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Review

Management of general surgical problems in the pregnant patient

David M. Melnick, M.D., M.P.H. [a], [*]
Wendy L. Wahl, M.D. [b]
Vanessa K. Dalton, M.D., M.P.H. [c]

[a] Department of Surgery
University of Wisconsin Medical School and Meriter Hospital
One South Park
Madison, WI 53715, USA

[b] Department of Surgery
University of Michigan Medical School
Ann Arbor, MI, USA

[c] Department of Obstetrics and Gynecology
University of Michigan Medical School
Ann Arbor, MI, USA

[*] Corresponding author. Tel.: +1-608-287-2100; fax: +1-608-287-2324.
E-mail address: dmelnick@wisc.edu

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Background

General surgeons are frequently consulted for nonobstetrical surgical problems in pregnant women, as up to 2% of pregnancies are complicated by such problems. Concerns over the increased morbidity for both the pregnant patient and the fetus are unique to this population.

Data sources

A review of the English language literature surrounding nonobstetrical surgical issues was collected through a Medline search and review of relevant society and academy papers.

Conclusions

This manuscript offers a review of current information regarding aspects of surgical care in the pregnant patient. Areas discussed include anesthesiology, radiology, laparoscopy, and specific common and uncommon surgical diseases found in the pregnant patient.

Keywords

Pregnancy

Surgery

Laparoscopy

As many as 2% of pregnancies are complicated by nonobstetrical surgical problems, with pregnant patients undergoing approximately 50,000 nonobstetrical operations each year in the United States [1] [2] . Concerns over the increased morbidity for both the pregnant patient and the fetus are unique to this population. Most morbidity and mortality for both mother and fetus is secondary to the underlying disease process and not the diagnostic or therapeutic maneuvers performed. It is helpful to understand potential iatrogenic complications to improve outcomes for both the mother and fetus. This review summarizes current data regarding relevant care issues for anesthesia, diagnostic and therapeutic radiology, laparoscopy and common and unusual general surgical pathology in the pregnant patient.

Anesthetic consideration in the pregnant patient

Anesthetic concerns in the pregnant patient can be broken down into two major categories: teratogenicity of the anesthetic agents and maternal physiologic changes as a result of anesthetic agents. The teratogenicity of anesthetic agents, defined as the potential effect in chromosomal damage or in carcinogenesis in the fetus, is minimal. Currently known levels of medication safety in pregnancy are described by the following categories: A: safety established using human studies; B: presumed safety based on animal studies; C: uncertain safety; no human studies, animal studies show adverse effect; D: unsafe; evidence of risk that may in certain clinical circumstances may be justifiable; X: highly unsafe [3] .

Studies that have specifically evaluated the effects of anesthetic agents on the fetus have concluded that the morbidity to the fetus is primarily from the underlying disease, not from the anesthetic agents [4] . Nearly all analgesics and anesthetics are in pregnancy category C. Importantly, nearly all teratogenic medications exhibit the same effect on animals as they do on humans, so animal studies are useful in evaluating the teratogenicity of maternal medications. In a consensus statement printed in the *New England Journal of Medicine* in 2000, no anesthetic agents were listed as definitively causative of fetal malformations [5] . Anxiety and pain in pregnant patients should be treated, as there are adverse effects of the symptoms themselves, including cardiac (sympathetic stimulation causes tachycardia, increased myocardial oxygen consumption), pulmonary (decreased vital capacity, forced expiratory volume in one second, diminished coughing), gastrointestinal (ileus, nausea, vomiting), and a generalized catabolic state with increases in catecholamines, steroids, and other modulators [6] . Paralytics do not

cross the placenta. Inhalational and local anesthetics, muscle relaxants, narcotic analgesics, and benzodiazapenes have all been shown, with reasonable certainty, to be safe in pregnancy [4] [7] [8] .

Multiple cardiovascular and pulmonary physiologic changes occur in the mother during pregnancy. Both the general surgeon and anesthesiologist should be aware of these alterations to prevent fetal hypoxia and hypotension. The cardiovascular system of the pregnant patient is hyperdynamic, with an increased cardiac output and an increased heart rate. Total blood volume increases up to 40% while red blood cell volume rises by about 25%. This results in a relative anemia of pregnancy with a drop in hematocrit by approximately 30%. The enlarging uterus also can decrease blood return from the inferior vena cava to the heart through an increased intraabdominal pressure.

Increased oxygen consumption and mechanical displacement of the abdominal organs cause the pregnant patient to increase minute ventilation, primarily through a 30% to 40% increase in tidal volume [9] . A compensatory respiratory alkalosis with a $PaCO_2$ from 30 to 35 mm Hg develops. Intubation may be more difficult because of increased airway edema later in the pregnancy, and smaller endotracheal tubes should be used at this time. Because decreased lower esophageal sphincter pressure and delayed gastric emptying in pregnancy can cause an increased risk of aspiration, cricoid pressure should be used to prevent aspiration during intubation [2] . End-tidal CO_2 monitoring should be used intraoperatively.

Hypotension in the pregnant patient should be treated initially with aggressive intravenous fluid resuscitation. The patient should be placed in the left lateral decubitus position, if possible, to increase venous return. Trendelenburg positioning can also be used in the hypotensive patient to increase venous return. Pressors may be used if needed.

Obstetric consultation is helpful in the perioperative management of the pregnant patient. Fetal monitoring to evaluate for fetal distress should be utilized perioperatively and placed in the medical record.

Radiological issues in the pregnant general surgical patient

Diagnostic radiological studies and therapeutic radiation for malignancy are often considered during the surgical management of a pregnant patient. Practitioners may be reluctant to order a radiological study because of the potential teratogenic risks to the fetus as well as the medical-legal implications of the radiation dose causing birth defects. For an acute indication, if there are good maternal indications, the benefits for the mother usually outweigh the small risk to the fetus. It is important for all caregivers, including the general surgeon, to have an understanding of those risks.

Radiological exposure is measured using units of either rad (radiation absorbed dose) or centiGrey (1 RAD = 1 cGy.) Data regarding the dose dependent nature of the harmful effects of radiation come from animal studies, observational studies of human exposure, and studies of humans exposed to the atomic bomb. The greatest effects of radiation

occur during the period of rapid cell proliferation, from approximately the first week after conception through week 25. The recommended total dose of radiation during this time is less than 5 to 10 rad. During the first 2 to 3 weeks of pregnancy, while cells are not yet specialized, radiation injury will cause failure of implantation or undetectable death of the embryo. After that, injury usually occurs in the organs under development at the time of exposure. The central nervous system develops from weeks 8 to 25, and it is at this time that neurologic effects of radiation are most prominent. During this time, and especially from weeks 8 through 15, radiation doses to the fetus of greater than 10 rad may result in a decrease in IQ, where doses greater than 100 rad will probably result in severe mental retardation of the fetus [10] .

Further along in pregnancy, concern changes to increasing the risk of a childhood hematologic cancer. The background incidence of childhood cancer and leukemia is about 0.2% to 0.3%. An estimate of the increased risk of a childhood malignancy as result of radiation exposure of greater than 1 cGy, taken from many epidemiological studies, is probably less than 40%, or about 0.3% to 0.4%. Radiation may increase the incidence of childhood cancer by 0.06% per 1 cGy delivered to the fetus [10] .

Current recommendations on radiation exposure are as follows: “No single diagnostic procedure results in a radiation dose that threatens the well-being of the developing embryo and fetus” (American College of Radiology) [11] . “Fetal risk is considered to be negligible at 5 rad or less when compared with the other risks of pregnancy, and the risk of malformations is significantly increased above control levels only at doses above 15 rad.” (National Council on Radiation Protection) [12] . “…[E]xposure to less than 5 rad has not been associated with an increase in fetal anomalies or pregnancy loss.” (American College of Obstetrics and Gynecology [ACOG]) [13] . “Prenatal doses from most properly done diagnostic procedures present no measurably increased risk of prenatal death, malformation, or impairment of mental development over the background incidence of these entities. Higher doses, such as those involved in therapeutic procedures, can result in significant fetal harm.” (International Commission on Radiological Protection [ICRP]) [10] .

Doses of radiation from common diagnostic studies are listed in Table 1 [10] [14] [15] [16] [17] . It is important to note the possible range of exposures for a given diagnostic study. More technologically advanced equipment may deliver lower radiation doses. Also, a radiologist can coordinate particular parameters of a study to minimize the radiation dose to the fetus while optimizing the diagnostic quality of the study. Iodinated contrast dye is considered a pregnancy class B drug, and animal experimentation at doses up to 100 times that of the normal human dose have shown no adverse fetal effects [18] .

Table 1. Approximate fetal radiation doses from common diagnostic studies

Sources: Toppenberg KS. Safety of radiographic imaging during pregnancy. *Am Fam* Phys 1999;59:1813–18. Osei EK, Faulkner K. Fetal doses from radiological examinations. *Br J Radiol* 1999;72:773–80. Winer-Muram HT, Boone JM, Brown HL, et al. Pulmonary embolism in pregnant patients: fetal radiation dose with helical CT. *Radiology* 2002;224:487–92. Parry RA, Glaze SA, Archer BR. The AAPM/RSNA physics tutorial for residents. *Radiographics* 1999;19:1289–302. Mettler FA, Brent RL, Streffer C, et al. Pregnancy and medical radiation. *Ann ICRP* 2000;30:1–42.CT = computed tomography.

Study	Dose (rads)
Complete spine series	0.37
Chest radiograph	<0.001
Acute abdominal series	0.245
Pelvis radiograph	0.04
Mammogram	0.01
Head CT	<0.05
Chest CT	0.01–0.2
Abdominal CT	0.8–3
Pelvis CT	2.5–7.9
CT scan of uterus	1–4
Upper gastrointestinal series	0.05–0.1
Barium enema	0.3–4
Ventilation-perfusion scan	<0.4
HIDA scan	0.15
Background dose over 9 months	0.1

Regarding magnetic resonance imaging (MRI), ACOG advises against using it during the first trimester, although no data exist to support any adverse effects. It is important to understand that the physics of MRI are completely different than that of conventional radiology and computed tomographic (CT) examinations. Magnetic resonance imaging studies do not deliver radiation to the patient, but rather deliver radiowaves within a magnetic field to the patient. Therefore the etiology of teratogenicity resulting from MRI would be different than that of radiation. The American College of Radiology (ACR), in a paper on the safety of MRI, states that pregnant patients may undergo MRI at any stage of pregnancy provided that (1) the Attending radiologist confers with the referring physician and the patient about the possible risks of the study, (2) the study is needed during the pregnancy and should not wait until after delivery, and (3) the information needed could not be obtained by nonionizing diagnostic studies (eg, ultrasound) [19] . The ACR also states that MRI contrast material should not routinely be used in the pregnant patient, although it can be used if the risks and benefits are discussed with the patient. Magnetic resonance imaging contrast material is designated a pregnancy class C drug, although anecdotal cases of its use without adverse fetal effects have been reported [18] .

Nuclear medicine studies can often be utilized in the pregnant patient. The ICRP issued a paper describing current guidelines for radiation exposure in the pregnant patient, and the following information is based on that paper [10] . Fetal radiation exposure potentially derives from both the radiopharmaceutical delivered as well as the gamma camera. Therefore, it is important to establish a pregnancy history prior to delivery of these agents. Most radiopharmaceuticals, such as technetium-99m, do not cross the placenta and do not deliver a large fetal dose. Radioactive iodine, however, does cross the placenta and can have a greater effect on the fetus, and should not be used during pregnancy.

As with conventional and CT studies, technical details of nuclear medicine studies can limit the exposure to the fetus. Using lower doses with longer exposure times can give equivalent information with lower fetal exposure. Ventilation-perfusion scans are usually performed ventilation first, then perfusion. In the pregnant patient, the perfusion scan can occur first, and if normal, the ventilation scan can be avoided. Many radiopharmaceuticals are excreted by the maternal kidney and fetal exposure can occur from the urinary bladder reservoir. Pregnant patients should be encouraged to hydrate themselves well and void frequently to limit fetal exposure.

Adverse effects from ultrasound result from heat produced by the dissipation of energy of the ultrasound waves and cavitation, a phenomenon resulting from microscopic air bubbles forming at air-fluid interfaces. Modern ultrasound devices utilizing higher energy outputs have an indicator of these effects on the display. Current data indicate that diagnostic ultrasound is safe throughout pregnancy when performed by trained individuals using appropriate equipment [20] [21] [22] . Color doppler/duplex ultrasound distributes more energy to the tissues and may cause a rise in temperature that may have a low risk of adverse effects if used for a prolonged period of time [23] . The ACOG has a statement that ultrasound is safe throughout pregnancy [14] .

In summary, judicious use of radiologic studies with proper shielding and avoidance of repeat studies will minimize the radiation risk to the fetus. Informed decision making about the risk and benefits of the study should involve the surgeon, radiologist and mother.

Thrombotic disease in pregnancy

Pregnancy may induce a hypercoagulable state with increased activity of clotting factors and decreased fibrinolysis. Changes in coagulation along with the increased pressure of the uterus on the inferior vena cava lead to an increased risk of deep venous thrombosis (DVT) with an incidence of approximately 0.1% to 0.2%. Historically, most DVTs developed during the postpartum period when women were discouraged from walking for a period of days after delivery or cesarean section. In the present, most DVTs develop during pregnancy, while most pulmonary emboli occur postpartum [24] . In the pregnant population, DVT most often affects the more proximal deep veins (iliac veins), and is more likely to occur on the left side [25] . Other factors which may increase the risk of deep vein thrombosis during pregnancy include prolonged bed rest during pregnancy or the

puerperium, instrument-assisted or cesarean delivery, hemorrhage, sepsis, multiparity, smoking, and advanced maternal age [24] [26] .

Diagnostic workup for DVT includes venous doppler examination, which should be performed with the uterus displaced to the left to reduce the chance of a false positive test. Chest radiograph, chest CT scanning [15] [16] , and pulmonary ventilation-perfusion scanning [27] if used with proper shielding and technique, are safe in pregnancy, with each test radiating less than 0.4 rads to the fetus. Chest CT delivers less radiation to the fetus at earlier stages of pregnancy because the fetus is farther away from the target organ, the chest, during that time. Pulmonary angiography can be used if needed, although alternative diagnostic modalities are preferred.

Lower extremity sequential compression devices should be used liberally during periods of bedrest or in the operating room. Treatment of DVT includes full anticoagulation with heparin. Warfarin is contraindicated during pregnancy because of severe fetal malformations and associated death, but heparin and low molecular rate heparin can be used [28] . Vena caval filters may be used, but should be placed in the suprarenal position [24] . Patients at higher risk for DVT such as those with a history of DVT may be offered prophylaxis with subcutaneous heparin during pregnancy.

For severe episodes of DVT, such as phlegmasia cerulea dolens, treatment options include thrombolytics and surgery. Recombinant tissue plasminogen activator (alteplase) is a pregnancy class C medication that does not cross the placenta and is not antigenic, and case series of its use report minimal adverse effects [29] . Venous thrombectomy via a longitudinal venotomy and an arteriovenous fistula using a side branch of the greater saphenous vein to the femoral or popliteal artery has also been described, with good results [30] .

Surgical considerations in the pregnant patient

Laparoscopy

In general, laparoscopy has been well tolerated by both mother and fetus during pregnancy. Case series have reported increased utilization of laparoscopy in the pregnant patient with minimal apparent adverse effects, if any, compared with laparotomy. However, by the end of the second trimester, at 26 to 28 weeks, the size of the uterus often interferes with the laparoscopic view and approach and open surgery may be indicated [31] [32] [33] . A widely cited animal study by Hunter et al [34] showed that pneumoperitoneum with carbon dioxide can induce a mild metabolic acidosis with an increase in heart rate and blood pressure compared with controls in sheep experiments. This acidosis was not clinically significant and was likely secondary to carbon dioxide resorption, as the acidosis did not occur while using nitrous oxide as the insufflation gas [34] .

One concerning case series reported in *The American Journal of Surgery* in 1997 reported four fetal deaths out of seven laparoscopic surgeries during pregnancy [35] . However, the indications for surgery were for acute abdominal diseases such as appendicitis, **perforated appendicitis**, cholecystitis and gallstone pancreatitis. The authors state that of the three patients with gallstone pancreatitis and one patient with **perforated appendicitis**, three fetal deaths occurred. The authors do not otherwise state which surgeries resulted in the fetal deaths, and the causes of death are not clear from this report.

A study from the Swedish Health Registry evaluated 2,233 laparoscopic and 2,491 open laparotomy cases from 2 million deliveries in Sweden from 1973 to 1993 [36] . Outcomes evaluated birth weight, gestational duration, intrauterine growth retardation, congenital malformations, stillbirths, and neonatal deaths. There were no statistically significant differences comparing the laparoscopy group with the laparotomy group. Although the statistics are not fully evaluated in the paper, it appears that there was an increased risk for infants in both laparoscopy and laparotomy groups to weigh less than 2,500 g, to be delivered before 37 weeks, and to have an increased incidence of growth restriction compared with the total population.

The Society of American Gastrointestinal Endoscopic Surgeons (SAGES) has recommendations regarding laparoscopic surgery during pregnancy which can be found in pamphlet form and on the internet. Highlights of SAGES recommendations appear in Table 2 [37] .

Table 2. Highlights of the Society for American Gastrointestinal Endoscopic Surgeons (SAGES) recommendations for laparoscopic surgery during pregnancy

Source: SAGES publication 0023: SAGES guidelines for laparoscopic surgery during pregnancy. Available at: http://80-www.sages.org.proxy.hsclib.sunysb.edu/sg_pub23.html, SAGES, 2000.

1. Obtain an obstetrics consult preoperatively.

2. When possible, delay operative intervention in elective cases until the second trimester.

3. Use lower extremity pneumatic compression devices, as pregnancy and pneumoperitoneum may induce a hypercoagulable state.

4. Follow maternal and fetal physiologic status intraoperatively. Follow maternal end tidal CO_2.

5. Protect uterus with lead shield if contemplating intraoperative cholangiography.

6. Use open technique to gain pneumoperitoneum.

7. Tilt table left side down to move gravid uterus off vena cava.

8. Minimize pneumoperitoneum to 8 to 12 mm Hg.

Appendicitis

Appendicitis is the most common operative indication for nonobstetric surgery during pregnancy, with an occurrence of about 1 in 1500 pregnancies and representing more than 25% of the indications. Other common operative pathology includes adnexal masses, gallbladder disease, breast cancer, and hernias [38] . The importance of the diagnosis and treatment of appendicitis were recognized as far back as 1908, where it was quoted that, “The mortality of appendicitis complicating pregnancy is the mortality of delay” [39] . Surgeons should not be fearful of exploring a pregnant patient for presumed appendicitis. However, the clinical diagnosis of appendicitis is more difficult in the pregnant patient, and the percentage of pathologically normal appendices is higher than among nonpregnant patients.

It is generally taught that as pregnancy progresses and the uterus enlarges it pushes the appendix superiorly. However, clinical studies have shown that the vast majority of pregnant women presenting with appendicitis have right lower quadrant pain, not right upper quadrant pain [40] . Other clinical signs used to diagnose appendicitis may not have the reliability in the pregnant patient. A common source of confusion is the normal leukocytosis of pregnancy, with white blood counts up to 16,000 and higher in the late stages [41] . Rebound tenderness and guarding are less frequently found in pregnant patients [42] [43] .

In a series from Phoenix, 67 pregnant patients out of approximately 67,000 pregnancies presented with a diagnosis of acute appendicitis, of whom 45 had pathology of acute appendicitis [40] . In all trimesters, more than 80% of the subjects had right lower quadrant pain, including the third trimester, where only 2 of 13 patients with a pathologic diagnosis of appendicitis had pain other than right lower quadrant pain. Neither fever, leukocytosis nor bandemia were significantly associated with an abnormal vs. a normal appendix.

In many series, normal appendices were found approximately 50% of the time, highlighting the difficulty of the diagnosis in the pregnant population. However, no maternal or fetal morbidity was found to be associated with a negative operation [44] . The risk of a perforated appendix on the fetus may be substantial, with fetal loss occurring approximately 20% of the time in that setting [45] .

Computed tomography scanning can be useful in diagnosing appendicitis, although the fetal radiation exposure should be evaluated. In a case series of 7 pregnant patients evaluated for appendicitis at the Massachusetts General Hospital, 5 patients with negative CT scans did not develop clinical appendicitis and 2 patients with positive CT scans had appendicitis confirmed by pathology [46] . The group used a limited scan with a 0.3 rad dosage, below the accepted 5 rad limit.

Operatively, the surgeon should try to avoid manipulation of the uterus during the procedure. Intraoperative or perioperative fetal monitoring should be used in viable

pregnancies older than 24 weeks. Obstetricians may also recommend tocolytics to prevent preterm labor, as this may complicate the early postoperative course. A study evaluating the Swedish registry found that the rate of preterm labor was 22% if the fetus was older than 23 weeks, with an associated increased rate of preterm delivery [47] . However, if there was no preterm labor in the first postoperative week, there was no increased risk of preterm delivery.

Gallstones

Two percent to 4% of pregnant patients will have gallstones seen on obstetric ultrasound. Of these, approximately 5%, or a total of 1 in 1,000 pregnancies, will develop symptoms. Pregnancy may predispose women to increased rates of complications from gallstone disease because of increased bile stasis and decreased gallbladder contraction resulting in a dilated gallbladder [45] [48] [49] . A study out of the University of Southern California study observed 242 women recruited during the first trimester of pregnancy. Ultrasonography initially revealed gallbladder sludge in 15%, stones in 6%. New sludge or stones were found in 30% and 2% respectively of the women at the end of the pregnancy. Postpartum sonography revealed disappearance of sludge in 61% of those women who had previously demonstrated sludge, and disappearance of stones in 28% of those who had stones. Therefore, the study concluded, some patients who may have symptomatic cholelithiasis during pregnancy may not have it after the delivery [50] . Studies in dogs have found that progesterone also decreases gallbladder emptying and may contribute to stone formation [51] . Unfortunately, approximately 50% of women presenting with symptoms will have recurrence of symptoms prior to delivery [52] .

Diagnosis is made using a right upper quadrant ultrasound, as in the nonpregnant patient. HIDA scanning delivers 0.15 rads and can probably be used safely in selected cases, although some authors believe it is contraindicated in pregnancy [48] . Treatment of acute cholecystitis involves antibiotics and intravenous fluids. It may be advantageous to perform laparoscopic cholecystectomy in the second trimester, as the risks of organogenesis are limited and the uterus is still relatively small, allowing adequate space in the peritoneal cavity.

A case series out of the University of California, San Francisco, followed 47 pregnant patients with symptomatic gallstones from 1980 through 1996, during which time approximately 30,000 deliveries occurred [53] . Thirty-three women presented with biliary colic, 12 with acute cholecystitis, and 2 with pancreatitis. In total, 17 of the 47 women, or 36%, failed nonoperative management and required cholecystectomy during pregnancy. Fourteen women underwent laparoscopic cholecystectomies and 3 women underwent open cholecystectomies. More than half of the patients with biliary colic had recurrences, and one quarter required a cholecystectomy. Five of the 12 patients with acute cholecystitis required cholecystectomy while pregnant and 4 more required it postpartum. The study reports no fetal morbidity or mortality. They conclude that most pregnant patients can be managed nonoperatively, but those with recurrent symptoms or severe

symptoms should undergo laparoscopic cholecystectomy with special care to protect the fetus.

Endoscopic retrograde cholangiopancreatography (ERCP) has been performed in pregnant patients with no adverse outcomes to the fetus. If indicated, steps should be taken to limit the potential deleterious effects of radiation on the fetus. Experienced endoscopists using minimal exposure time with fetal shielding to limit the teratogenicity of the radiation will minimize fetal risks [54] .

Trauma in pregnancy

A study out of the Cook County Medical Examiners office in Chicago revealed that of 95 maternal deaths occurring from 1983 to 1986, 45% were a result of trauma, making trauma the number one cause of maternal death in this series [55] . This is consistent with trauma being the number one cause of death in all women of childbearing age. The maternal mortality rate has dropped considerably the past 50 years, from 582 maternal deaths per 100,000 live births to 7.8 deaths per 100,000 live births. Fifty years ago, most deaths could be attributable to poor obstetric care.

Advanced Trauma Life Support (ATLS) guidelines should be followed for the injured pregnant patient. ATLS protocol highlights, “Treatment priorities for an injured pregnant patient remain the same as for the nonpregnant patient” [56] . The risks of fetal mortality rise with increasing injury severity of the mother and injuries to the fetus itself, and do not appear to be related to anesthesia, medications, or surgical procedures [57] [58] . The treatment should be modified based on the unique anatomic and physical characteristics of the pregnant patient.

Supplemental oxygen and intravenous fluid administration should start early. Pregnant patients should be positioned in the left lateral decubitus position unless a spinal injury is suspected [56] . This involves placing the patient in a c-collar and on a backboard, and then turning the patient in the left lateral decubitus position. This will move the uterus off of the IVC, increasing venous return to the heart. As discussed earlier, the maternal blood volume can increase significantly from the nonpregnant state. Therefore, significant hemorrhage can occur prior to a change in the maternal physiologic parameters, while the fetus may be approaching shock. Fetal shock can occur in the setting of a normotensive mother [59] . For this reason, aggressive fluid resuscitation is recommended, with minimal dependence on pressors.

A surgeon and obstetrician should be involved early in the care of the injured pregnant patient. Fetal heart monitoring should be utilized liberally. Radiographic studies should be utilized as needed, with care taken to shield the fetus and to avoid unnecessary or duplicate studies if possible. Maximum recommended total radiation exposure for the fetus for the pregnancy is approximately 5 rads. Trauma ultrasound, or FAST (focused abdominal sonography for trauma), is effective in assessing for intra-abdominal injury in the pregnant patient [60] and an additional view of the uterus can evaluate for placental abruption and fetal abnormalities.

The risk of fetomaternal hemorrhage should be considered if the trauma has any relation to the uterus. In an Rh-negative mother, the Kleihauer-Betke test can be used to detect fetal cells in the mother's serum. If there is a possibility of fetomaternal hemorrhage in an Rh-negative mother, Rh immune globulin should be administered to the mother within 72 hours of injury as the Kleihauer-Betke test can be falsely negative. The dose of Rh immune globulin is 300 micrograms initially, then 300 micrograms for every 30 cc fetomaternal hemorrhage that the Kleihauer-Betke test estimates [61] . Standard laboratory studies and an alcohol level should be sent, and tetanus administered as appropriate.

Abdominal trauma can be more difficult to manage in the pregnant patient. The uterus enlarges and pushes the small bowel out of the way, so there is a decreased risk of small bowel injury in penetrating trauma. In blunt trauma, the uterus and its contents absorb much of the abdominal force. The primary concern specific to trauma in the pregnant patient is placental abruption, which is a leading cause of fetal death in the injured pregnant patient [59] . Ultrasound is a useful and noninvasive way to evaluate the uterus for abruption and the fetus for abnormalities. Abruption can be difficult to predict and life threatening to mother and fetus. Abruption may occur in the setting of even minor trauma. At the University of Michigan, all traumas occurring after 20 weeks gestation are monitored for at least four hours. If, during that time, patients have more than three contractions in any hour, uterine tenderness, abnormal fetal tracing, ruptured membranes or vaginal bleeding, observation is continued for 24 hours [62] [63] . A secondary complication from traumatic abruptio placenta is that of disseminated intravascular coagulation, which can occur in up to 30% of affected patients [64] . Uterine rupture may also occur, although much less frequently, on the order of 0.6% of blunt trauma cases. Risk factors include multiple gestations, later gestations and a previous uterine scar [65] . Obstetricians and perinatologists can be helpful if there is difficulty determining the estimated gestational age of the fetus.

As one would expect, fetal and maternal mortality rates from pelvic trauma and associated fractures are primarily correlated with injury severity to the mother. Mechanisms of fetal death include direct injury to the placenta and uterus, direct injury to fetus, maternal hemorrhage, maternal hypotension, and maternal death [66] . Complications that can occur from pelvic trauma in a pregnant patient include hemorrhage, especially given the vascularity of the gravid uterus, abruptio placenta with resultant hemorrhage, increased abdominal pressure, and coagulopathy secondary to amniotic fluid embolism. As in other emergencies, treatment should be directed initially at the mother. Fractures should be repaired as needed, with an attempt to decrease the amount of radiation exposure to the pelvis. Perfect anatomic reduction may need to be sacrificed if that would put the fetus in jeopardy. In some cases, definitive care can be delayed so the fetus can reach a level of maturity suitable for cesarean section, followed by fracture repair [67] . An unstable pelvis is a contraindication to vaginal delivery [68] .

Emergency cesarean section in the unstable mother can be used to save the fetus. A retrospective study involving nine level 1 American College of Surgeons designated trauma centers evaluated 32 emergency cesarean sections performed on more than 441 pregnant women out of 114,952 consecutive trauma admissions [69] . Overall, 42% of the

fetuses survived. Seventy-five percent of the fetuses who were older than 26 weeks estimated gestational age and who had fetal heart tones survived. Seventy-two percent of the mothers survived.

It is generally recommended that in selective cases of maternal distress, with the presence of fetal heart tones and an estimated gestational age of greater than 26 weeks, cesarean section can be beneficial [61] . The primary guiding principle is the resuscitation of the mother. All resuscitation measures including medications and ACLS protocols should be done as in a nonpregnant patient. The second principle is to save the fetus. However, often one cannot save the mother without an emergent cesarean section and thus, the fetus needs to be delivered very preterm. In the case of maternal cardiac arrest, cardiopulmonary resuscitation should be initiated and if the estimated gestational age of the fetus is greater 26 to 28 weeks, a cesarean section should be performed. Chest compressions may not be as effective in the setting of an enlarged uterus, and the emptying of the placenta has the potential for saving both mother and fetus [61] . After 4 minutes of fetal hypoxia, neurological damage will likely occur [70] . Estimated gestational age can be determined quickly by palpating the uterus above the umbilicus. For an age of 26 weeks, the uterus should be at least 2 to 3 fingerbreadths above the umbilicus. Maternal survival of cardiac arrest is possible after emergent cesarean section.

Morris et al [69] describe performing the cesarean section as follows. A generous midline incision is made through the skin, fascia and peritoneum. A vertical incision is made in the uterus and the placenta as well, if it is anterior. The fetus is delivered, cord clamped and cut, and neonatal resuscitation begun. Maternal resuscitation should continue as there are anecdotal reports of maternal survival.

Significant fetal complications at this early stage of pregnancy include adult respiratory distress syndrome, intracerebral hemorrhage, and necrotizing enterocolitis. In general, uterine atony is the most common cause of postpartum hemorrhage, and is treated with oxytocin.

Pregnancy is one of several risk factors for domestic violence, and approximately 5% to 30% of female trauma patients have a recent history of domestic violence. Common anatomic sites of abuse among pregnant women include the gravid abdomen, breasts, and genitals [71] . Simple screenings exist for domestic violence [72] , including questions such as, “Have you been hit, kicked, punched or otherwise injured by someone within the past year? If so, by whom?” Domestic violence screening tests have been accepted by female trauma patients as a beneficial part of their postinjury care [73] . Various agencies can help in the prevention of further domestic violence, and social workers can help in the screening and management of the affected women.

Breast cancer

Pregnancy-associated breast cancer, which occurs during or within 1 year of pregnancy, presents in approximately 1 of 5,000 pregnancies [74] . It is believed that because of the difficulty in diagnosing breast cancer during and after pregnancy, affected women are

diagnosed later and with more advanced disease. Although it was previously believed that the hormonal changes during pregnancy may worsen the prognosis, this has not been proven in modern studies [75] . Stage for stage, it has about the same survival as breast cancer not associated with pregnancy.

The difficulty in diagnosing pregnancy-associated breast cancer lies in not expecting it as well as the difficulty in examining the pregnant patient's breasts. Because of the intense hormonal surge, the breast enlarges and becomes more firm. If an abnormal firmness is identified, it should be followed up closely and biopsied if it does not regress. Mammography is both safe and useful in the diagnostic workup of a clinically evident mass [76] [77] . The radiation dose to a properly shielded fetus is approximately 0.01 rads, less than the accepted 5 rad limit. Ultrasonography can be used to evaluate a lesion as solid or cystic and to aid in biopsy. Currently, there are no absolute indications for MRI in the diagnosis of breast cancer during pregnancy, although it can be used to survey for distant metastases instead of a CT scan. Fine-needle aspiration biopsy of an abnormal mass should pose no increased risk to the mother or the fetus. Core biopsies can also be performed with minimal risk, although the rare complication of milk fistula after core biopsy has been reported [74] .

Treatment for pregnancy-associated breast cancer involves the same principles as treatment for breast cancer not associated with pregnancy. The main difference lies in the use of radiation therapy, which is contraindicated during pregnancy. Even with proper fetal shielding, therapeutic radiation for breast cancer involving 50 rad to the breast will deliver 15 to 18 rads to the fetus, higher than the 5 to 10 rads thought to be safe [79] . Treatment options in the early part of pregnancy would include mastectomy, while later in pregnancy, breast conservation therapy could be used with a delay in radiation until after delivery. If mastectomy with reconstruction is contemplated, the reconstruction should be delayed until after the pregnancy when the contralateral breast returns to its normal size, so an aesthetic and balanced reconstruction can be accomplished.

Chemotherapy may also have adverse effects on the fetus, with the most severe teratogenetic effects during the first trimester including a high rate of stillbirths and major malformations [80] . In one series, all four fetuses exposed to chemotherapy during the third trimester were delivered alive and healthy. A multiinstitutional survey in France found 20 pregnant patients with breast cancer treated with chemotherapy. The data were obtained by questionnaires sent to members of various French oncological societies. Of two women treated during the first trimester, both had spontaneous abortions. Of the remaining 18, there was one stillbirth and two pregnancy complications, but of the 17 deliveries, the children did well in the short term [81] . In general, chemotherapy should be avoided during the first trimester, and can be used fairly safely in the second and third trimesters. No data currently definitively show how maternal outcome is affected by chemotherapy given during pregnancy versus delaying until after delivery. Chemotherapy should be stopped approximately 3 weeks prior to delivery to limit the leukopenia and associated potential complications that can occur with the fetus [78] . Hormonal therapy is not recommended during pregnancy as the fetus may experience adverse effects [82] .

As of this point in time, sentinel lymph node (SLN) biopsy has not been studied in pregnant women, and major multicenter studies of SLN biopsy specifically exclude pregnant women [78] . SLN biopsy uses either the nuclear isotope technecium-99m or isosulfan blue dye (Lymphazurin, US Surgical Corporation, Norwalk, Connecticut,) or both, to identify the primary draining lymph nodes in the ipsilateral axilla. Theoretically, exposure of 1 mCi of technicium-99m to the breast would distribute a very low dose to the fetus, given that it does not cross the placenta. Isosulfan blue dye is a pregnancy category C drug, and it has not been tested on pregnant animals or humans. Keleher et al [78] from the M. D. Anderson Cancer Center currently do not recommend the use of isosulfan blue dye in the lymphatic mapping of pregnant patients.

The issue of therapeutic abortion for breast cancer is a difficult one. It is generally believed that the hormonal changes occurring during pregnancy do not lead to a worse prognosis for the cancer [75] [82] . Current data suggest that therapeutic abortion will not, in general, improve prognosis through endocrinological effects in pregnant women with breast cancer [82] . An indication for therapeutic abortion may be a patient with an aggressive breast cancer diagnosed early in pregnancy, who may benefit from an immediate start of chemotherapy. With discovery later in pregnancy, the mother may decide to wait until after delivery to start chemotherapy. This is a difficult decision and should involve discussions with the patient and her physicians.

A study from M. D. Anderson of 24 patients with pregnancy-associated breast cancer showed no adverse fetal effects from treatment [83] . Breast conservation with radiation therapy was not used in this series. Chemotherapy consisting of FAC (5-fluorouracil, doxorubicin, and cyclophosphamide) was utilized during the second and third trimesters, with no severe complications. The only complication reported was a transient leukopenia after a preterm delivery 2 days after the last chemotherapy dose. Maternal survival in this series was similar, stage for stage, with nonpregnancy-associated breast cancer survival. The study concludes that breast cancer can be safely treated during pregnancy with surgery and chemotherapy with good outcomes for mother and fetus. Methotrexate is associated with fetal malformations and is not recommended during pregnancy [78] [83] .

The same group has more recently published a case series of 4 patients diagnosed with breast cancer from 17 to 30 weeks gestational age who underwent breast conservation therapy with postpartum radiation therapy [84] . Using proper shielding, mammography and chest films were used to evaluate for multifocal disease. The group reports no adverse maternal or fetal outcomes using this approach, with a median follow-up of 44 months and no evidence of recurrence in the mother.

In summary, surgeons should be diligent in their workup for breast masses in pregnancy, using mammograms, ultrasounds and biopsies as needed. The hormonal state of pregnancy has not been shown to hasten the aggressiveness of breast cancer or worsen the prognosis for a given stage. Pregnancy is not a contraindication for a surgical resection of a breast cancer, although sentinel lymph node biopsies have not been studied in pregnant women. Radiation therapy should not be used during pregnancy, but breast conservation can be an option if the radiation therapy is delayed until the postpartum

period. FAC chemotherapy can be used during the second and third trimesters of pregnancy with low risk to the fetus, but it is contraindicated during the first trimester. The issue of therapeutic abortion is difficult, and the patient should make the decision after a thorough discussion with the surgeon and oncologist about the potential risks and benefits of the procedure. It would most likely benefit maternal prognosis in the case of an aggressive cancer in the early stages of pregnancy when the oncologist would recommend chemotherapy without delay. Subsequent pregnancy after the diagnosis and treatment of breast cancer does not appear to increase the likelihood of progressive or recurrent breast cancer [85] [86] .

Uncommon surgical problems in pregnancy

Splenic artery aneurysms

Although uncommon, splenic artery aneurysms can be fatal in pregnant patients. Pregnancy, multiple gestations and portal hypertension are the most important risk factors for the development of splenic artery aneurysms. The association with pregnancy is believed to be caused by the changes in the hormonal milieu found during pregnancy, and may also be influenced by hypertension associated with pregnancy [87] . The mortality of ruptured splenic artery aneurysm during pregnancy is around 75%, with a fetal mortality rate of 95% [88] . Unfortunately, most splenic artery aneurysms in pregnant patients are discovered upon rupture, where treatment consists of splenectomy and splenic artery ligation.

Hepatic adenomas

Hepatic adenomas are most commonly associated with oral contraceptive use. When discovered in the nonpregnant patient, the oral contraceptives should be stopped and the adenomas observed and resected if they fail to disappear. The sex steroid surge associated with pregnancy increases the vascularity of the liver, increasing the propensity of existing tumors to rupture resulting in maternal and fetal mortality of greater than 50% each [89] . If discovered during pregnancy, hepatic adenomas should be followed with ultrasonography and resected if they continue to grow or are larger than 5 cm. There are numerous reports of successful pregnancy outcomes after liver resection for hepatic adenoma [90] .

Pheochromocytoma

Pheochromocytoma, although rare in pregnancy, should be suspected in the pregnant patient with labile hypertension, and approximately 200 cases have been reported in the literature [91] . Failure to diagnose pheochromocytoma prior to delivery will result in both maternal and fetal mortality of around 50%. Resection prior to delivery can reduce mortality to less than 5%. The workup is similar to nonpregnant patients, and MRI is the diagnostic modality of choice. Treatment initially involves control of blood pressure with

phenoxybenzamine and possibly beta blockers. Adrenalectomy, either laparoscopic or open, in the second trimester is safe. In the third trimester, vaginal delivery followed by postpartum elective adrenalectomy or combined cesarean section and adrenalectomy are appropriate approaches.

Conclusions

Throughout a practice, a general surgeon will encounter pregnant women presenting with a variety of general surgical issues, elective, urgent and emergent. In general, in the urgent and emergent settings, care should proceed in the same manner as with a nonpregnant patient. An obstetrician should be consulted to assist in the management of mother and fetus. The surgeon should have a basic understanding of the issues specific to pregnancy that make care more challenging.

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