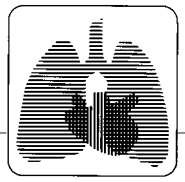



# Risks of and Recommendations for Flexible Bronchoscopy in Pregnancy*

## A Review

*Imad J. Bahhady, MD; and Armin Ernst, MD, FCCP*

***(CHEST 2004; 126:1974–1981)***

**Key words:** bronchoscopy; complications; pregnancy

**Abbreviations:** FB = flexible bronchoscopy; FDA = Food and Drug Administration

Generally, medical procedures such as flexible bronchoscopy (FB) are avoided in pregnancy as a result of procedure- and sedation-related risks to the mother and the fetus. However, there are situations in which these procedures might be diagnostically or therapeutically indicated and should not be delayed.

The current published knowledge about FB in pregnancy is limited to a few case reports[1–8] and one review article[9]; however, upper and lower GI endoscopy during pregnancy is well described, and the lessons learned may be partially extrapolated to FB.

The published studies on endoscopy during pregnancy are mostly retrospective and small.[10] The only exception is a large, case-control study[11] comparing 83 pregnant women undergoing esophagogastroduodenoscopy with matched pregnant (not undergoing the procedure) and nonpregnant (undergoing the same procedure) women as control subjects. The study reported no increase in adverse events among the pregnant treatment group. However, statistical power was insufficient to exclude a small, but clinically important, fetal risk from endoscopy.

Bronchoscopy during pregnancy has its own specific risks from inserting instruments into the airway, such as impaired gas exchange, severe violent cough, and barotrauma (pneumothorax and pneumomediastinum), which may actually be more hazardous to the pregnant patient. Medications used during endoscopy, and thus bronchoscopy, seem to be responsible for many of the endoscopic risks during pregnancy, but their risks are imprecisely defined, apart from the direct effect of each drug on the fetus.

In this review, we describe the major issues of performing FB in pregnant women, such as changes in the respiratory system, the potential risks associated with FB, the major indications for FB, the use of diagnostic radiation, and the monitoring of the mother and the fetus during FB. Finally, we list some general recommendations for performing bronchoscopy in pregnant patients.

### Respiratory System Changes During Pregnancy

The respiratory system undergoes multiple physiologic and anatomic changes during pregnancy. The bronchoscopist should understand the implications of these changes when planning, preparing, and monitoring the procedure in pregnant women.

#### *Functional Respiratory Changes in Pregnancy*

Large airway function does not seem to change during pregnancy.[12] The respiratory centers in the brain do appear to change homeostatic set points during pregnancy, as manifested by increased respiratory drive, which is probably a function of increasing levels of progesterone.[13] The mechanism of this change is thought to involve an increasing sensitivity of the medulla to carbon dioxide, such that increases in $Paco_2$ elicit an exaggerated respiratory effort, although a direct effect of progesterone on the respiratory center cannot be excluded.[14]

Residual volume and expiratory reserve volume

*From the Divisions of Pulmonary, Critical Care, and Sleep Medicine (Dr. Bahhady), Tufts-New England Medical Center; and Beth Israel Deaconess Medical Center (Dr. Ernst), Boston, MA.

Manuscript received March 25, 2004; revision accepted July 12, 2004.



*Correspondence to: Armin Ernst, MD, FCCP, Director, Interventional Pulmonology, Beth Israel Deaconess Medical Center, 330 Brookline Ave, Boston, MA 02215; e-mail: aernst@bidmc.harvard.edu*

both decrease in pregnancy; hence, the decrease in functional residual capacity of approximately 18%.[15] However, the increased inspiratory capacity results in minimal decreases in total lung capacity, and it leaves vital capacity virtually unchanged. The decrease in functional residual capacity is caused by diaphragmatic elevation (caused by increased intra-abdominal pressure) and possibly by increased pulmonary blood flow. These changes likely result in increased uptake and elimination of inhalational anesthetics and with rapid oxygen desaturation during hypoventilation episodes, and this in turn makes endotracheal intubation at term more hazardous[16]

Relative hyperventilation begins in the first trimester of pregnancy, with the minute ventilation rising by almost 50% at term.[17] The increase in minute ventilation is primarily the result of a large (up to 40%) increase in tidal volume; the respiratory rate does not change.[18] Pregnant women with normal respiratory rates often complain of dyspnea, which is usually the result of these respiratory adaptations.[19]

Oxygen consumption increases by almost 20% during pregnancy, to meet the increased metabolic demands of the placenta, fetus, and maternal organs. However, as mentioned above, minute ventilation rises disproportionately, leading to a rise in alveolar and arterial oxygen levels (normal $Pa_{O_2}$ in pregnant women ranges from 100 to 110 mm Hg).[20] In addition, $Pa_{CO_2}$ decrease from the nonpregnant average of 40 mm Hg to a plateau of 27 to 32 mm Hg during pregnancy.[13] This respiratory alkalosis is followed by compensatory renal excretion of bicarbonate so that the resultant arterial pH is normal to slightly alkalotic (usually a pH between 7.40 and 7.45).[21] The decrease in $Pa_{CO_2}$ probably helps the fetus to eliminate carbon dioxide across the placenta.

### *Anatomic Respiratory Changes in Pregnancy*

Increased estrogen levels during pregnancy[22] cause several changes in the upper airway mucosa, such as hyperemia, glandular hyperactivity, increased phagocytic activity, and increased mucosal mucopolysaccharide content.[23] These changes, in turn, lead to the so-called "rhinitis of pregnancy," which occurs in approximately 30% of all pregnancies, and pregnancy-induced gingivitis, which occurs in 40 to 100% of all pregnancies).[24] The result is increased mucosal edema and likelihood of bleeding, which makes the case for oral, rather than nasal, bronchoscope insertion in the pregnant women.

Changes in the thorax and abdomen appear to occur early in pregnancy, well before simple displacement from the enlarging uterus could cause such an effect. In the first trimester, the subcostal angle can change from 68° to as much as 103°.[25] The diaphragm rises by up to 4 cm, and the chest diameter can increase $\geq 2$ cm.[26] Diaphragmatic excursion is not limited by the uterus, and actually increases by up to 2 cm.[27] The result of these changes is a more "barrel-chested" appearance during pregnancy.

### *Other Changes in Pregnancy Relevant to Bronchoscopy*

The increased prevalence of gastroesophageal reflux during pregnancy involves both mechanical and intrinsic factors that reduce lower esophageal sphincter tone, which in turn increases the theoretical risk of aspiration during conscious sedation and bronchoscopy.[28,29]

Uterine enlargement beyond 20 weeks of gestational age can compress the inferior vena cava, markedly reducing cardiac preload and causing the so-called "supine hypotensive syndrome" in approximately 8% of all pregnancies.[30,31] This syndrome is characterized by the symptoms and signs of reduced cardiac output, mean arterial pressure decrease of $> 15$ mm Hg, and sympathetic activation, within 3 to 10 min of lying supine, and can harm the mother and the fetus. A sedated patient may not be able to respond to early warning signs appropriately. Therefore, procedures such as FB should be done with the patient in the left lateral tilt position, which is achieved by placing a wedge under the right side, having the patient lie on her left side, or adjusting the operating table to a 30° left lateral tilt[32]

## Potential Risks of Bronchoscopy in Pregnancy

Risks associated with FB can be classified into those related to conscious sedation and medications and those related to the procedure itself. Risks from conscious sedation and other medications used during the procedure include medication-related teratogenesis, induction of premature labor, maternal cardiac arrhythmias, and depressed mental status with resultant hypoventilation (which in turn can cause hypoxemia), airway vulnerability, and possible pulmonary aspiration or respiratory distress.[33] Risks associated with the procedure itself generally include pneumothorax, hypoxemia, airway hyperreactivity, pulmonary hemorrhage, and systemic hypotension or hypertension.[34]

The fetus is particularly sensitive to maternal hypoxia and hypotension.[35] Maternal hypoxia can result from medications,[36] vagally mediated bronchospasm, and pulmonary aspiration.[37] We found no

published information on the pulmonary complications associated with FB in pregnancy.

## Medications Commonly Used During Bronchoscopy and Pregnancy

Medications used during FB should be considered carefully before being administered to pregnant women, as a result of the potential risks of inducing hemodynamic effects in the mother that can affect the fetus (Table 1). Also, the possible direct effects on the fetus, other than the other usual effects of sedatives and analgesics, must be considered (Table 2).

## Patient and Fetal Monitoring During Bronchoscopy

As in other procedures done under conscious sedation, monitoring of pregnant women undergoing FB under conscious sedation should include the following: (1) an initial assessment of the medical history, including previous instances of complicated conscious sedation and allergies, and a general physical examination with specific attention to airway patency; (2) continuous monitoring with intermittent sphygmomanometry, cardiac rhythm and rate monitoring, and pulse oximetry (see below); capnography is optional (see below), but special attention should be paid to the presence of apnea and hypopnea; and (3) there are no formal recommendations regarding fetal heart monitoring during FB. The few case series that address endoscopy during pregnancy suggest that fetal heart monitoring is indicated only in high-risk pregnancies or in procedures done during the third trimester.[38] However, anesthesia departments may require fetal heart monitoring during any procedure done under conscious sedation.

### *Pulse Oximetry*

Maranetra et al[39] evaluated changes in hemoglobin oxygen saturation with pulse oximetry during diagnostic bronchoscopy in 100 patients. They reported an average oxygen desaturation of 5.6% in approximately 97% of the patients, a recuperation time of 1 to 34 min, and increased desaturation when patients were examined while seated. These findings stress the importance of pulse oximetry during bronchoscopy, especially in pregnant women, given the potential detrimental effect of hypoxemia on the fetus described above. Therefore, oxygen should be administered during the procedure to keep oxygen saturation at 97 to 100% at all times.

### *Capnography*

Studies[40–42] have documented the occurrence of marked hypercapnia in the absence of profound hypoxemia in patients receiving sufficient amounts of oxygen, even though these results have been put into question. In an animal study,[43] the fetal heart rate response to either hypoxemia or hypercapnia consisted of slowing and increased variability. Slowing was more consistent with hypercapnia than with hypoxemia.

Cognitive skills were lower in 26 preterm-birth preschool and early school-age children with a slight-to-moderate risk for perinatal hypoxia when compared with matched control subjects; however this study[44] was retrospective and the patients had marked hypoxemia in addition to hypercapnia, and its applicability is therefore limited. Other evidence

**Table 1—*FDA Categories of Fetal Risk From Drugs Administered During Pregnancy***

| FDA Pregnancy Risk Category | Fetal Risk From Drugs Administered During Pregnancy |
|---|---|
| A | Controlled studies in women show no risk to the fetus in the first trimester (and there is no evidence of risk in later trimesters), and the possibility of fetal harm appears remote. |
| B | Animal reproduction studies have reported no fetal risk, and there are no controlled studies in pregnant women, or animal-reproduction studies have shown an adverse effect (other than a decrease in fertility) that was not confirmed in controlled studies in women in the first trimester (and there is no evidence of a risk in later trimesters). |
| C | Studies in animals have revealed adverse effects on the fetus (teratogenic or embryocidal, or other) and there are no controlled studies in women, or studies in women and animals are not available. Drug should be administered only if the potential benefit justifies the potential risk to the fetus. |
| D | There is positive evidence of human fetal risk, but the benefits from use in pregnant women may be acceptable despite the risk (*eg*, if the drug is needed in a life-threatening situation or for a serious disease for which safer drugs cannot be used or are ineffective). |
| X | Studies in animals or humans have reported fetal abnormalities or there is evidence of fetal risk based on human experience, or both, and the risk of the use of the drug in pregnant women clearly outweighs any possible benefit. The drug is contraindicated in women who are or may become pregnant. |

**Table 2—*Safety and Recommendations for Medications Commonly Used During Bronchoscopy in Pregnant Women***

| Medication | FDA Pregnancy Risk Category | Recommendations During Pregnancy | Summary of Safety Literature on Human Fetus |
|---|---|---|---|
| Lidocaine | B (manufacturer) | Patient to gargle and spit out (not to swallow) for local oral anesthesia, to minimize absorption. | Inhaled lidocaine up to 8.2 mg/kg has been well-tolerated and free of side effects in asthmatic patients undergoing bronchoscopy.[53] |
| | C (expert analysis) | Adverse reactions are dose related. No indication of increased drug absorption in pregnant women. The lowest dosage needed to provide effective anesthesia should be used. The maximum recommended dose of 4% lidocaine topical solution should be such that the dose of lidocaine HCl is kept < 300 mg and in any case should not exceed 4.5 mg/kg (2 mg/lb) body weight. | IV administration was generally safe in one large study.[54] Lidocaine crosses the placental and blood-brain barriers, presumably by passive diffusion. |
| $\beta_2$-agonists | C | Do not use routinely. If indicated, use only the minimum needed dose. | Albuterol crosses the placenta; tocolytic effects, fetal tachycardia, and fetal hypoglycemia secondary to maternal hyperglycemia with oral or IV administration have been reported. Evidence suggests safe use during pregnancy.[55] |
| Inhaled ipratropium | B | May be used instead of albuterol (if possible), but onset of action is slower. | Poorly absorbed from the lung (15% of dose), so systemic effects are rare. |
| Atropine (subcutaneous injection) | C | Crosses placenta! Avoid if possible. | Differences in fetal heart rates or variability and changes in maternal BP not found.[56] |
| Epinephrine (submucosal injection) | C | Should be used during pregnancy only if the potential benefit justifies the potential risk to the fetus. | Epinephrine has been teratogenic in rats when administered in doses approximately 25 times the human dose. There are no adequate and well-controlled studies in pregnant women. |
| Benzodiazepine | | Avoid oversedation and use the lowest dose possible. | Evidence is insufficient to determine whether the potential benefits of benzodiazepines to the mother outweigh the risks to the fetus.[57] |
| Diazepam | D | Do not use. Midazolam is the preferred benzodiazepine for FB. | Association with oral clefts rose in the literature but not reported in large controlled studies; possible transient muscular hypotonia. High maternal doses can lead to a fetal withdrawal syndrome. Association with neurologic defects or mental retardation raised in literature but unproven.[58] |
| Midazolam | D | Avoid use if possible. Use cautiously and in low dose for FB | Administration during labor may transiently depress respiration and may transiently depress neurobehavioral responsiveness of newborns. Pharmacologic effects resemble those of diazepam, but no studies report an association with oral clefts. Midazolam is less well-studied than diazepam during pregnancy. |
| Meperidine | B | Use in low dose for FB. | Apparently not teratogenic. Causes transient neonatal respiratory depression and decreased alertness when administered during labor. Can cause diminished fetal beat-to-beat cardiac variability that lasts for about 1 h after maternal administration. |
| Fentanyl | C | Use in low dose for FB. | Generally safe to the fetus when administered during labor. Rare case reports of transient neonatal toxicity. |
| Propofol | B | Administer with caution and in the lowest dose possible. An anesthesiologist should be on standby to obtain newborn airway access if delivery occurs. | Considered relatively safe; however, it crosses the placenta and can cause neonatal depression. |
| Flumazenil | C | Avoid. Use only for benzodiazepine overdose. | Two cases reported of drug administration during pregnancy. In both cases healthy infants were subsequently delivered.[38] |
| Naloxone | B | Avoid. Should be restricted to pregnant patients who suffer signs of potential narcotic toxicity, such as respiratory depression, systemic hypotension, or unresponsiveness, and should be administered, in these cases, in small graded doses that are titrated to the desired effect. | Naloxone administration after meperidine administration to mothers in labor produced no untoward neonatal effects in two small studies. One reported a fatality associated with neonatal administration. Administration to patients dependent on opiates can precipitate opiate withdrawal and is dangerous. |

of mild and temporary respiratory acidosis effects on human fetal growth and development is lacking; however, until such evidence is obtained, hypoventilation should be avoided during procedures in pregnant women.

End-tidal $PaCO_2$ (capnometry) is a more sensitive measure of the hypoventilation that is being masked by supplemental oxygen delivery than is direct visual monitoring.[45] A controlled trial[46] evaluating this approach in 195 patients undergoing endoscopic retrograde cholangiopancreatography found that hypercapnia was not reliably detected by clinical observations or by pulse oximetry in patients receiving supplemental oxygen. The addition of transcutaneous carbon dioxide monitoring prevented severe hypercapnia more effectively than intensive clinical monitoring and pulse oximetry alone. Routine capnometry, however, is not currently widely available or included in current recommendations for monitoring patients undergoing conscious sedation.[46]

## Indications for Bronchoscopy in Pregnancy

The indications for bronchoscopy in pregnant patients are similar to those for patients who are not pregnant (Table 3).[47]

### *Emergent Bronchoscopy in Pregnancy*

As in any other emergent situations, lifesaving procedures should be performed in pregnant women regardless of the stage of pregnancy or the status of the fetus. Emergent bronchoscopy is no exception. Emergent indications for FB include airway maintenance in cases of upper airway obstruction caused by critical subglottic-tracheal stenosis, marked lung collapse caused by an obstructing foreign body, or massive hemoptysis caused by tumors. The primary concern should be the safety and survival of the mother. However, harm to the fetus can be minimized by fetal monitoring, adequate oxygenation of the mother during the procedure, and avoiding hypotension-inducing drugs. Well-trained operators working in well-controlled settings, such as in the operating room, also decrease risk.

### *Nonemergent Bronchoscopy in Pregnancy*

The decision to perform nonemergent bronchoscopy should be individualized to each patient and should depend on the clinical setting, indication, mother's health status, and stage of pregnancy. In addition, the following considerations are important:

- If possible, postpone diagnostic bronchoscopy until the patient has given birth. Timing will be dictated by clinical needs

**Table 3—*Indications for FB During Pregnancy**

| |
|---|
| Diagnostic uses |
| To evaluate lung lesions of unknown cause that appear on chest radiographs |
| To assess airway patency |
| To investigate unexplained hemoptysis, unexplained cough, localized wheeze, or stridor |
| To search for the origin of a suspicious or positive sputum cytology sample |
| To investigate unexplained paralysis of a vocal cord, hemidiaphragm, superior vena cava syndrome, chylothorax, or unexplained pleural effusion |
| To evaluate problems associated with endotracheal tubes, such as tracheal damage, airway obstruction, or tube placement |
| To stage lung cancer preoperatively and subsequently to evaluate, when appropriate, the response to therapy |
| To obtain material for microbiologic studies in suspected pulmonary infections |
| To evaluate the airways for suspected bronchial tear or other injury after thoracic trauma |
| To evaluate a suspected tracheoesophageal fistula |
| To determine the location and extent of respiratory tract injury after acute inhalation of noxious fumes or aspiration of gastric contents |
| To obtain material for study from the lungs of patients with diffuse or focal lung diseases |
| Therapeutic uses |
| To remove retained secretions or mucous plugs not mobilized by conventional noninvasive techniques |
| To remove foreign bodies |
| To remove abnormal endobronchial tissue or foreign material by use of forceps or laser techniques |
| To perform difficult intubations |
| Conditions involving increased risk |
| Lack of patient cooperation |
| Recent myocardial infarction or unstable angina |
| Partial tracheal obstruction |
| Unstable bronchial asthma |
| Respiratory insufficiency associated with moderate-to-severe hypoxemia or any degree of hypercarbia |
| Uremia and pulmonary hypertension (possible serious hemorrhage after biopsy) |
| Lung abscess (danger of flooding the airway with purulent material) |
| Immunosuppression (danger of postbronchoscopy infection) |
| Obstruction of the superior vena cava (possibility of bleeding and laryngeal edema) |
| Debility and malnutrition |
| Unstable cardiac arrhythmia |
| Respiratory failure requiring mechanical ventilation |
| Disorders requiring laser therapy, biopsy of lesions obstructing large airways, or multiple transbronchial lung biopsies |
| Danger of a serious complication from bronchoscopy is especially high in patients with: |
| Malignant arrhythmia |
| Profound refractory hypoxia |
| Severe bleeding diathesis that cannot be corrected when biopsy is anticipated |
| Contraindications |
| Absence of consent from the patient or his or her representative |
| Inexperienced bronchoscopist working without direct supervision |
| Lack of adequate facilities and personnel to care for emergencies, such as cardiopulmonary arrest, pneumothorax, or bleeding |
| Inability to adequately oxygenate the patient during the procedure |

*From Baughman et al.[47]

- If possible, postpone bronchoscopy until there is good chance of delivering a viable healthy newborn, usually after 28 weeks of pregnancy.
- New technologies can, in selected cases, substitute for bronchoscopy. For example, three-dimensional CT and virtual bronchoscopy can be used to follow an endobronchial lesion in a patient who has undergone an initial diagnostic FB. However, the limitations and potential harmful effects (such as radiation, see below) of these technologies on the mother and the fetus must be kept in mind.

## Radiation Exposure During Pregnancy

The potential harmful consequences of radiation for the fetus can be classified into four categories: intrauterine death, malformations, growth and developmental disturbances, and mutagenic and carcinogenic effects.[48] The danger to the fetus from radiation during fluoroscopic procedures depends on the dose of radiation (which in turn is related to exposure time, the number of films obtained, beam size, and imaging area) and gestational age. The preimplanted embryo is most at risk from the lethal effects of radiation.[49]

The risk is greatly diminished by appropriate and complete abdominal lead shielding, a short radiation exposure time, and performance of the procedure after the 14th week of gestation, when organogenesis has already been achieved. A study[50] of radiation in pregnant women with appropriate abdominal shielding reported no abnormalities related to radiation.

The exact dose of radiation received during fluoroscopic FB is not known; however, a study[49] of cardiac catheterization and valvuloplasty reported no adverse fetal effects of ionizing radiation at doses of $< 5$ rad. The margin of safety is augmented by the fact that most exposures to diagnostic imaging radiation are spread over a period of time; this type of exposure is less harmful than acute exposure.[51] The same risk-benefit analysis should be applied when deciding to use fluoroscopy for diagnostic FB, keeping in mind that fluoroscopy does not improve the yield for transbronchial biopsy, especially in diffuse lung diseases.[52]

## General Recommendations for Bronchoscopy During Pregnancy

1. When possible, defer bronchoscopy until after the pregnancy is ended or, if that is not possible, until after the 28th week of pregnancy.
2. Explain to the patient the risks and benefits of the procedure, as well as the associated medications, to her and to the fetus. Obtain informed and written consent to perform the procedure.
3. Perform the bronchoscopy in a well-equipped hospital with ready access to anesthesia, obstetric, and neonatology services in case of emergency.
4. Consult a pharmacologist regarding the teratogenicity of any medications to be used.
5. Consult an anesthesiologist about options for conscious sedation.
6. Consider an obstetric consultation to help identify and manage at-risk pregnancies.
7. For conscious sedation, use the lowest effective dose of the drug. Do not use US Food and Drug Administration (FDA) category X or category D drugs (Tables 1, 2).
8. Avoid using optional drugs. When alternative drugs are available, use the drug that is safest for the fetus.
9. Perform continuous cardiac monitoring, pulse oximetry, and intermittent sphygmomanometry during the procedure.
10. Capnography has not been studied in pregnant women during procedures that require conscious sedation and therefore is not recommended.
11. Monitor the fetus if possible.
12. Position the patient in the left lateral decubitus position if possible, and if not, in a seated position.
13. Complete the procedure as soon as possible. For example, avoid lengthy examination of the distal airways if it is not indicated during preprocedure planning.
14. Terminate poorly tolerated procedures.
15. Have the most experienced bronchoscopist available perform the procedure.
16. Base the decision to use fluoroscopy in FB during pregnancy on an individual risk-benefit analysis.
17. Consider alternatives to bronchoscopy when appropriate, such as imaging technologies.
18. Consider referrals to a specialized center if you are unsure whether all needed services (anesthesia, critical care, obstetrics, neonatology) are available.

## Summary

When performing FB on pregnant women, common sense and generally used precautions should be considered, including appropriate planning and careful review of medication effects on the fetus. No studies, other than some case reports, have tested

the utility and safety of bronchoscopy and other associated diagnostic and therapeutic procedures during pregnancy. Until such studies are published, bronchoscopy should be reserved for indications that cannot wait until the postpartum period. Advances in the diagnosis and treatment of lung and airway diseases, such as endobronchial ultrasound, CT fluoroscopy, and virtual bronchoscopy, may be combined with FB to decrease the risks to the mother and the fetus.

## References


1 Venu K, Diggikar AD, Rao BK. Carcinoid tumour: laser therapy. Indian J Chest Dis Allied Sci 1997; 39:129–132
2 Downs TW, Chao CR. Massive hemoptysis in pregnancy treated with bronchial artery embolization. Am J Perinatol 1997; 14:51–53
3 Losa Garcia JE, Mateos Rodriguez F, de la Calle B, et al. Acute eosinophilic pneumonia in a pregnant woman. Arch Bronconeumol 1997; 33:306–308
4 Aithan S, Khan J, Bazarbashi M. Total lung collapse after pulmonary infarction. Thorax 1994; 49:938–939
5 Albino JA, Shapiro JM. Respiratory failure in pregnancy due to *Pneumocystis carinii*: report of a successful outcome. Obstet Gynecol 1994; 83:823–824
6 Salama DJ, Body SC. Management of a term parturient with tracheal stenosis. Br J Anaesth 1994; 72:354–357
7 Bruhwiler H, Wild A, Luscher KP. Bronchus cancer and pregnancy. Geburtshilfe Frauenheilkd 1988; 48:654–655
8 Dieter RA Jr, Livermore J, Tu R, et al. Mucoepidermoid tracheal adenoma during pregnancy. Int Surg 1983; 68:271–272
9 Betti A, Cavaliere S, Bergonzini R. Bronchoscopy in pregnancy. Radiol Med (Torino) 1999; 97:327–330
10 Cappell MS, Sidhom O. Multicenter, multiyear study of safety and efficacy of flexible sigmoidoscopy during pregnancy in 24 females with follow-up of fetal outcome. Dig Dis Sci 1995; 40:472–479
11 Cappell MS, Colon VJ, Sidhom OA. A study of eight medical centers of the safety and clinical efficacy of esophagogastroduodenoscopy in 83 pregnant females with follow-up of fetal outcome with comparison control groups. Am J Gastroenterol 1996; 91:348–354
12 Milne JA, Mills RJ, Howie AD, et al. Large airways function during normal pregnancy. Br J Obstet Gynaecol 1977; 84: 448–451
13 Liberatore SM, Pistelli R, Patalano F, et al. Respiratory function during pregnancy. Respiration 1984; 46:145–150
14 Skatrud JB, Dempsey JA, Kaiser DG. Ventilatory response to medroxyprogesterone acetate in normal subjects: time course and mechanism. J Appl Physiol 1978; 44:939–944
15 Noble PW, Lavee AE, Jacobs MM. Respiratory diseases in pregnancy. Obstet Gynecol Clin North Am 1988; 2:391–428
16 Rizk NW. The lungs in obstetric gynecologic disease. In: Nadel M, ed. Textbook of respiratory medicine. New York, NY: WB Saunders Company, 2000; 2317–2318
17 Liberatore SM, Pistelli R, Patalano F, et al. Respiratory function during pregnancy. Respiration 1984; 46:145–150
18 Milne JA. The respiratory response to pregnancy. Postgrad Med J 1979; 55:318–324
19 Milne JA, Howie AD, Pack AI. Dyspnoea during normal pregnancy. Br J Obstet Gynaecol 1978; 85:260–263
20 Artal R, Wiswell R, Romem Y, et al. Pulmonary responses to exercise in pregnancy. Am J Obstet Gynecol 1986; 154:378–383
21 Hernandez E, Angell CS, Johnson JW. Asthma in pregnancy: current concepts. Obstet Gynecol 1980; 55:739–743
22 Bende M, Hallgarde M, Sjogren U, et al. Nasal congestion during pregnancy. Clin Otolaryngol 1989; 14:385–387
23 Toppozada H, Michaels L, Toppozada M, et al. The human respiratory nasal mucosa in pregnancy: an electron microscopic and histochemical study. J Laryngol Otol 1982; 96: 613–626
24 Raber-Durlacher JE, van Steenbergen TJ, Van der Velden U, et al. Experimental gingivitis during pregnancy and postpartum: clinical, endocrinological, and microbiological aspects. J Clin Periodontol 1994; 21:549–558
25 Turner AF. The chest radiograph in pregnancy. Clin Obstet Gynecol 1975; 18:65–74
26 Weinberger SE, Weiss ST, Cohen WR, et al. Pregnancy and the lung. Am Rev Respir Dis 1980; 121:559–581
27 Gilroy RJ, Mangura BT, Lavietes MH. Rib cage and abdominal volume displacements during breathing in pregnancy. Am Rev Respir Dis 1988; 137:668–672
28 DeMeester TR, Bonavina L, Iascone C, et al. Chronic respiratory symptoms and occult gastroesophageal reflux: a prospective clinical study and results of surgical therapy. Ann Surg 1990; 211:337–345
29 Barish CF, Wu WC, Castell DO. Respiratory complications of gastroesophageal reflux. Arch Intern Med 1985; 145:1882–1888
30 Lanni SM, Tillinghast J, Silver HM. Hemodynamic changes and baroreflex gain in the supine hypotensive syndrome. Am J Obstet Gynecol 2002; 187:1636–1641
31 Kinsella SM, Lohmann G. Supine hypotensive syndrome. Obstet Gynecol 1994; 83:774–788
32 Shay DC, Bhavani-Shankar K, Datta S. Laparoscopic surgery during pregnancy. Anesthesiol Clin North America 2001; 19:57–67
33 Epstein H, Waxman A, Gleicher N, et al. Meperidine-induced sinusoidal fetal heart rate pattern and reversal with naloxone. Obstet Gynecol 1982; 59:22S–25S
34 DiSario JA, Waring JP, Talbert G, et al. Monitoring of blood pressure and heart rate during routine endoscopy: a prospective, randomized, controlled study. Am J Gastroenterol 1991; 86:956–960
35 Kammerer WS. Nonobstetric surgery during pregnancy. Med Clin North Am 1979; 63:1157–1164
36 Rozen P, Fireman Z, Gilat T. The causes of hypoxemia in elderly patients during endoscopy. Gastrointest Endosc 1982; 28:243–246
37 Taylor PA, Cotton PB, Towey RM, et al. Pulmonary complications after oesophagogastroscopy using diazepam [abstract]. BMJ 1972; 1:666
38 Cappell MS. The fetal safety and clinical efficacy of gastrointestinal endoscopy during pregnancy. Gastroenterol Clin North Am 2003; 32:123–179
39 Maranetra N, Pushpakom R, Bovornkitti S. Oxygen desaturation during fibreoptic bronchoscopy. J Med Assoc Thai 1990; 73:258–263
40 Frumin MJ, Epstein RM, Cohen G. Apneic oxygenation in man. Anesthesiology 1959; 20:789–798
41 Comroe JH, Dripps RD. Artificial respiration. JAMA 1946; 130:381–383
42 Cote CJ. Pulse oximetry during conscious sedation. JAMA 1994; 271:429; discussion 429–430
43 Ikenoue T, Martin CB Jr, Murata Y, et al. Effect of acute hypoxemia and respiratory acidosis on the fetal heart rate in monkeys. Am J Obstet Gynecol 1981; 141:797–806
44 Hopkins-Golightly T, Raz S, Sander CJ. Influence of slight to moderate risk for birth hypoxia on acquisition of cognitive and language function in the preterm infant: a cross-sectional

comparison with preterm-birth controls. Neuropsychology 2003; 17:3–13
45 Nelson DB, Freeman ML, Silvis SE, et al. A randomized, controlled trial of transcutaneous carbon dioxide monitoring during ERCP. Gastrointest Endosc 2000; 51:288–295
46 Practice guidelines for sedation and analgesia by non-anesthesiologists: a report by the American Society of Anesthesiologists Task Force on Sedation and Analgesia by Non-Anesthesiologists. Anesthesiology 1996; 84:459–471
47 Baughman RP, Golden JA, Keith FM. Bronchoscopy, lung biopsy, and other diagnostic procedures. In: Nadel M, ed. Textbook of respiratory medicine. New York, NY: WB Saunders Company, 2000; 729t–730t
48 Yamazaki JN, Schull WJ. Perinatal loss and neurological abnormalities among children of the atomic bomb: Nagasaki and Hiroshima revisited, 1949 to 1989. JAMA 1990; 264:605–609
49 Brent RL. The effect of embryonic and fetal exposure to x-ray, microwaves, and ultrasound: counseling the pregnant and nonpregnant patient about these risks. Semin Oncol 1989; 16:347–368
50 Ben Farhat M, Gamra H, Betbout F, et al. Percutaneous balloon mitral commissurotomy during pregnancy. Heart 1997; 77:564–567
51 Brent RL. The effect of embryonic and fetal exposure to x-ray, microwaves, and ultrasound: counseling the pregnant and nonpregnant patient about these risks. Semin Oncol 1989; 16:347–368
52 Anders GT, Johnson JE, Bush BA, et al. Transbronchial biopsy without fluoroscopy: a seven-year perspective. Chest 1988; 94:557–560
53 Langmack EL, Martin RJ, Pak J, et al. Serum lidocaine concentrations in asthmatics undergoing research bronchoscopy. Chest 2000; 117:1055–1060
54 Heinonen OP, Slone D, Shapiro S. Birth defects and drugs in pregnancy. Boston, MA: John Wright, 1982
55 Albuterol. Available at: http://www.PDR.net. Accessed September 14, 2004
56 Abboud T, Raya J, Sadri S, et al. Fetal and maternal cardiovascular effects of atropine and glycopyrolate. Anesth Analg 1983; 62:426–430
57 Iqbal MM, Sobhan T, Ryals T. Effects of commonly used benzodiazepines on the fetus, the neonate, and the nursing infant. Psychiatr Serv 2002; 53:39–49
58 Iqbal MM, Sobhan T, Aftab SR, et al. Diazepam use during pregnancy: a review of the literature. Del Med J 2002; 74:127–135