Surgical Emergencies in the Pregnant Patient

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Synopsis: One in 500 to 700 pregnancies in the United States are complicated by an abdominal emergency necessitating surgery. Addressing these emergencies during pregnancy presents several decision making challenges and commonly calls into question the appropriate approach for evaluation and definitive care. Ultimately, surgical intervention can be performed safely during pregnancy independent of trimester and offers definitive therapy and a quicker recovery when performed laparoscopically.

Keywords: pregnancy, emergency, abdominal, appendicitis, cholecystitis, trauma

Keypoints:

- One in 500 to 700 pregnancies in the United States present with an abdominal emergency requiring surgery
- Treatment of the mother is the focus, but consideration of the impact on the fetus should be weighed
- When indicated, timely operative intervention is better than delaying care
- During pregnancy, diagnostic radiologic tests should enlist ultrasound first and foremost

Introduction

One in 500 to 700 pregnancies in the United States are complicated by an abdominal emergency.[1,2] Several indications can present that necessitate operative intervention in as many as 2% of cases. The most common developments include appendicitis, acute cholecystitis, ovarian torsion, small bowel obstruction, and traumatic injury (Table 1). Other less common etiologies include hepatic lesions, worsening inflammatory bowel disease, vascular pathology including splenic artery aneurysm, and urolithiasis with renal colic.[1] The dilemma of addressing these ailments can present challenges in any patient, pregnancy adds to the complexity and commonly calls into question the appropriate approach for definitive care. In general, it is commonly considered that infectious or hematologic issues can threaten both the fetus and the mother unless addressed in a timely manner. Advancements in radiologic tools and understanding of their impact on the fetus has altered diagnostic methodology and algorithm. Establishing best practices for the management of non-obstetrical abdominal emergencies that occur during pregnancy is key to the goal of reaching term and the delivery of a healthy baby.

Table 1. Incidence of Abdominal Emergencies During Pregnancy[1-3]

Pathology	Incidence
Acute appendicitis	1 in 500 to 2000 pregnancies
Acute cholecystitis	1 in 1000 pregnancies
Ovarian torsion	1 in 1000 to 2500 pregnancies
Bowel obstruction	1 in 1500 to 16,000 pregnancies
Abdominal trauma	1.5 to 5% of traumas in women
Abdominal wall hernias	1 in 500 pregnancies
Hepatic adenoma	1 in 1,000,000 women
Inflammatory bowel disease	Pre-pregnancy disease status determines severity, new diagnosis consistent with general population
Renal colic	1 in 3300 pregnancies
Splenic artery aneurysm	1 in 1000 women

Evaluation

The diagnosis and evaluation of surgical emergencies requires an understanding of the typical physiologic changes associated with each trimester of pregnancy. Grasping these changes in a pregnant woman's anatomy will help provide a basis for comparison, reframe testing results, and avoid unnecessary invasive tests or procedures.

Physiology and Physical Exam

During pregnancy, the development of the fetus is associated with numerous physiological changes of the mother in addition to the increasing size of the uterus. The cardiovascular system sees an overall increase in plasma volume, cardiac output, stroke volume, and heart rate. However, blood pressure dips during late second trimester and early third trimester before it returns to baseline.

There is an increase blood flow to several organs including the kidneys. Glomerular filtration rate increases along with the blood flow. Common laboratory tests shift during pregnancy including white blood cell count. There is also a decrease in the serum albumin concentration and a reduction in the oncotic pressure of the mother's serum. Liver oxidative enzymes including cytochrome P450 are altered.

Pulmonary physiology demonstrates an increase in tidal volume and minute ventilation. This is largely related to increased oxygen needs of the fetus and commonly results in mild tachypnea (16 breaths per minute). Other gastrointestinal changes include an increase in gastric emptying and small intestinal transit time which can lead to nausea and vomiting and associated gastroesophageal reflux disease.

Naturally, the growth of the fetus is the most obvious change in physiology and physical exam. In general, the fundal height presents at predictable locations throughout the advancing pregnancy. Examples include breaching of the fundus above the symphysis pubis at 12 weeks. At 20 weeks, the fundal height commonly reaches the umbilicus. At term, the uterus is generally palpable and

approaches the costal margin. As the uterine fundus grows, it exerts pressure to surrounding abdominal structures which may affect their function. For example, mothers in the last trimester of pregnancy are advised to avoid lying supine in an effort to prevent complete occlusion of the inferior vena cava. It is important for the general surgeon to recognize the changes that occur in the mother's anatomy by the expanding uterus as they impact placement of incisions and positioning on the operating table if an operative intervention is warranted.

Laboratory

In addition to anatomical changes, physiologic changes during pregnancy are also reflected in common laboratory tests (Table 2).[1,4] Hematologic tests including the complete blood count (CBC) commonly demonstrate changes beginning at the end of the first trimester. Erythropoietin leads to increased red blood cell mass and red blood cell volume. However, an increase in plasma volume that also accompanies pregnancy leads to hemodilution that generates a common picture of anemia most pronounced in the second trimester. In the third trimester, HELLP syndrome (hemolysis, elevated liver enzymes, low platelet count) can present and is associated with 10 to 15% of pre-eclampsia cases. As a result of increased polymorphonuclear cells, leukocytosis is also associated with pregnancy, particularly during the second semester where the white blood cell count may reach 16,000 WBC/mm^2. Coagulation indices are commonly altered during pregnancy with the development of a hypercoagulable state reflected by increased coagulation factors and reduced coagulation inhibitors.

Changes are also commonly seen in chemistry tests. The increase in plasma volume leads to a hemodilutional effect on serum creatinine and blood urea nitrogen. This is compounded by an increase in creatinine clearance and glomerular filtration rate. Similar hemodilutional effects are commonly seen in levels of albumin, bilirubin, and transaminases. However, alkaline phosphatase, produced by the

placenta, is commonly elevated from two to fifteen times normal values. In addition, the sedimentation rate is consistently elevated throughout pregnancy.

Table 2. Common Laboratory Changes During Pregnancy[1,4]

		1st Trimester	2nd Trimester	3rd Trimester
Complete Blood Count (CBC)				
	Hemoglobin (g/dL)	11.7 – 13.7	9.7 – 11.5	9.8 – 12.3
	Hematocrit (%)	36	33	34
	Leukocytes (1000 per mm^3)	3.2 – 15.3	6.3 – 16.1	5.0 – 16.6
	Platelet Count (per mm^3)	Unchanged	Unchanged	Unchanged
Liver Function Tests				
	AST/ALT (µmol/L)	Unchanged	Unchanged	Unchanged
	Bilirubin (µmol/L)	Unchanged	Unchanged	Unchanged
	Alkaline phosphatase (IU/L)	Unchanged	2 – 15 X normal	2 – 15 X normal
Chemistries				
	Na+ (mmol/L)	140 ± 5	Stable	Stable
	K+ (mmol/L)	3.5 – 4.5	Stable	Stable
	BUN (g/L)	Decreased	Decreased	Decreased
	Creatinine (µmol/L)	Decreased	Decreased	Decreased
	Lipase (IU/L)	Decreased	Stable	Stable
Inflammatory Indicators				
	C reactive protein (mg/L)	Unchanged	Unchanged	Unchanged
	Sedimentation rate (mm/hr)	Very high	Very high	Very high

Radiology

Radiologic diagnostic tests have become a hallmark of modern medical evaluation. X-ray exposure to the developing fetus is unwanted in all phases of pregnancy, but it is most impactful during the first trimester where teratogenic effects are the most significant.[5] Fortunately, X-ray-based technology has improved dramatically in recent years yielding a lower amount of radiation exposure to all patients. As a result, these tests remain available, but they are commonly used only after alternatives that do not expose the patient to radiation have been considered and either proven ineffective or unavailable.

It is helpful to consider the amount of radiation exposure provided by each X-ray-based exam (Table 3) and the risks. Current guidelines recommend a cumulative exposure of less than 100 mGy of X-ray radiation to the fetus to limit teratogenic risk.[3] In addition to concerns regarding teratogenesis, studies raise concerns for the development of childhood cancer especially when radiation exposure occurs during the first trimester at a level greater than 50 mGy[6]. Generally, the risks for teratogenesis and childhood cancer fall significantly when exposure occurs in the second or third trimester. Limiting the radiation dose is key. This is commonly done with efficient use of CT studies and algorithms, and the application of a lead apron over the fetus when the abdomen and pelvis are not actively being examined. Ultimately, in the later phases of pregnancies, CT, even with intravenous contrast, can be considered an acceptable tool if other options have proven ineffective and it prevents delay in diagnosis and the eventual management of the patient.[3]

Table 3. Radiation Exposure to Fetus from Common Radiating Tests

Test/Procedure	Fetal Absorbed Dose (mGy)*
Background	0.5 – 1
Abdomen X-ray	1 – 3
Abdominal CT**	4
Abdominal & pelvic CT**	25
Chest CT**	0.02

*Radiation shield placed over abdomen when not in the test field, **CT = computerized tomogram

During pregnancy and especially the first trimester ultrasound is generally considered the first choice for the evaluation of the abdomen based upon its lack of radiation exposure to the patient, its common use by obstetricians, rapid turn-around time, and overall availability in multiple healthcare environments including outpatient clinics. In addition, ultrasound is very effective at evaluating solid organs and several common areas of concern in the gastrointestinal track including the gallbladder and appendix. Finally, obstetricians are able to use ultrasound to evaluate the status of the fetus to determine the impact of maternal maladies on it.

Second to ultrasound, magnetic resonance imaging (MRI) is called often upon to evaluate pregnant patients with potential surgical emergencies. Currently, the American College of Radiology recommends MRI over CT for the evaluation of pregnant patients. Although iodinated contrasts used in CT appear to have limited impact of fetal development, gadolinium crosses the placenta into the fetal circulation and may result in nephrogenic systemic fibrosis. So, its use is limited to a very select group of circumstances including *placenta percreata*.[3]

Common Emergencies

Appendicitis

Presentation

Among non-obstetrical surgical emergencies, acute appendicitis is clearly the most common representing about 25% of cases with an incidence of 0.5 to 2 per 1000 pregnancy women.[1] Although it occurs most commonly during the second trimester, its incidence is roughly the same as in the general population.

Pain in the right lower quadrant remains the most common presenting symptom, but the movement of the appendix as a result of displacement by the enlarging uterus can lead to pain in right upper quadrant, flank, or even back. Physical exam findings of peritoneal signs including guarding and rebound tenderness can still occur, but they may also be impacted by the displacement of the appendix. Complaints of anorexia and nausea are also common, but these issues are common for all pregnant women, especially those in the first trimester. History and physical exam, while suggestive, are typically not adequate to secure the diagnosis in the pregnant patient.

Evaluation

With regard to laboratory blood tests, the presence of a leukocytosis, the hallmark of acute appendicitis, is an unreliable tool in the evaluation of pregnant women as a result of the physiologic leukocytosis of pregnancy. Given the limitations of history and physical exam and laboratory analysis in the pregnant patient, diagnosis of acute appendicitis relies mainly on radiologic tests. In order of preference, modalities commonly relied upon include ultrasound, MRI, and CT. Earlier in pregnancy, before the displacement of the appendix and small intestine, ultrasound performed by a skilled technician is usually effective in securing the diagnosis. However, later in pregnancy, at locations where ultrasound is unavailable, or ultrasound findings are equivocal, MRI provides exceptional sensitivity and specificity for the diagnosis of acute appendicitis.[7] Nevertheless, MRI may also provide challenges based on availability and practicality, rendering CT the remaining modality which is equally sensitive for the diagnosis in pregnant patients as in the general population. When other diagnostic modalities are unavailable or inconclusive, concerns regarding radiation exposure by CT independent of trimester, have to be balanced with the impact on the mother and fetus of a delayed or missed diagnosis. It is important for the surgeon to recognize that appendiceal perforation resulting from a diagnostic delay is associated with premature uterine contractions, pre-term labor (in the third trimester), and fetal loss.

Treatment

Although non-operative treatment of acute appendicitis continues to be explored within the general population, appendectomy remains the main stay of treatment for acute appendicitis in pregnant women.[8,9] Laparoscopic appendectomy is the preferred approach for the treatment of acute appendicitis in the pregnant patient.[3,11] Initial port placement should consider the uterine fundal height, and the surgeon should rely upon the entry technique with which he or she is most experienced and comfortable.

When an open technique is employed the incision location should be determined by the point of greatest tenderness.[12] Reliably, in the first trimester, a classic right lower quadrant incision will prove effective. As pregnancy progresses, however, the best location for the incision will rise higher on the right side. In the third trimester, some surgeons prefer an upper midline incision to provide better access and exposure. A periumbilical midline incision is used effectively in cases of diffuse peritonitis.

Acute Cholecystitis

Presentation

Biliary track disease, specifically acute cholecystitis, is the second most common non-obstetrical surgical emergency occurring at a rate of one per 1600 to 10,000 pregnancies. The most common etiology of acute cholecystitis in this setting is gallstones.

Presentation commonly follows classical teaching with nausea ± vomiting, fatty food intolerance, and colicky right upper quadrant pain. Although this pattern of symptoms is similar to presentation among the general population, the differential diagnosis generated by this pattern of presenting complaints is much wider in the pregnant patient and has potentially greater impact if incorrect. A differential diagnosis mainly includes pancreatitis, hepatitis, peptic ulcer disease, pneumonia, and pyelonephritis. In addition, due to its shifting location, appendicitis may also present with a similar pattern of signs and symptoms. Obstetrical diseases including fatty liver disease of pregnancy resulting from pre-eclampsia with HELLP syndrome must also be considered.

Evaluation

Laboratory blood tests can be quite helpful in focusing the differential diagnosis, but physiologic leukocytosis and an elevated alkaline phosphatase associated with pregnancy render these specific tests less reliable. As a result, radiologic tests are relied upon commonly to provide definitive diagnosis of

acute cholecystitis. As in the general population, ultrasound remains the main modality for the evaluation of the biliary track including the gallbladder. The presence of gallstones, gallbladder wall thickening, and peri-cholecystic fluid in a pregnant patient with suggestive symptoms confirm the diagnosis similar to the general population. When the diagnosis is uncertain, a radionucleotide exam performed through nuclear medicine is generally considered safe and can be adjusted to limit radiation exposure to the fetus.[3]

Treatment

Although non-operative management has been the traditional approach in the pregnant patient out of fear for spontaneous abortion or premature delivery after surgery, surgical intervention is currently the treatment of choice for numerous reasons. When delaying treatment, recurrent gallbladder symptoms have been reported to occur in 44-92% of patients depending on pregnancy trimester, half of which will require hospitalization [130] and up to 23% will develop acute cholecystitis, cholangitis, or gallstone pancreatitis [90, 131]. Importantly, depending on severity, complicated gallstone disease has been reported to lead to preterm labor in up to 20% of cases and fetal loss in 10% to 60% of cases, [132, 133].

For these reasons laparoscopic cholecystectomy is the treatment modality of choice for pregnant patients in the setting of acute cholecystitis, regardless of trimester.[13,14] Laparoscopic cholecystectomy has been reported to lead to shorter length of stay, shorter operative times, fewer complications, and decreased rates of spontaneous abortion and preterm labor when compared to laparotomy [127][6]. When choledocholithiasis is suspected, intraoperative cholangiography can be applied safely and effectively.[3] Endoscopic ultrasound and choledochoscopy are good alternatives in the presence of appropriate expertise and avoid patient exposure to radiation. Further, choledochoscopy can also be therapeutic allowing removal of common bile duct stones. Given that laparoscopic

choledochoscopy experience of general surgeons tends to be limited, endoscopic retrograde cholangiopancreatography (ERCP) is usually employed for the treatment of choledocholithiasis in the pregnant patient similar to the general population. ERCP during pregnancy has been shown to be safe and effective [63, 136, 137] and associated with low radiation exposure of the pregnant patient. Endoscopic ultrasound and stenting provide options to further limit radiation exposure when addressing common bile duct stones. Gallstone pancreatitis presents an even greater challenge for diagnosis and treatment. Although ultrasound may be of benefit, generally MRI and CT are relied upon for diagnostic purposes. Initial management is mainly supportive with limited oral intake, intravenous fluids, and pain control as in the general population. Given that recurrent pancreatitis is of significant concern and much more common than in the general population, early laparoscopic cholecystectomy after the pancreatitis has resolved may also be the best approach independent of trimester.[3]

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Ovarian Torsion

Presentation

Impacting approximately 1 in 1000 to 1 in 2500 pregnancies, ovarian torsion commonly presents with abdominal pain corresponding to the affected adnexa and nausea and vomiting.[1,15] Those patients who underwent fertility treatments are at greater risk for the development of ovarian torsion. In addition, torsion appears to occur more commonly during the first trimester and more commonly on the right side. It would appear that the presence of the corpus luteum and an overall increased ovarian mass as a result of hormonal stimulation contribute to the development of torsion. The differential diagnosis for right sided pain should always include appendicitis and other pathologies.

Evaluation

Physical examination will demonstrate ipsilateral adnexal tenderness. However, examination of the ovary may become more difficult as the pregnancy progresses. Laboratory tests demonstrate a leukocytosis that is generally unhelpful in pregnancy when an increased white blood cell count is typical. Therefore, ultrasound is the tool of choice to confirm the diagnosis. During the first trimester, a multicystic ovary is commonly identified[16] , while a normal appearing ovary is commonly seen in the later stages of pregnancy. The corpus luteum is commonly present in the affected ovary. The diagnosis is confirmed when reduced or absence of blood flow to the affected ovary is detected by doppler.

Treatment

Surgical detorsion with oophoropexy is the treatment of choice with less common cystectomy or oophorectomy.[17] In limited studies evaluating ovarian torsion, time from presentation to operative intervention was significantly less for those in the first trimester rather than later stages. Potential explanations include more challenging physical exam of the ovaries due to the larger uterus and a lower threshold to operate on patients in earlier stages of pregnancy when preterm labor is less likely. Interestingly, the time from presentation to operative intervention is less for those in the first trimester than the non-pregnant population. Perhaps, the presence of pain in this population more commonly leads to early presentation and an increased suspicion of an abdominal emergency despite the vague, nondescript symptoms that may accompany the development of torsion.

Diagnostic laparoscopy can be used to confirm the diagnosis in settings of unclear pathology. Delays in diagnosis and treatment may result in tissue necrosis necessitating resection. As torsion commonly involves the ovary containing the corpus luteum, progesterone therapy may be required for episodes of torsion occurring during the first trimester.[3]

Bowel Obstruction

Presentation

Occurring in 1 in 1500 to 16,000 pregnancies, bowel obstruction resulting predominantly from adhesions is the third most common non-obstetrical surgical emergency.[1] Historically, these patients experience significant risks for morbidity and mortality of both the fetus and the mother. As the uterus grows in size, cecal volvulus should be considered on the differential diagnosis as well. With a pattern of symptoms similar to the general population, bowel obstruction in the pregnant patient is associated with central colicky abdominal pain, bloating or distension, nausea and vomiting, constipation and/or obstipation.

Evaluation

Some reports have demonstrated the benefits of ultrasound in the diagnosis of bowel obstruction.[18] However, X-ray-based tests, specifically plain radiographs of the abdomen, prove most effective in the analysis of the patient with small bowel obstruction. The addition of enteral contrast can provide further elucidating information. The addition of enteral ionic contrast has proven safe in the pregnant patient. When administered with a CT, it can provide both diagnostic and therapeutic benefits.[19,20]

Treatment

In the stable patient, initial supportive care and expectant management including nasogastric decompression and hydration is appropriate.[21] Similar to the non-pregnant patient, failure of non-operative management to result in resolution of the obstruction requires operative intervention.[22] When clinical findings are concerning for ischemia, immediate operative intervention is indicated similar to the general population. The patient's surgical history and size of uterus may assist in the consideration for operative approach with the potential for laparoscopy offering a safe option and shorter convalescence.

Abdominal Trauma

Presentation

Between 1.5 and 5% of women suffering traumatic injuries are pregnant.[23] Abdominal trauma during pregnancy most commonly results from motor vehicle accidents (34 to 70%), falls (9 to 26%), and physical assault (11 to 12%).[24] Although a very limited number of patients require surgical intervention, trauma represents the most common cause of non-obstetrical maternal death. Fetal death from trauma-related injury is estimated at 3.7 fetal deaths per 100,000 live births. Obtaining an accurate history is of key importance in determining the potential systems exposed to injury.[25]

Evaluation

A full trauma survey including the initial assessment and the secondary survey are needed to identify areas of concern. These surveys proceed largely unchanged from those used for evaluation of a non-pregnant patient. However, the secondary survey should include a detailed obstetrical history including last menstrual cycle, expected delivery date, and problems that have occurred to date during the pregnancy. During the secondary survey, the abdominal examination should also include an assessment of uterine size to help confirm estimated gestational age of the fetus; this can be used to determine the predicted survival of the fetus if cesarean section is required. Uterine fundal height at or above the umbilicus suggests a fetus with potential extra-uterine viability. The secondary survey should also include a direct fetal assessment including examination of fetal heart rate and the presence of movement.

Discrepancies between the stated gestational age and the estimated gestational age determined by physical exam could suggest uterine trauma. In addition, the presence of vaginal bleeding, membrane rupture, bulging perineum, and the presence of contractions should all raise concern for serious injury. Laboratory tests including a Kleihauer-Betke test performed in all women more than 12 weeks gestational age assesses the presence of fetal blood cells in the maternal blood stream and

suggests trauma to the uterus and fetus. Although there is no clear correlation between the severity of trauma and the presence of fetal cells in maternal circulation, a positive test should raise concern for severe injury and consideration for the administration of Rho(D) immune globin (RHOgam) to avoid Rh sensitization. Some argue that all Rh- pregnant women suffering severe trauma should receive RHOgam within 72 hours of the traumatic event regardless of test results.[26]

A focused assessment with sonography in trauma (FAST) provides both high sensitivity and specificity for detecting major abdominal trauma.[27] Although ultrasound and MRI are commonly preferred modalities, it is generally recommended that the treating surgeons utilize the appropriate radiologic tests for effective evaluation of traumatic injuries regardless of radiation exposure.[6] It is recommended that a limitation of radiation dose is coordinated with the radiology technician when multiple X-ray based tests are needed.[28]

Treatment

Prehospital management of pregnant trauma patients recommends supplemental oxygen and liberal use of intravenous fluids to prevent fetal hypoxia. However, the underlying *modus operandi* aim to address treatment of the mother over the treatment of the fetus. A tool used on a limited basis for management of severe blunt traumatic injury in the general population, military antishock trousers (MAST) are contra-indicated during pregnancy as they can exacerbate injury to uterus or fetus during the second and/or third trimester. In addition, transport of patients at 20 weeks gestation age or greater requires tilting of the back board to the left to avoid aorto-caval collapse. Elevating the right hip approximately 4 to 6 inches with a wedge can provide a similar effect.

Management of blunt traumatic injury in pregnant patients largely follows the algorithms generated for non-pregnant patients.[29] Specifically, non-operative management of solid organ injury is commonly successful. However, maternal hypotension is more commonly associated with fetal distress.

Therefore, the threshold to intervene operatively should be lowered in the pregnant patient. In the second trimester, as the uterus becomes an abdominal organ, risk of direct trauma to the uterus rises dramatically despite natural tendencies of the uterine muscle and the amniotic sac to absorb energy. Hemorrhage from the traumatized gravid uterus can be extensive. Fortunately, even at later stages of pregnancy, the rate of uterine rupture remains extremely low.

Table 4. American Association for the Surgery of Trauma Gravid Uterus Injury Scale

Injury Grade	Description of Injury
I	Contusion or hematoma (without placental abruption)
II	Superficial laceration (<1 cm) or partial placental abruption < 25%
	Deep laceration (≥1 cm) occurring in second trimester or placental abruption > 25%
III	Superficial laceration (<1 cm) or partial placental abruption < 50%
	Deep laceration (≥ 1 cm) in third trimester
	Laceration involving uterine artery
IV	Deep laceration (≥ 1 cm) with > 50% placental abruption
	Uterine rupture
V	Second trimester
	Third trimester
	Complete placental abruption

Advance one grade for multiple injuries up to grade III. Adapted from Moore EE, *et al.*[30]

Treatment for penetrating trauma to the pregnant patient is also largely impacted by the gestational age of the fetus with the safety of the pelvis disappearing after week 12 (Table 4).[30] As in all cases of gunshot wounds, the type of firearm and the distance from the shooter dramatically impacts the outcome. Ultimately, if the bullet has entered or traversed the uterus and the fetus is viable, cesarean section should be performed. Hysterectomy is indicated if the uterus is beyond repair.

In the scenario of a lack of maternal pulses, cardiopulmonary resuscitation (CPR) is initiated. Chest compressions become less effective as the gestational age enters the third trimester. Monitoring of fetal blood flow is judged not only by the generation of a carotid pulse and a return of end-tidal carbon dioxide in the mother but also by the presence of appropriate fetal heart tones. Suggestion of fetal distress during CPR potentially from inadequate chest compressions should raise considerations for

open cardiac massage. If open cardiac massage proves ineffective in the setting of gestational age greater than 24 weeks, immediate cesarean section should be performed. Even in the setting of maternal death, a cesarean section performed within 5 to 10 minutes of cardiac arrest is felt to provide the fetus with a high probability of survival.[25,27] Trauma surgeons, likely unfamiliar with the technique, are urged to abandon the typical low transverse incision in the uterus in favor of a midline opening that will facilitate delivery and avoid damage to the uterine vessels. An even more challenging ethical dilemma that fortunately remains rare is the scenario of maternal brain death with a viable fetus. In general, the fetus may remain *in utero* to mature. Maintaining the mother's body until after 28 weeks gestational age offers the fetus the greatest opportunity for survival, but making this decision requires the assistance of an ethics team along with the patient's family and treating surgeons.

Less Common Emergencies

Hepatic Adenomas

Development of hepatic adenomas, generally solitary, is commonly associated with oral contraceptives and other hormone therapy. However, pregnancy is also associated with adenoma growth and risk of rupture.[31] Right upper quadrant pain should be evaluated with ultrasound. Although a cystic structure requires no immediate follow-up, a solid mass requires a non-contrasted MRI.[32] While smaller adenomas benefit from frequent follow-up ultrasounds to assess their growth, surgeons should consider resecting adenomas greater than 5 cm in diameter as they are associated with high risk of rupture and bleeding.[33]

Inflammatory Bowel Disease

Fortunately, the new diagnosis of Crohn's disease is less common in pregnancy than in the general public. Symptoms are commonly vague and can be misinterpreted as other benign intestinal maladies leading to a delay in diagnosis.[34] Crohn's disease flare ups are common during pregnancy and

typically present in the first trimester, but the course of disease is commonly dictated by the state of disease at the time of conception.[35] Ultrasound is unlikely to provide definitive information with most practitioners relying more on MRI and/or CT imaging. Operative intervention should favor conservative dogma including a tendency toward fecal diversion rather than primary anastomosis.[36] Abscesses developing in the setting of Crohn's disease are challenging to control during pregnancy.[37] Moreover, free perforation in the setting of Crohn's disease occurs at an even higher incidence. Therefore, patients with peritoneal signs require immediate evaluation and likely surgical intervention. A three stage surgical approach is common including initial resection, secondary reconstruction with proximal fecal diversion, and eventual reversal of the proximal diversion after delivery.[38]

Renal Colic

Urolithiasis is a common disease associated with severe abdominal/ flank pain and ureteral obstruction. A history and physical commonly narrows the differential diagnosis. Laboratory tests including urinalysis and renal ultrasound are confirmatory. Pain control is affected by the safety of analgesics during pregnancy.[39] Fortunately, acetaminophen and antispasmodics are commonly successful as non-steroidal anti-inflammatory medications are contraindicated in the later stages of pregnancy. Corticosteroids, considered when analgesics fail, are effective in postponing surgical intervention.[40] Persistent obstruction necessitates placement of a ureteral stent.[41]

Splenic Artery Aneurysm

Splenic artery aneurysm is the most common splanchnic arterial aneurysm and the third most common abdominal aneurysm following aorta and iliac arteries.[42] While splenic artery aneurysms generally are asymptomatic or generate vague symptoms, they may rupture during pregnancy (95% of cases present during pregnancy) presenting as sudden unexpected shock or even death.[43] Rupture is of greatest risk in mothers less than 45 years old and in the third trimester of pregnancy. Mortality risk is

high for both the mother and the fetus. Therefore, a timely diagnosis is key for a successful rescue, but rupture prevention is the preferred treatment strategy. The diagnosis may be raised with auscultation of a bruit in the abdominal left upper quadrant, observation of a calcified ring within the left upper quadrant, or with an ultrasound or CT. Treatment generally involves rupture avoidance through splenectomy with arterial resection or ligation of the artery with subsequent splenectomy.[44]

Abdominal Wall Hernias

The incidence of primary abdominal wall hernias (ventral and groin) has been shown to be 0.002% in a cohort of 20,714 pregnant patients[45]. Interestingly, none of these patients required elective or emergent repair during their pregnancy and in some their groin hernias disappeared spontaneously after delivery. Watchful waiting is, therefore, the currently recommended approach for primary hernias in a pregnant patient. When an operation is required to address a strangulated hernia timely surgical repair is advised.

Considerations During Treatment

Fetal Monitoring

Any evaluation and treatment of a pregnant patient should include an assessment of the fetus and determination of fetal health. The most rudimentary assessment remains the physical exam from which estimated gestational age, auscultated fetal heart tones, and palpation of fetal movement can be obtained. For patients in the earlier phases of pregnancy, ultrasound is a key component of this assessment. Formal ultrasonography helps assess the fetus in depth, but a Doppler probe or continuous fetal heart rate monitoring is an important adjunct to determining fetal health. The presence of a fetal heart rate between 120 and 160 beats per minute suggests good health while decelerations suggest distress. The combination of tocographic monitoring with fetal cardiac monitoring provides a highly sensitive and specific assessment of fetal and maternal condition and identifies elements of preterm labor. In fact, the combination of cardio and tocographic monitoring for fetal distress is more effective

than direct fetal ultrasonographic evaluation for identifying uterine catastrophic events including abruption or rupture.

Operative Technique

Upon initial assessment of a pregnant patient who may require operative intervention, a surgeon should consult and maintain consistent communication with obstetrical experts. Fetal monitoring before and after an operation is important but can present challenges when attempted intraoperatively; the value of the latter has not been conclusively shown and, therefore, is not routinely recommended [3]. Appropriate fluid resuscitation takes into consideration the increased plasma volume during pregnancy and supplemental oxygenation avoids maternal and fetal hypoxia. If operative intervention is necessary in patients in the second and third trimesters, a modified left lateral position is used to prevent uterine compression of primarily the inferior vena cava and less commonly the aorta. Abdominal surgery requires recognition of the changing uterine size and its impact on the placement of the initial port in laparoscopic surgery or the location of the incision in open procedures. Recognition of the changing uterine fundal height and adjustment of the location of initial port placement should allow surgeons to use the technique with which they are most comfortable and confident: open (Hasson), Veress needle, or optical trocar.[3] Insufflation pressures can initially be set at levels consistent with the general population. However, adjustment of the pressure should be considered if the patient's physiology doesn't support higher pressures (e.g. persistent maternal hypotension) or limited visibility sacrifices safety in lower pressures. In addition to the risk of fetal hypoxia from maternal hypoxia or hypotension, fetal acidosis associated with maternal and fetal hypercarbia can be equally detrimental. As a result, intraoperative monitoring of maternal capnography is strongly recommended.[3]

Complications

Thromboembolic events represent the most common cause of maternal morbidity and mortality in a normal pregnancy. In addition to amniotic fluid embolism resulting from uterine trauma, this rings true for post-operative pregnant patients as well. In general, a hypercoagulable state exists during pregnancy with elevated levels of thrombotic factors and reduced levels of fibrinolysis. One of the most significant hematologic complications during pregnancy is disseminated intravascular coagulation.

Preventative measures should be used to limit the risk of thrombotic events. Placement of pneumatic compression devices on the lower extremities is strongly recommended[3]. Early mobilization, generally encouraged after all operative interventions today, is more easily attained after laparoscopic surgical procedures. Prophylactic use of chemoprophylaxis is less well researched. Surgeons should consider use of these agents during prolonged operative procedures. Unfractionated heparin is generally the preferred agent.[3]

Signs of preterm labor, more common in the third trimester, should dictate the use of tocolytic therapy. Prophylactic use of tocolytics is not recommended.[3]

Conclusions

Emergencies in the general population that necessitate abdominal surgery can generate diagnostic and ethical dilemmas that challenge the surgeon and the healthcare team. Similar emergencies occurring in the pregnant patient create even more challenging clinical decision making. The most common surgical emergencies during pregnancy including appendicitis, cholecystitis, bowel obstruction, and trauma are still fairly infrequent and commonly extrapolate to only a couple of patients annually for most hospitals. A lack of familiarity with this clinical scenario is a setting for diagnostic missteps and delays in diagnosis that likely result from an over emphasis on protecting the fetus that ultimately negatively impacts both the mother and the fetus.

Physiologic monitoring perioperatively with the assistance of tocographic equipment is an important component of assessing fetal condition. Predictable changes in maternal laboratory tests should be considered during the evaluation process. Radiology tests are commonly used to confirm the diagnosis. Of the commonly used modalities, ultrasound should be used preferentially followed by non-contrasted MRI and then X-ray techniques including radiographs, fluoroscopy, and CT imaging with or without iodinated contrast materials. Limiting radiation exposure to avoid teratogenic effects and risks of childhood cancer is key, but it should not compromise diagnostic accuracy to the detriment of the mother and the fetus.

Surgical intervention offers definitive therapy for common emergencies that present during pregnancy. If one takes into consideration the physiologic and anatomical changes that occur to the mother during pregnancy, operative intervention can be offered safely with appropriate monitoring, patient positioning, preventative prophylactic measures, and operative techniques. When appropriate, minimally invasive options including laparoscopy offer the benefits of the same quick recovery as that witnessed in the general population.

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