



How to Manage Allergic Reactions to Contrast Agent in Pregnant Patients

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OBJECTIVE. This article reviews optimal treatment of allergic reactions to iodinated contrast material in pregnant patients. Initial evaluation and treatment of a pregnant patient is similar to that for a nonpregnant patient. However, additional steps, including assessment for uterine cramping, using left uterine displacement to improve venous return, and maintaining blood pressure to ensure placental perfusion, may be required.

CONCLUSION. Adequate preparation and a team approach will provide optimal care for a pregnant patient who has an allergic reaction to a contrast agent.

As the use of CT has significantly increased in recent years, so has its use in evaluating pregnant patients [1, 2]. Despite the increase in the use of CT, radiologists' knowledge of how to treat contrast agent-induced allergic reactions, particularly the rare severe reactions, has historically been suboptimal [3–5].

A reaction to contrast agent in any patient must be evaluated promptly and, if necessary, treated. An acute reaction to contrast agent in a pregnant patient is a very uncommon event with which most radiologists have little to no experience. Questions to be considered include the following: Are there differences in which medications should be administered? How does the presence of the fetus affect the type of treatment? How does the gestational age of the fetus affect the treatment for a reaction to a contrast agent? The purpose of this article is to discuss how to optimally treat reactions to iodinated contrast material for CT in pregnant patients.

Indications for Contrast-Enhanced CT in Pregnancy

Radiologists' recommendations and protocols for imaging the acutely ill pregnant patient should be guided by the clinical presentation. Sonography is usually the imaging modality of choice when evaluating the pregnant patient [6]. When the findings of sonography or unenhanced MRI are nondiagnostic or equivocal, or when the risk of radiation to the fetus is outweighed by the benefit of making a significant diagnosis in the mother, the

use of CT is advocated for diagnosing the cause of abdominal pain, tumor staging, and postoperative complications [6]. Additional clinical situations where the use of contrast-enhanced CT may be indicated during pregnancy include assessment of acute trauma and suspected pulmonary embolism [7].

The American College of Radiology's (ACR's) recommendation regarding the use of CT in pregnant patients, as in all patients, is to keep radiation dose as low as reasonably achievable (i.e., the ALARA principle) [6, 8]. For an imaging examination using ionizing radiation, oral and written informed consent should be obtained from the pregnant patient [8, 9]. Iodinated contrast material is considered safe in pregnancy if needed (U.S. Food and Drug Administration [FDA] category B) [6].

Risk Factors for Reaction to IV Contrast Agent

The ACR has cited three general principles for the use of contrast material in patients undergoing CT examinations: ensure that the administration of contrast material is appropriate for the patient and imaging indication, minimize the likelihood of a reaction to the contrast material, and be prepared to treat a reaction in case one does occur [9]. Factors that increase the risk of an adverse reaction to IV contrast material in pregnant patients are similar to those for nonpregnant patients. These include a history of allergies, especially a prior allergic reaction to contrast agent, asthma, significant cardiac disease, and anxiety [9]. There is no evidence in the

Keywords: allergic reaction, computed tomography, iodinated contrast, pregnancy

DOI:10.2214/AJR.15.14976

Received May 7, 2015; accepted after revision July 23, 2015.

Based on a presentation at the Radiological Society of North America 2014 annual meeting, Chicago, IL.

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AJR 2016; 206:247–252

0361–803X/16/2062–247

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TABLE 1: Categories of Acute Reactions to IV Contrast

Mild	Allergiclike	Physiologic
	Limited urticaria/pruritus	Limited nausea/vomiting
	Limited cutaneous edema	Transient flushing/warmth/chills
	Limited "itchy"/"scratchy" throat	Headache/dizziness/anxiety
	Nasal congestion	Mild hypertension
	Sneezing/conjunctivitis/rhinorrhea	Vasovagal reaction that resolves spontaneously
Moderate	Allergiclike	Physiologic
	Diffuse urticaria/pruritus	Protracted nausea/vomiting
	Diffuse erythema, stable vital signs	Hypertensive urgency
	Facial edema without dyspnea	Isolated chest pain
	Throat tightness or hoarseness without dyspnea	Vasovagal reaction that requires and is responsive to treatment
	Wheezing/bronchospasm mild or no hypoxia	
Severe	Allergiclike	Physiologic
	Diffuse edema, or facial edema with dyspnea	Vasovagal reaction resistant to treatment
	Diffuse erythema with hypotension	Arrhythmia
	Laryngeal edema with stridor and/or hypoxia	Convulsions, seizures
	Wheezing/bronchospasm, significant hypoxia	Hypertensive emergency
	Anaphylactic shock (hypotension + tachycardia)	

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literature that pregnancy increases the risk of an allergic reaction to contrast.

Recognizing an Allergic Reaction to Contrast Agent

When evaluating patients for a potential reaction, the patient should quickly be assessed in terms of how they look and whether they are able to speak and breathe, which can be determined by asking the patient to describe how they are feeling. This should be followed by checking the pulse rate and strength, listening to the lungs with a stethoscope, and checking the blood pressure [9]. Once it has been determined that a pregnant patient has had a reaction to a contrast agent, it should be classified as mild, moderate, or severe according to ACR guidelines [9] (Table 1). Such reactions may occur immediately (nearly all life-threatening reactions to contrast material occur within the first 20 minutes after injection) or can be delayed (30 minutes to 7 days), with most delayed reactions occurring between 3 hours and 2 days after injection [9].

There are several potential contrast reaction symptoms unique to pregnancy that should be assessed. Some examples are intense vulvar and vaginal itching, low back pain, and uterine cramps [10]. Nonreassuring fetal status, as assessed by fetal heart rate monitoring and preterm labor, should be considered severe reactions [10].

Treatment

The treatment of an acute reaction in a pregnant patient is similar to that for a non-pregnant patient, with several modifications (Table 2). Many of the drugs used to treat allergic reactions to contrast agents have historically been labeled as FDA pregnancy category B (i.e., animal reproduction studies have failed to demonstrate a risk to the fetus, and there are no adequate and well-controlled studies on pregnant women) or C (i.e., animal reproduction studies have shown an adverse effect on the fetus and there are no adequate and well-controlled studies in humans, but potential benefits may warrant the use of the drug in pregnant women despite

potential risks) [11]. According to the Pregnancy and Lactation Labeling Rule issued by the FDA on December 4, 2014 [12], all FDA pregnancy categories A, B, C, D, and X were to be removed from prescription drugs by June 30, 2015. Therefore, this article will mention but not emphasize FDA pregnancy categories when discussing the treatment of reactions to contrast agents. In the new system, there will be a risk and benefit discussion for each drug's labeling, instead of a distinct category. This was done to assist health care providers in counseling of pregnant women who need to take medication, recognizing that many pregnant women need to continue taking medications for chronic conditions throughout their pregnancy, thus allowing them to make informed and educated decisions [12]. Because of the time-sensitive nature of treating an acute reaction to a contrast agent, treating the allergic reaction with the appropriate medications takes priority over obtaining a detailed medical history to determine whether the patient has a chronic condition that might be a contraindication to the medication in the nonacute setting.

Mild-to-Moderate Reaction

During the evaluation and treatment of reactions to contrast agents, IV access should be preserved or reestablished if the IV line has already been removed. Vital signs should be monitored for at least 30 minutes or as long as necessary to ensure clinical stability and improvement in symptoms. The patient should be monitored with pulse oximetry, and oxygen should be given by mask if indicated [9]. This evaluation and treatment typically takes place in close proximity to the CT scanner, in a patient holding area or where IV lines are started.

For mild reactions such as urticaria, antihistamines are generally considered safe when necessary [13, 14]. Much of the literature on antihistamine use in pregnancy is based on chronic conditions such as asthma, pregnancy urticaria, and other allergic diseases. First-generation antihistamines are preferred in this body of literature, with chlorpheniramine, hydroxyzine, and dexchlorpheniramine (all FDA category B) considered the safest during pregnancy [14]. The American College of Obstetricians and Gynecologists and the American College of Allergy, Asthma, and Immunology have recommended chlorpheniramine and triprolidine as the antihistamines of choice

Allergic Reactions to Contrast Agents During Pregnancy

TABLE 2: Treatment of Selected Acute Reactions to IV Contrast Agents Including Suggested Modifications for Pregnant Patients

Reaction	Monitoring	Medications	Modification for Pregnant Patients
Mild hives	IV, vital signs, pulse oximetry, O ₂ by face mask	None or diphenhydramine 25–50 mg by mouth	First-generation antihistamines (chlorpheniramine, tripelemnamine, diphenhydramine); alternatives are loratadine or cetirizine
Diffuse erythema and hypotension	IV, vital signs, pulse oximetry, O ₂ by face mask	Epinephrine IV 1–3 mL of 1:10,000 dilution; administer slowly into a running IV infusion of saline; can repeat up to 1 mg total OR intramuscular epinephrine 0.3 mg (1:1000), can repeat up to 1 mg total	None
Mild bronchospasm	IV, vital signs, pulse oximetry, O ₂ by face mask	Albuterol 2 puffs	None
Moderate-to-severe bronchospasm	IV, vital signs, pulse oximetry, O ₂ by face mask	Albuterol and epinephrine 0.3 mg intramuscularly (1:1000)	None
Laryngeal edema	IV, vital signs, pulse oximetry, O ₂ by face mask	Epinephrine IV 1–3 mL of 1:10,000 dilution; administer slowly into a running IV infusion of saline; can repeat up to 1 mg total OR epinephrine 0.3 mg intramuscularly (1:1000), can repeat up to 1 mg total	None
Hypotension, bradycardia	IV, vital signs, pulse oximetry, O ₂ by face mask, raise legs, IV fluids	Atropine 0.6–1 mg IV	Left lateral tilt. Atropine may cause a change in fetal behavior (e.g., increase in fetal heart rate, decrease in fetal heart rate variability, decrease in fetal breathing)
Hypotension, tachycardia	IV, vital signs, pulse oximetry, O ₂ by face mask, raise legs, IV fluids	Epinephrine IV 1–3 mL of 1:10,000 dilution; administer slowly into a running IV infusion of saline; can repeat up to 1 mg total OR epinephrine 0.3 mg intramuscularly (1:1000), can repeat up to 1 mg total	Left lateral tilt. Maintain systolic blood pressure > 90 mm Hg or > 80% of baseline systolic blood pressure to ensure adequate perfusion to placenta
Hypertensive crisis	IV, vital signs, pulse oximetry, O ₂ by face mask	Labetalol 20 mg IV or nitroglycerin sublingual 0.4 mg and furosemide 20–40 mg IV	Gradual reduction in blood pressure to not compromise uterine perfusion. Labetalol or hydralazine are preferred agents in pregnancy [27]. Avoid furosemide unless evidence of fluid overload. Nitroglycerin is a strong tocolytic, and pregnant patients are typically resistant to its hypotensive effects
Pulmonary edema	IV, vital signs, pulse oximetry, mask O ₂ , elevated head of bed	Furosemide 20–40 mg IV and morphine 1–3 mg IV	Furosemide 20–40 mg IV. Morphine can decrease fetal heart rate variability, perinatal risk may outweigh the theoretic benefit
Seizures	IV, vital signs, pulse oximetry, O ₂ by face mask, turn patient on side	Lorazepam 2–4 mg IV	Early intervention to secure maternal airway due to full stomach and increased aspiration risk after 18–20 weeks' gestation
Hypoglycemia	IV, O ₂ by face mask	Oral glucose, 50% dextrose in water 1 ampule, 50% dextrose in water IV fluids	None
Panic attack	IV, vital signs, pulse oximetry	Supportive care	None

Note—Monitoring and Medications columns are based on recommendations from the American College of Radiology [9]. The pulse oximetry goal is > 94% in pregnancy.

in a joint position statement [15]. The older first-generation antihistamines are likely endorsed because they have been studied more extensively than other newer antihistamines. Diphenhydramine (FDA category B; Bena-

dryl, McNeil Consumer Healthcare), another first-generation antihistamine, is more widely available in radiology departments in the United States and is also generally considered safe. This is administered orally in

cases of mild or moderate urticaria, but intramuscular or IV administration is used in cases of severe urticaria. If an oral second-generation antihistamine is to be used, loratadine or cetirizine should be selected, but

their use is somewhat controversial in early pregnancy (first trimester) in the nonacute setting [13–15].

A unique form of urticaria associated with pregnancy is termed “pregnancy urticaria” or “pruritic urticarial papules and plaques of pregnancy,” the cause of which is not well understood [13, 16]. This is a benign self-limited pruritic papulourticarial inflammatory disorder that usually affects the primigravida in the last trimester of pregnancy. This condition is characterized by intensely pruritic urticarial papules within or adjacent to striae on the abdomen or limbs [16]. If a radiologist assesses a pregnant patient with a urticarial reaction after a CT scan, it is important to inquire whether the patient arrived for the CT scan with pregnancy urticaria, either previously diagnosed or noticed before the administration of contrast agent, to distinguish it from an acute reaction to contrast agent. It is not known whether a history of pregnancy urticaria would increase the risk of a reaction to contrast agent, or whether a patient with pregnancy urticaria should be premedicated.

When treating moderate reactions, such as mild-to-moderate bronchospasm, a short-acting inhaled β_2 -agonist is recommended. Albuterol is the short-acting inhaled β_2 -agonist of choice because of its excellent safety profile [17]. This can be administered via nebulizer treatment or simple metered dose inhaler.

Severe Reactions

The treatment of severe reactions to contrast agent is the most critical for all radiologists to be familiar with, because these reactions can cause permanent morbidity or death if not managed appropriately [9]. When treating an acute anaphylactoid reaction in a pregnant patient, advanced cardiovascular life support (ACLS) guidelines should be followed. The initial evaluation should include assessment of the maternal circulation, airway and breathing, and assessment of skin and mental status changes. The appropriate emergency response team should be notified. This is preferably an obstetrically oriented code team. The suggested composition of such a team includes members of the regular adult resuscitation team, an obstetrician, an obstetrical nurse, an obstetrical anesthesiologist, and a member of the neonatology service [18].

The mother should be placed in the left lateral decubitus position, supine with a leftward tilt using a wedge, or supine with manu-

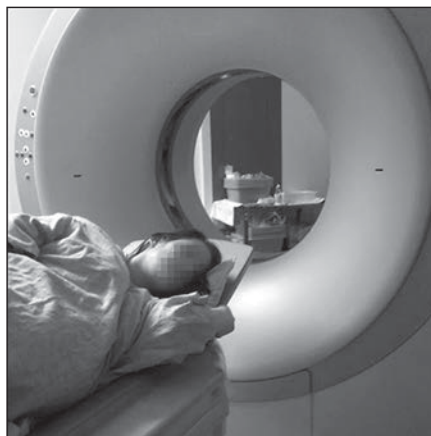


Fig. 1—Photograph of pregnant patient in left lateral decubitus position. Left lateral decubitus positioning of pregnant patient alleviates inferior vena cava compression and improves venous return.

al left uterine displacement for any pregnant patient with an obviously gravid uterus (Figs. 1 and 2). These maneuvers are used to prevent the gravid uterus from compressing the inferior vena cava and obstructing venous return to the heart [19]. The manual left uterine displacement maneuver should be used if an extra provider is available to perform this maneuver, and when chest compressions are necessary, which are better performed when the patient is supine [19].

If the patient is more than 24 weeks pregnant, continuous external fetal heart rate monitoring should be instituted to aid in guiding resuscitation efforts because of potential fetal viability. The patient should be given 100% oxygen, and IV access should be established and maintained above the diaphragm. In addition, the mother should be assessed for hypotension. Maternal hypotension that warrants therapy is a systolic blood pressure less than 100 mm Hg or less than 80% of baseline, because this can result in reduced placental perfusion [19]. It is of utmost importance to maintain left uterine displacement and the systolic blood pressure greater than 90 mm Hg to ensure adequate placental perfusion [10]. The patient should be given epinephrine (FDA category C) if needed for life-threatening emergencies [13].

There are no good data in humans to show whether epinephrine should be administered intramuscularly or IV during anaphylaxis [20]. However, both a meta-analysis on using epinephrine for the treatment of anaphylaxis and a review of how to treat anaphylaxis during pregnancy recommend the intramuscu-



Fig. 2—Manual displacement of gravid uterus. Photograph shows how manual displacement of gravid uterus, pushing upward and to left, alleviates inferior vena cava compression and improves venous return. This should be used in severe reactions requiring advanced cardiovascular life support treatment and chest compressions, which are easier to perform while patient is supine, when additional provider is available to perform manual uterine displacement.

lar route [10, 20]. Epinephrine intramuscular autoinjectors (EpiPen, Mylan Specialty) are often available in radiology departments and are easier to use and train people to use than IV epinephrine, considering that radiologists only infrequently administer epinephrine. Although the ACR manual on contrast media recommends IV over intramuscular administration of epinephrine because, in hypotensive patients, the extremities may not be perfused sufficiently to allow adequate absorption of an intramuscularly administered drug [9], this consideration needs to be balanced with the risk of a fatal overdose of IV epinephrine [19].

Therefore, for providers who are unaccustomed to administering epinephrine, the intramuscular route may be preferred, whereas code teams and providers who frequently administer epinephrine often administer it IV. IV epinephrine (1–3 mL of 1:10,000 dilution) is administered slowly into a running IV infusion of saline and can be repeated up to 1 mg in total. Intramuscular epinephrine (0.3 mg, 1:1000 dilution) can be repeated up to 1 mg in total.

IV fluids should also be administered, 5–10 mL/kg [10] or 1000 mL of 0.9% saline, rapidly within the first 5–10 minutes. The patient should not sit or stand suddenly because this can lead to cardiac arrest caused by the empty inferior vena cava or empty ventricle syndrome [10].

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Maternal hypoxemia can also affect the fetus and should be immediately corrected, with the goal of maintaining peripheral oxygen saturation greater than 94%. In cases of airway obstruction, intubation and possibly tracheostomy may be required. Endotracheal tube insertion may be difficult because of pregnancy-associated edema and friability of the upper airway and should be performed by the most experienced health care professional available [10]. Because of possible full-stomach status and anticipated rapid desaturation, rapid sequence induction after thorough preoxygenation is preferred.

A nonreassuring fetal heart rate tracing, as evidenced by recurrent late decelerations or prolonged fetal bradycardia, may necessitate consideration of delivery if it persists despite maternal resuscitative efforts. Maternal resuscitation is far superior to delivery, if possible. The benefits of emergent cesarean delivery in refractory anaphylaxis need to be balanced with the risks of performing surgery in a hypoxic or hypotensive pregnant patient and the possible neonatal morbidity and mortality related to prematurity, especially at early gestational ages [10].

Cardiovascular collapse is common in severe anaphylaxis. If it is not promptly corrected, vasodilation and increased capillary permeability can cause decreased preload and relative hypovolemia and can rapidly lead to cardiac arrest. The patient should be assessed for hypovolemia and given a fluid bolus when required. If a pregnant patient develops cardiac arrest, according to the American Heart Association Guidelines [18], treatment should follow the basic life support and ACLS algorithms with the following modifications: left uterine displacement should be maintained; the IV line should be started above the diaphragm; if the patient is receiving IV or intraosseous magnesium, the magnesium should be stopped and the patient should be given IV or intraosseous calcium gluconate; and hand placement for chest compressions should be approximately 2–3 cm higher on the sternum than in the nonpregnant patient.

It is important to note that none of the resuscitation drugs are absolutely contraindicated in maternal cardiac arrest [21]. If the gestational age is greater than 20 weeks and there is no return of spontaneous circulation within 4 minutes, consideration should be given to emergent cesarean delivery, not for fetal benefit but to optimize maternal resuscitative efforts [18]. Figure 3 summarizes the

Fig. 3—Initial treatment of acute anaphylaxis in pregnant patient [10, 19, 21].

- Assess maternal circulation, airway, breathing, mental status and skin.
- Trigger emergency response: preferably “obstetrical code team” or call emergency response services.
- Adult resuscitation team, obstetrician, obstetrical anesthesiologist, and neonatologist.
- Promptly administer 0.3 mg epinephrine intramuscularly. This can be repeated every 5 to 15 minutes.
 - OR Epinephrine IV 1–3 ml of 1:10,000 dilution; administer slowly into a running IV infusion of saline; can repeat up to 1 mg total.
- Administer high-flow 100% humidified O₂ through a close-fitting mask.
- Place patient in left lateral decubitus position or perform leftward manual uterine displacement.
- Establish large-bore IV access: either two 14- or 16-gauge.
- If hypotensive, administer fluids, can administer up to 7 L.
- Maintain maternal systolic blood pressure > 90 mm Hg to ensure adequate perfusion to the placenta.
- Continuous noninvasive electronic monitoring of blood pressure, heart rate, and oxygenation.
- Initiate cardiopulmonary resuscitation when appropriate.

initial steps in treating anaphylaxis in pregnant patients [10, 19, 21].

Two additional relatively rare severe reactions to contrast media include seizures and pulmonary edema. In the event of a seizure after administration of iodinated contrast material, IV lorazepam should be administered initially to stop the seizure, similar to treatment in nonpregnant patients [22]. The maternal airway should be secured early because of full stomach and increased aspiration risk after 18–20 weeks’ gestation.

Pulmonary edema is a rare severe reaction that is critical to recognize in the pregnant patient. The treatment is similar to that for nonpregnant patients, with IV furosemide considered the first-line therapy (FDA category C) [23]. IV morphine is also recommended by the ACR in the treatment of pulmonary edema due to a reaction to contrast material [9]; however, morphine will decrease fetal heart rate variability, and perinatal risk may outweigh the theoretic benefit in pregnant patients.

Discussion

The treatment of reactions to iodinated contrast material, particularly severe reactions, has historically been a situation for which diagnostic radiologists are unprepared and undertrained [3–5], likely related to the infrequency of such reactions. Allergic reactions to IV contrast agents in pregnant patients can be a source of even more anxiety for the treating radiologist because of their rarity, the young age of the pregnant patient, and the associated risk to the fetus. Being prepared to treat reactions to contrast agents in both pregnant and nonpregnant patients improves patient care and the confidence of the treating radiologist.

The ACR manual on contrast media [9] is a great resource for radiologists learning or reviewing how to treat reactions to contrast material. Their treatment tables can be posted in the reading rooms or kept close at hand in areas where such reactions may occur, such as the IV holding areas and the CT scanner rooms. The contrast manual can be bookmarked on the computers in these rooms. The ACR has a mobile version of the contrast manual as well. However, routine review of plans and procedures for treating contrast reactions by the radiology department staff is essential.

The literature has shown that simulation is an effective method of training for low-frequency high-acuity situations [24–26]. Simulation training has been successful in teaching radiologists how to treat reactions to contrast agents. As such training becomes more available in radiology residency programs and continuing medical education meetings, radiologists will be better prepared for treatment of all reactions to contrast agents in a variety of patients [26].

When evaluating a pregnant patient with a potential reaction to a contrast agent, there are several considerations unique to the pregnant patient that need to be assessed, most notably changes in fetal status or symptoms of labor, such as low back pain or uterine cramps. In the treatment of reactions to contrast agents in pregnant patients, the mother should initially be evaluated and treated similarly to a nonpregnant adult, in accordance with the ACR contrast manual guidelines [9]. In the event of a cardiac arrest, the pregnant patient should be treated per the ACLS and basic life support algorithms, with some modifications. Placing the patient in a left lateral decubitus position if pos-

sible or using a left uterine displacement maneuver, especially if the patient is in cardiac arrest, improves venous return. Maintaining the patient's blood pressure is of utmost importance to ensure placental perfusion. When indicated, it is important for the radiologist to call for help from a multidisciplinary obstetrical code team, which should ideally include an obstetrician, an obstetrical nurse, an obstetrical anesthesiologist, and a neonatologist. Being prepared and using a team approach will provide optimal care for a pregnant patient having a reaction to a contrast agent.

References

- Wang PI, Chong ST, Kiehl AZ, et al. Imaging of pregnant and lactating patients. Part I. Evidence-based review and recommendations. *AJR* 2012; 198:778–784
- Lazarus E, Debenedictis C, North D, Spencer PK, Mayo-Smith WW. Utilization of imaging in pregnant patients: 10-year review of 5270 examinations in 3285 patients—1997–2006. *Radiology* 2009; 251:517–524
- Bartlett MJ, Bynevelt M. Acute contrast reaction management by radiologists: a local audit study. *Australas Radiol* 2003; 47:363–367
- Confino-Cohen R, Goldberg A. Safe administration of contrast media: what do physicians know? *Ann Allergy Asthma Immunol* 2004; 93:166–170
- Lightfoot CB, Abraham RJ, Mammen T, Abdoell M, Kapur S, Abraham RJ. Survey of radiologists' knowledge regarding the management of severe contrast material-induced allergic reactions. *Radiology* 2009; 251:691–696
- Wieseler KM, Bhargava P, Kanak KM, Vaidya S, Stewart BK, Dighe MK. Imaging in pregnant patients: examination appropriateness. *RadioGraphics* 2010; 30:1215–1229; discussion, 1230–1233
- Goldberg-Stein S, Liu B, Hahn PF, Lee SI. Body CT during pregnancy: utilization trends, examination indications, and fetal radiation doses. *AJR* 2011; 196:146–151
- American College of Radiology. *ACR practice guideline for imaging pregnant or potentially pregnant adolescents and women with ionizing radiation*. Reston, VA: American College of Radiology, 2008
- American College of Radiology. *ACR manual on contrast media, version 9*. Reston, VA: American College of Radiology, 2013
- Simons FE, Schatz M. Anaphylaxis during pregnancy. *J Allergy Clin Immunol* 2012; 130:597–606
- U.S. Food and Drug Administration; Department of Health and Human Services. Content and format of labeling for human prescription drug and biological products: requirements for pregnancy and lactation labeling. Final rule. *Fed Regist* 2014; 79:72063–72103
- U.S. Food and Drug Administration (FDA). Pregnancy and lactation labeling final rule. FDA website. www.fda.gov/Drugs/DevelopmentApprovalProcess/DevelopmentResources/Labeling/ucm093307.htm. Published December 4, 2014. Accessed July 10, 2015
- Pali-Schöll I, Motala C, Jensen-Jarolim E. Asthma and allergic diseases in pregnancy: a review. *World Allergy Organ J* 2009; 2:26–36
- Kar S, Krishnan A, Preetha K, Mohankar A. A review of antihistamines used during pregnancy. *J Pharmacol Pharmacother* 2012; 3:105–108
- [No authors listed.] The use of newer asthma and allergy medications during pregnancy. The American College of Obstetricians and Gynecologists (ACOG) and The American College of Allergy, Asthma and Immunology (ACAAI). *Ann Allergy Asthma Immunol* 2000; 84:475–480
- Roth MM. Pregnancy dermatoses: diagnosis, management, and controversies. *Am J Clin Dermatol* 2011; 12:25–41
- National Heart, Lung, and Blood Institute; National Asthma Education and Prevention Program Asthma and Pregnancy Working Group. NAEPP expert panel report: managing asthma during pregnancy—recommendations for pharmacologic treatment; 2004 update. *J Allergy Clin Immunol* 2005; 115:34–46
- Hui D, Morrison LJ, Windrim R, et al. The American Heart Association 2010 guidelines for the management of cardiac arrest in pregnancy: consensus recommendations on implementation strategies. *J Obstet Gynaecol Can* 2011; 33:858–863
- Vanden Hoek TL, Morrison LJ, Shuster M, et al. Part 12: cardiac arrest in special situations—2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation* 2010; 122:S829–S861
- Sheikh A, Shehata YA, Brown SG, Simons FE. Adrenaline (epinephrine) for the treatment of anaphylaxis with and without shock. *Cochrane Database Syst Rev* 2008; 4:CD006312
- Lipman S, Cohen S, Einav S, et al. The Society for Obstetric Anesthesia and Perinatology consensus statement on the management of cardiac arrest in pregnancy. *Anesth Analg* 2014; 118:1003–1016
- Beach RL, Kaplan PW. Seizures in pregnancy: diagnosis and management. *Int Rev Neurobiol* 2008; 83:259–271
- Dennis AT, Solnordal CB. Acute pulmonary oedema in pregnant women. *Anaesthesia* 2012; 67:646–659
- Bruppacher HR, Alam SK, LeBlanc VR, et al. Simulation-based training improves physicians' performance in patient care in high-stakes clinical setting of cardiac surgery. *Anesthesiology* 2010; 112:985–992
- McCoy CE, Menchine M, Anderson C, Kollen R, Langdorf MI, Lotfipour S. Prospective randomized crossover study of simulation vs. didactics for teaching medical students the assessment and management of critically ill patients. *J Emerg Med* 2011; 40:448–455
- Wang CL, Schopp JG, Kani K, et al. Prospective randomized study of contrast reaction management curricula: computer-based interactive simulation versus high-fidelity hands-on simulation. *Eur J Radiol* 2013; 82:2247–2252
- Podymow T, August P. Update on the use of antihypertensive drugs in pregnancy. *Hypertension* 2008; 51:960–969

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