addressed chemical, biological, and physical hazards in veterinary practice that may impact female reproductive health. This is a broad topic, and it is possible that relevant literature was missed. We also attempted to capture all exposures relevant to veterinary personnel in the literature search; however, it is likely that some exposures that occur in other health-care disciplines and have implications for veterinary personnel were overlooked. Another potential limitation was that the review was focused on general hazard mitigation, as it was performed by public health and occupational health professionals without specialized knowledge in reproductive health.

A number of recent publications on this topic originated from sources in countries other than the United States, reflecting international recognition of the need for occupational health research and guidance for female veterinary personnel. Literature included in the review identified risks to reproductive health and recommendations to mitigate exposures. However, specific information about the extent or scope of risk, such as usage or exposure estimates for a particular hazard, was frequently lacking. Of the 66 published articles pertaining specifically to veterinary occupational

health that were identified in the literature search, only 32 (48%) included veterinary technicians and other veterinary staff, a population with arguably as much exposure (or even more exposure) to most hazards as veterinarians. A better understanding of where, how, to whom, and to what extent reproductive health hazards occur in the veterinary workplace would allow for targeted interventions.⁴⁶ Additional research is needed to evaluate associations between psychosocial or workplace stress, physically demanding work, zoonotic diseases, and adverse reproductive outcomes in veterinary clinical practice. In particular, there is an opportunity to apply to veterinary medicine what is known in other fields about mitigating psychosocial and workplace stress and other physical reproductive health hazards such as lifting, working long hours, and prolonged standing. Similarly, best practices for preparation and administration of antineoplastic pharmaceuticals are well established in human health care and can be used in private veterinary practice; however, data are needed on veterinary usage and exposure in the United States, and efforts should be made to increase awareness among veterinary personnel of the risks and recommendations to mitigate them. In the same way, female veterinarians, technicians, and staff represent a uniquely exposed workforce which, if followed over time, would provide health and safety information applicable to other fields involving animal care.

Although additional research is needed to more clearly define workplace hazards for female veterinary personnel, current knowledge is sufficient to justify instituting interventions to reduce reproductive risks and minimize adverse reproductive outcomes. Best practices for mitigating risk should be introduced and discussed during veterinary and veterinary technician training and integrated into employee training. Early introduction to and familiarity with reproductive health hazards and practical information about mitigating risk, with emphasis on developing a safety-focused work culture for all veterinary personnel, are critical for making the changes necessary to meet current and future veterinary occupational health challenges.

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References

- Jeyaretnam J, Jones H. Physical, chemical and biological hazards in veterinary practice. *Aust Vet J* 2000;78:751-758.
- Nienhaus A, Skudlik C, Seidler A. Work-related accidents and occupational diseases in veterinarians and their staff. *Int Arch Occup Environ Health* 2005;78:230-238.
- Wiggins P, Schenker MB, Green R, et al. Prevalence of hazardous exposures in veterinary practice. *Am J Ind Med* 1989;16:55-66.
- Fowler HN, Holzbauer SM, Smith KE, et al. Survey of occupational hazards in Minnesota veterinary practices in 2012. *J Am Vet Med Assoc* 2016;248:207-218.
- CDC. Veterinary safety and health. Available at: www.cdc.gov/niosh/topics/veterinary/chemical.html. Accessed May 4, 2016.
- Langley RL, Pryor WH, O'Brien KF. Health hazards among veterinarians: a survey and review of the literature. *J Agromed* 1995;2:23-52.
- Poole AG, Shane SM, Kearney MT, et al. Survey of occupational hazards in large animal practices. *J Am Vet Med Assoc* 1999;215:1433-1435.
- Poole AG, Shane SM, Kearney MT, et al. Survey of occupational hazards in companion animal practices. *J Am Vet Med Assoc* 1998;212:1386-1388.
- National Association of Veterinary Technicians in America. NAVTA news, NAVTA survey: Sept-Oct 2012. Available at: cymcdn.com/sites/www.navta.net/resource/resmgr/NAVTA_SeptOct12_Survey.pdf. Accessed May 4, 2016.
- AVMA, Association of American Veterinary Medical Colleges. 2016 AVMA & AAVMC Report on the market for veterinary education. April 2016. Available at: www.avma.org/PracticeManagement/BusinessIssues/Documents/2016-econ-rpt2-mktvet-education.pdf. Accessed May 4, 2016.
- AVMA. Market research statistics: US veterinarians 2015. Available at: www.avma.org/KB/Resources/Statistics/Pages/Market-research-statistics-US-veterinarians.aspx. Accessed May 4, 2016.
- Burns K. At veterinary colleges, male students are in the minority. *J Am Vet Med Assoc* 2010;236:376-377, 384.
- CDC National Institute for Occupational Safety and Health. National occupational research agenda, national healthcare and social assistance agenda for occupational safety and health research and practice in the US healthcare and social assistance (HCSA) sector. February 2013. Available at www.cdc.gov/niosh/nora/comment/agendas/hlthcaresocassist/pdfs/HlthcareSocAssistFeb2013.pdf. Accessed Jun 30, 2016.
- Meggs WJ. Chemical hazards faced by animal handlers. *Occup Med* 1999;14:213-224.
- CDC National Institute for Occupational Safety and Health. *NIOSH list of antineoplastic and other hazardous drugs in healthcare settings, 2014*. DHHS (NIOSH) publication No. 2014-138. Cincinnati: CDC, 2014. Available at: www.cdc.gov/niosh/docs/2014-138/pdfs/2014-138.pdf. Accessed Apr 21, 2016.
- CDC National Institute of Occupational Safety and Health. *Preventing occupational exposures to antineoplastic and other hazardous drugs in health care settings*. DHHS (NIOSH) publication No. 2004-165. Cincinnati: CDC, 2004. Available at: www.cdc.gov/niosh/docs/2004-165/pdfs/2004-165.pdf. Accessed Apr 21, 2016.
- CDC National Institute of Occupational Safety and Health. *Workplace solutions. Safe handling of hazardous drugs for veterinary healthcare workers*. DHHS (NIOSH) publication No. 2010-150. Cincinnati: CDC, 2010. Available at: www.cdc.gov/niosh/docs/wp-solutions/2010-150/pdfs/2010-150.pdf. Accessed Apr 21, 2016.
- US Department of Labor Occupational Safety and Health Administration website. Hazard communication. Available at: www.osha.gov/dsg/hazcom/. Accessed Apr 21, 2016.
- AVMA. Workplace hazard communications. Available at: www.avma.org/KB/Resources/Reference/Pages/Workplace-Hazard-Communications.aspx. Accessed Apr 21, 2016.
- Boivin JF. Risk of spontaneous abortion in women occupationally exposed to anaesthetic gases: a meta-analysis. *Occup Environ Med* 1997;54:541-548.
- Shirangi A, Fritschi L, Holman CD. Associations of unscavenged anesthetic gases and long working hours with preterm delivery in female veterinarians. *Obstet Gynecol* 2009;113:1008-1017.

22. Korczynski RE. Anesthetic gas exposure in veterinary clinics. *Appl Occup Environ Hyg* 1999;14:384-390.
23. Gold CB, Beran GW. Occupational hazards to pregnant veterinarians. *Iowa State Univ Vet* 1983;45:55-60.
24. Smith JA. Anesthetic pollution and waste anesthetic gas scavenging. *Semin Vet Med Surg (Small Anim)* 1993;8:90-103.
25. CDC National Institute of Occupational Safety and Health. *Waste anesthetic gases: occupational hazards in hospitals*. DHHS (NIOSH) publication No. 2007-151. Cincinnati: CDC, 2007. Available at: www.cdc.gov/niosh/docs/2007-151/pdfs/2007-151.pdf. Accessed Apr 21, 2016.
26. Moore RM Jr, Davis YM, Kaczmarek RG. An overview of occupational hazards among veterinarians, with particular reference to pregnant women. *Am Ind Hyg Assoc J* 1993;54:113-120.
27. Johnson JA, Buchan RM, Reif JS. Effect of waste anesthetic gas and vapor exposure on reproductive outcome in veterinary personnel. *Am Ind Hyg Assoc J* 1987;48:62-66.
28. Fritschi L, Shirangi A, Robertson ID, et al. Trends in exposure of veterinarians to physical and chemical hazards and use of protection practices. *Int Arch Occup Environ Health* 2008;81:371-378.
29. Shirangi A, Fritschi L, Holman CD. Maternal occupational exposures and risk of spontaneous abortion in veterinary practice. *Occup Environ Med* 2008;65:719-725.
30. Fransman W, Roeleveld N, Peelen S, et al. Nurses with dermal exposure to antineoplastic drugs: reproductive outcomes. *Epidemiology* 2007;18:112-119.
31. Stücker I, Caillard JF, Collin R, et al. Risk of spontaneous abortion among nurses handling antineoplastic drugs. *Scand J Work Environ Health* 1990;16:102-107.
32. Dranitsaris G, Johnston M, Poirier S, et al. Are health care providers who work with cancer drugs at an increased risk for toxic events? A systematic review and meta-analysis of the literature. *J Oncol Pharm Pract* 2005;11:69-78.
33. Henry C. Safe handling of antineoplastic agents: a survey of protocols from 24 veterinary referral institutions. *Vet Cancer Soc Newslett* 1993;17:1,4-6.
34. Lucroy M. Review of safe cytotoxic drug preparation practices. *Vet Cancer Soc Newslett* 2000;24:3,6-8.
35. Lucroy M. Chemotherapy safety in veterinary practice: hazardous drug preparation. *Compend Contin Educ Pract Vet* 2001;23:860-867.
36. Takada S. Principles of chemotherapy safety procedures. *Clin Tech Small Anim Pract* 2003;18:73-74.
37. Epp T, Waldner C. Occupational health hazards in veterinary medicine: physical, psychological, and chemical hazards. *Can Vet J* 2012;53:151-157.
38. Shirangi A, Bower C, Holman CD, et al. A study of handling cytotoxic drugs and risk of birth defects in offspring of female veterinarians. *Int J Environ Res Public Health* 2014;11:6216-6230.
39. CDC National Institute of Occupational Safety and Health. *Small business guide for ethylene oxide*. OSHA 3359-04 2009. Washington, DC: OSHA, 2009. Available at: www.osha.gov/Publications/ethylene-oxide-final.html. Accessed Apr 21, 2016.
40. Ethylene oxide standard. 29 CFR 1940, 1047.
41. Elsheikha HM, Saied NA, El-Dahtory F. Risks to vets from pesticides: study into organophosphates. *Vet Times* 2009;39:28-29.
42. Bukowski J. Real and potential occupational health risks associated with insecticide use. *Compend Contin Educ Pract Vet* 1990;12:1617-1626.
43. McKillen M. Health and safety management in veterinary practices 4. Risk assessments for selected hazards: risk control by means of personal protective equipment (PPE). *Ir Vet J* 1999;52:168.
44. Shirangi A, Fritschi L, Holman CD, et al. Birth defects in offspring of female veterinarians. *J Occup Environ Med* 2009;51:525-533.
45. Vanderwall D. Safe handling of reproductive hormones routinely used in equine practice. *Clin Theriogenology* 2012;4:39-48.
46. Hall AL, Davies HW, Demers PA, et al. Occupational exposures to antineoplastic drugs and ionizing radiation in Canadian veterinary settings: findings from a national surveillance project. *Can J Public Health* 2013;104:e460-e465.
47. Selevan SG, Lindbohm ML, Hornung RW, et al. A study of occupational exposure to antineoplastic drugs and fetal loss in nurses. *N Engl J Med* 1985;313:1173-1178.
48. Valanis B, Vollmer WM, Steele P. Occupational exposure to antineoplastic agents: self-reported miscarriages and stillbirths among nurses and pharmacists. *J Occup Environ Med* 1999;41:632-638.
49. Lawson CC, Rocheleau CM, Whelan EA, et al. Occupational exposures among nurses and risk of spontaneous abortion. *Am J Obstet Gynecol* 2012;206:e321-e328.
50. Meijster T, Fransman W, Veldhof R, et al. Exposure to antineoplastic drugs outside the hospital environment. *Ann Occup Hyg* 2006;50:657-664.
51. Barr FM. Waste anaesthetic gas exposure in veterinary surgeries: a need for scavenging systems. *N Z Vet J* 1987;35:68-71.
52. Cohen EN, Bellville JW, Brown BW Jr. Anesthesia, pregnancy, and miscarriage: a study of operating room nurses and anesthesiologists. *Anesthesiology* 1971;35:343-347.
53. Corbett TH, Cornell RG, Endres JL, et al. Birth defects among children of nurse-anesthetists. *Anesthesiology* 1974;41:341-344.
54. Hoerauf K, Lierz M, Wiesner G, et al. Genetic damage in operating room personnel exposed to isoflurane and nitrous oxide. *Occup Environ Med* 1999;56:433-437.
55. Ward GS, Byland RR. Concentrations of methoxyflurane and nitrous oxide in veterinary operating rooms. *Am J Vet Res* 1982;43:360-362.
56. Occupational disease among operating room personnel: a national study. Report of an ad hoc committee on the effect of trace anesthetics on the health of operating room personnel, American Society of Anesthesiologists. *Anesthesiology* 1974;41:321-340.
57. CDC National Institute of Occupational Safety and Health. *Criteria for a recommended standard: occupational exposure to waste anesthetic gases and vapors*. DHHS (NIOSH) publication No. 77-140. Cincinnati: CDC, 1977. Available at: www.cdc.gov/niosh/docs/1970/77-140.html. Accessed Apr 21, 2016.
58. McGregor DG. Occupational exposure to trace concentrations of waste anesthetic gases. *Mayo Clin Proc* 2000;75:273-277.
59. Meyer RE. Anesthesia hazards to animal workers. *Occup Med* 1999;14:225-234.
60. Short CE, Harvey RC. Anesthetic waste gases in veterinary medicine: analysis of the problem and suggested guidelines for reducing personnel exposures. *Cornell Vet* 1983;73:363-374.
61. Tannenbaum TN, Goldberg RJ. Exposure to anesthetic gases and reproductive outcome. A review of the epidemiologic literature. *J Occup Med* 1985;27:659-668.
62. Allweiler SI, Kogan LR. Inhalation anesthetics and the reproductive risk associated with occupational exposure among women working in veterinary anesthesia. *Vet Anaesth Analg* 2013;40:285-289.
63. Lindbohm ML, Taskinen H. Spontaneous abortions among veterinarians. *Scand J Work Environ Health* 2000;26:501-506.
64. Shuhaiber S, Einarson A, Radde IC, et al. A prospective-controlled study of pregnant veterinary staff exposed to inhaled anesthetics and x-rays. *Int J Occup Med Environ Health* 2002;15:363-373.
65. Steele LL, Wilkins JR III. Occupational exposures and risks of spontaneous abortion among female veterinarians. *Int J Occup Environ Health* 1996;2:26-36.
66. Manley SV, McDonnell WN. Recommendations for reduction of anesthetic gas pollution. *J Am Vet Med Assoc* 1980;176:519-524.
67. Wilkins JR III, Steele LL. Occupational factors and reproductive outcomes among a cohort of female veterinarians. *J Am Vet Med Assoc* 1998;213:61-67.
68. Longley L. Exotic patients: biosecurity aspects worth considering. *Vet Times* 2010;40:14-15.

69. Jones M, Jeal H, Schofield S, et al. Rat-specific IgG and IgG(4) antibodies associated with inhibition of IgE-allergen complex binding in laboratory animal workers. *Occup Environ Med* 2014;71:619–623.
70. Gulsun S, Aslan S, Satıcı O, et al. Brucellosis in pregnancy. *Trop Doct* 2011;41:82–84.
71. Carcopino X, Raoult D, Bretelle F, et al. Q fever during pregnancy: a cause of poor fetal and maternal outcome. *Ann N Y Acad Sci* 2009;1166:79–89.
72. Williams CJ, Scheftel JM, Elchos BL, et al. Compendium of veterinary standard precautions for zoonotic disease prevention in veterinary personnel. *J Am Vet Med Assoc* 2015;247:1252–1277.
73. Guerra MA. Leptospirosis. *J Am Vet Med Assoc* 2009;234:472–478.
74. Puliyaath G, Singh S. Leptospirosis in pregnancy. *Eur J Clin Microbiol Infect Dis* 2012;31:2491–2496.
75. Baer R, Turnberg W, Yu D, et al. Leptospirosis in a small animal veterinarian: reminder to follow standardized infection control procedures. *Zoonoses Public Health* 2010;57:281–284.
76. Hankenson C. The 3 R's for laboratory animal zoonoses. *Contemp Top Lab Anim Sci* 2003;42:66,68,70.
77. Stewardson AJ, Grayson ML. Psittacosis. *Infect Dis Clin North Am* 2010;24:7–25.
78. Iowa State University, Center for Food Security and Public Health. Chlamydiosis. Available at: www.cfsph.iastate.edu/Factsheets/pdfs/chlamydiosis.pdf. Accessed Jun 6, 2016.
79. LeJeune J, Kersting A. Zoonoses: an occupational hazard for livestock workers and a public health concern for rural communities. *J Agric Saf Health* 2010;16:161–179.
80. Anderson A, Bijlmer H, Fournier PE, et al. Diagnosis and management of Q fever—United States, 2013: recommendations from CDC and the Q Fever Working Group. *MMWR Recomm Rep* 2013;62:1–30.
81. Nielsen SY, Molbak K, Nybo Andersen AM, et al. Prevalence of *Coxiella burnetii* in women exposed to livestock animals, Denmark, 1996 to 2002. *Euro Surveill* 2013;18:20528.
82. Weese JS, Peregrine AS, Armstrong J. Occupational health and safety in small animal veterinary practice: part II—parasitic zoonotic diseases. *Can Vet J* 2002;43:799–802.
83. Shuhaiber S, Koren G, Boskovic R, et al. Seroprevalence of *Toxoplasma gondii* infection among veterinary staff in Ontario, Canada (2002): implications for teratogenic risk. *BMC Infect Dis* 2003;3:8.
84. Waghorn DJ, Robson M. Occupational risk of *Pasteurella multocida* septicaemia and premature labour in a pregnant vet. *BJOG* 2003;110:780–781.
85. Sharpe D. Implementing a medical surveillance program for animal care staff. *Lab Anim (NY)* 2009;38:275–278.
86. Cheek R. What can you get from your pet? *Vet Tech* 2009;30:32–38.
87. McGrath J. Beware the unseen bugs. *Ir Vet J* 2009;62:794–795.
88. Widmer WS, Shaw SM, Thrall DE. Effects of low-level exposure to ionizing radiation: current concepts and concerns for veterinary workers. *Vet Radiol Ultrasound* 1996;37:227–239.
89. US Nuclear Regulatory Commission website. 10 CFR § 20.1208. Dose equivalent to an embryo/fetus. Available at: www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1208.html. Accessed Jan 2, 2017.
90. Baker M. An introduction to radiation protection in veterinary radiography. *Vet Nurse* 2014;5:496–501.
91. Tyson R, Smiley DC, Pleasant RS, et al. Estimated operator exposure for hand holding portable x-ray units during imaging of the equine distal extremity. *Vet Radiol Ultrasound* 2011;52:121–124.
92. Barbee D. Invited guest editorial in response to: estimated operator exposure for hand holding portable x-ray units during imaging of the equine distal extremity (lett). *Vet Radiol Ultrasound* 2011;52:213–214; author reply, 214.
93. Martinez NE, Kraft SL, Gibbons DS, et al. Occupational per-patient radiation dose from a conservative protocol for veterinary (18) F-fluorodeoxyglucose positron emission tomography. *Vet Radiol Ultrasound* 2012;53:591–597.
94. Shirangi A, Fritschl L, Holman CD. Prevalence of occupational exposures and protective practices in Australian female veterinarians. *Aust Vet J* 2007;85:32–38.
95. Thomas HL, Trout DR, Dobson H, et al. Radiation exposure to personnel during examination of limbs of horses with a portable hand-held fluoroscopic unit. *J Am Vet Med Assoc* 1999;215:372–379.
96. Moritz SA, Hueston WD, Wilkins JR III. Patterns of ionizing radiation exposure among women veterinarians. *J Am Vet Med Assoc* 1989;195:737–739.
97. Crimmins WF. Practices should take precautions to protect pregnant workers. *J Am Vet Med Assoc* 2001;218:1251–1252.
98. Saurel-Cubizolles MJ, Zeitlin J, Lelong N, et al. Employment, working conditions, and preterm birth: results from the European case-control survey. *J Epidemiol Community Health* 2004;58:395–401.
99. Henriksen TB, Hedegaard M, Secher NJ, et al. Standing at work and preterm delivery. *Br J Obstet Gynaecol* 1995;102:198–206.
100. Mozurkewich EL, Luke B, Avni M, et al. Working conditions and adverse pregnancy outcome: a meta-analysis. *Obstet Gynecol* 2000;95:623–635.
101. Henriksen TB, Hedegaard M, Secher NJ. Standing and walking at work and birthweight. *Acta Obstet Gynecol Scand* 1995;74:509–516.
102. MacDonald LA, Waters TR, Napolitano PG, et al. Clinical guidelines for occupational lifting in pregnancy: evidence summary and provisional recommendations. *Am J Obstet Gynecol* 2013;209:80–88.
103. Reijula K, Rasanen K, Hamalainen M, et al. Work environment and occupational health of Finnish veterinarians. *Am J Ind Med* 2003;44:46–57.
104. Wilkins JR III, Bowman ME. Needlestick injuries among female veterinarians: frequency, syringe contents and side-effects. *Occup Med (Lond)* 1997;47:451–457.
105. Wright JG, Jung S, Holman RC, et al. Infection control practices and zoonotic disease risks among veterinarians in the United States. *J Am Vet Med Assoc* 2008;232:1863–1872.
106. Hafer AL, Langley RL, Morrow WM, et al. Occupational hazards reported by swine veterinarians in the United States. *J Swine Health Prod* 1996;4:128–141.
107. Schenker MB, Samuels SJ, Green RS, et al. Adverse reproductive outcomes among female veterinarians. *Am J Epidemiol* 1990;132:96–106.
108. Hedegaard M, Henriksen TB, Secher NJ, et al. Do stressful life events affect duration of gestation and risk of preterm delivery? *Epidemiology* 1996;7:339–345.
109. Hansen D, Lou HC, Olsen J. Serious life events and congenital malformations: a national study with complete follow-up. *Lancet* 2000;356:875–880.
110. Khashan AS, McNamee R, Abel KM, et al. Rates of preterm birth following antenatal maternal exposure to severe life events: a population-based cohort study. *Hum Reprod* 2009;24:429–437.
111. Larsen AD. The effect of maternal exposure to psychosocial job strain on pregnancy outcomes and child development. *Dan Med J* 2015;62:B5015.
112. Hansez I, Schins F, Rollin F. Occupational stress, work-home interference and burnout among Belgian veterinary practitioners. *Ir Vet J* 2008;61:233–241.
113. Fenster L, Schaefer C, Mathur A, et al. Psychologic stress in the workplace and spontaneous abortion. *Am J Epidemiol* 1995;142:1176–1183.
114. Jeyaretnam J, Jones H, Phillips M. Disease and injury among veterinarians. *Aust Vet J* 2000;78:625–629.
115. Nett RJ, Witte TK, Holzbauer SM, et al. Risk factors for suicide, attitudes toward mental illness, and practice-related stressors among US veterinarians. *J Am Vet Med Assoc* 2015;247:945–955.
116. Scotney RL, McLaughlin D, Keates HL. A systematic review of the effects of euthanasia and occupational stress in personnel working with animals in animal shelters, veterinary clinics, and biomedical research facilities. *J Am Vet Med Assoc* 2015;247:1121–1130.
117. CDC National Institute of Occupational Safety and Health

- website. Reproductive health and the workplace. Available at: www.cdc.gov/niosh/topics/repro/default.html. Accessed May 4, 2016.
118. CDC National Institute of Occupational Safety and Health. *The effects of workplace hazards on female reproductive health*. DHHS (NIOSH) publication No. 99-104. Cincinnati: CDC, 1999. Available at: www.osha.gov/dsg/hazcom/. Accessed Apr 21, 2016.
 119. CDC National Institute of Occupational Safety and Health. Veterinary safety and health. Available at: www.cdc.gov/niosh/topics/veterinary/hazard.html. Accessed Apr 21, 2016.
 120. US Department of Labor Occupational Safety and Health Administration website. Available at: www.osha.gov. Accessed May 4, 2016.
 121. AVMA. About AVMA. Available at: www.avma.org/About/Pages/default.aspx. Accessed Jan 2, 2017.
 122. AVMA. Available at: www.avma.org/Pages/home.aspx. Accessed Jan 2, 2017.