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**Laparoscopic surgery in pregnancy**

George P *et al*. Laparoscopic surgery in pregnancy

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**Abstract**

Each year, roughly 2% of pregnant women will undergo non-obstetrical abdominal surgery. Appendicitis, symptomatic cholelithiasis and adnexal masses are some of the common diagnoses encountered. Pregnancy poses challenges in the diagnosis and surgical management of these conditions for several reasons. Since the 1990’s, laparoscopic surgery has gained popularity and in the past few years has become the standard of care for pregnant women with surgical pathologies. The advantages of laparoscopic surgery include shorter hospital stay, lower rates of wound infection, and decreased time to bowel function. This brief review discusses key points in laparoscopic surgery during pregnancy and highlights studies comparing laparoscopic and open approaches in common surgical conditions during pregnancy.

**Key words:** Pregnancy; Laparoscopy; Surgery

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**Core tip:** Laparoscopic surgery is increasingly common in pregnancy. The indications for surgery are similar to non-pregnant patients in the same age population. The benefits of laparoscopic surgery include decreased length of staying, lower rates of wound infection and ventral hernia apply to pregnant patients as well. This brief review highlights studies comparing laparoscopic surgery to open approach in common clinical scenarios.

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**INTRODUCTION**

Roughly two percent of pregnant women require nonobstetric surgical procedures each year[1]. The common indications for surgery are similar to an age-matched, non-pregnant population and include appendicitis, symptomatic cholelithiasis, breast masses and trauma. However, changes in maternal-fetal physiology and maternal organ placement can obscure the diagnosis and make treatment in these patients challenging since even common physiologic changes in pregnancy can present as an acute. The physical examination of a pregnant female change with the gestational age and the usual workup of a surgical abdomen using laboratory tests and imaging is also of limited value considering the physical and chemical changes that take place during pregnancy[2]. Furthermore, for many years, laparoscopic surgery was considered hazardous and was contraindicated during pregnancy. With the increasing use and development in surgical and laparoscopic techniques, the advantages of laparoscopy were evident in pregnant patients. In order to understand the concerns and risks of laparoscopic surgery in pregnancy and avoid them, one should be familiar with the difference in physiology and anatomy in a pregnant patient. This review article will evaluate the benefits and use of laparoscopic surgery in pregnancy in comparison to contemporary approaches.

**Research**

A systematic literature search was conducted in the PubMed, Cochrane, MEDLINE with the following individual and combined key words: pregnancy, surgery, laparoscopy, minimally invasive surgery, appendectomy, cholecystectomy, adnexal disease, randomized, meta-analysis. References cited in the articles retrieved were also searched in order to identify other potential sources of information. The results were limited to human studies available in English.

**Differences in Anatomy and Physiology**

There are numerous anatomic and physiologic changes in pregnant woman that affect the clinical presentation and the decisions made when planning surgery and anesthesia.

***Cardiovascular***

Circulating volume in the pregnant patient can increase by up to 40% and cardiac output can increase by as much as 45%[3,4]. These changes occur gradually over the course of the pregnancy to a peak at around 32 wk gestational age. Overall systemic vascular resistance is decreased to accommodate the increased load of circulating volume. While the circulating volume is increased, only a percentage is erythrocyte volume and mass, creating a physiologic anemia of pregnancy. The minute ventilation in pregnant women is 50% higher than that in non-pregnant women. This change results in a marked decrease in arterial carbon dioxide concentration, and a resulting mild respiratory alkalosis. There is also increase in heart rate and oxygen consumption due to increased demands by the fetus and placenta.

***Gastrointestinal***

There is a decrease in gastrointestinal motility caused by mechanical changes in the abdomen from an enlarging uterus as well as from smooth muscle relaxation caused by the increased production of progesterone. The uterine fundus at the end of the first trimester is at the level of the pubic symphysis, but by the end of the second trimester it is at the level of the umbilicus. Furthermore, the decrease in lower esophageal sphincter competence caused by mechanical shifting from the gravid uterus combined with increased intra-abdominal pressure leading to an increase in reflux and dyspepsia[5]. These changes have led to a recommendation of rapid induction anesthesia in pregnant women undergoing surgery.

***Hepatobiliary***

Hepatic and biliary changes include elevated liver enzymes as well as a relative decrease in concentration of plasma proteins from dilution[4,5]. This leads to higher free levels of protein bound drugs, which adds another level of consideration to anesthetic techniques. Throughout pregnancy, there is an increase in gallbladder volume and delayed emptying, which lead to a higher incidence of gallstones[6]. Portal pressures are higher due to increased abdominal pressure, which lead to an increased incidence of both gastric and esophageal varices as well as symptomatic hemorrhoids.

***Renal/hematologic***

In the kidney, there is an increase in the glomerular filtration rate by 50% with a concurrent decrease in plasma values of creatinine, urea, and uric acid. There are changes in the coagulation factors during pregnancy[3]. These changes include an increase in fibrinogen, factor VII, and factor XII, and a decrease in antithrombin III. All of these changes result in an increased risk of venous thromboembolism.

Even knowing the physiological changes occurring in pregnancy, distinguishing between abdominal pain caused from normal pregnancy and abdominal pain caused by a pathophysiologic cause is challenging. Abdominal pain, nausea and vomiting are common in pregnancy. Tachycardia, mild hypotension and low grade fever are also common. Changes in the position and orientation of the abdominal organs from the enlarging uterus can change the physical examination expected in some abdominal pathologies. Take for instance that the average pregnant patient with radiographically diagnosed appendicitis presents with rigidity in only 55% of cases and rebound tenderness in only 60%[2]. The progressive rise in the leukocyte count throughout pregnancy and the imaging limitations can often delay diagnosis. To illustrate the harm that a confusing diagnostic picture can play, delaying surgery up to 24 h in patients with suspected appendicitis can increase perforation rate by 14%-43%[7,8].

**Laparoscopic surgery in Pregnancy**

In 1989, Mazze *et al*[9] published data from three Swedish healthcare registries between the years 1973 to 1981 and investigated adverse outcomes of non-obstetrical operations during pregnancy. 5405 operative cases were evaluated, 16.1% of which were diagnostic laparoscopies. They reported no increase in stillbirths or congenital anomalies in the pregnant patient who underwent surgery. However, there was an increase in low birth weight infants, premature delivery, and infants who died within 168 h from delivery compared with women who did not require surgery. There was, however, no difference in adverse outcomes between the laparoscopy and open surgery groups. Diagnostic laparoscopies were normally done to diagnose ectopic pregnancies before converting patients to laparotomies, but by the mid 1970’s, many adnexal surgeries were being fully done laparoscopically.

For many years, pregnancy was considered a relative contraindication for laparoscopic surgery. The lack of information and experience with laparoscopy in these patients raised concerns about the effect of CO2 pneumoperitoneum used on venous return, cardiac output, uterine perfusion and fetal acid base status. Furthermore, there was a concern about the risk of injury to the uterus with laparoscopy. Starting in the late 1990’s, more and more laparoscopy was being performed for diagnosis and management of abdominal pain in the pregnant patient. In 1997, Reedy *et al*[10] retrospectively reviewed 413 laparoscopic procedures performed during pregnancy in the first report to specifically address the safety and complications of laparoscopy in pregnancy. They concluded that there is no difference in maternal or fetal complication rate between patients that had laparoscopic surgery and patients that had open surgery. In 2008, Jackson *et al*[11] comprehensively reviewed the literature which supported the safety and efficacy of laparoscopy in cholecystectomy, appendectomy, solid organ resection and oophorectomy in the gravid patient. The authors made their recommendations based on existing data, or consensus of expert opinion when little or no data were available. This and other publications have led to the adoption of laparoscopic surgery as a safe technique during pregnancy when used selectively and carefully.

Similar to the non-pregnant patient, decreased pain is one of the main benefits of laparoscopic surgery. The need for less narcotic pain control in laparoscopic surgery may decrease fetal depression. Other advantages include lower rates of wound infection and incisional hernia, decreased manipulation of the uterus, diminished postoperative maternal hypoventilation, decreased risk of thromboembolic events, faster recovery with early return to normal function and decreased risk of ileus[10,12,13]. Laparoscopy may have special advantage during pregnancy since abdominal organs may shift, and their exact location may be difficult to predict. The appendix for instance, may significantly shift from the right lower quadrant owing to the gravid uterus. Laparotomy for appendiceal disease may require large incision during pregnancy to localize the appendix. Diagnostic laparoscopy is safe and effective when used in selected patients and can be an alternative to radiologic imaging[10,11,14,15]. It avoids fetal radiation, provides direct visualization of the pathology, and allows rapid surgical treatment of the problem at the time of diagnosis. On the other hand, the potential hazards of laparoscopy include uterine injury during trocar placement, decreased uterine blood flow, preterm labor due to increased intra-abdominal pressure, and decreased visualization with the enlarged uterus.

Historically, it was believed that laparoscopic surgery should not take place in the first trimester of pregnancy since the fetus is still undergoing organogenesis, but it has been shown that laparoscopy can be performed safely during any trimester with minimal morbidity to the fetus and the mother. There have been no studies showing long term negative cognitive or motor defects in child after mother undergoes laparoscopic surgery. Postponing necessary operations may increase the rates of complications[10,13,15,16]. It has also been suggested that laparoscopic surgery should not be attempted after 28 wk of pregnancy due to the size of the uterus, but several studies showed that laparoscopic cholecystectomy and appendectomy have been successfully performed late in the third trimester[15,17].

Laparoscopic surgery can be safely performed with the help of several modifications of surgical technique. When the pregnant patient is placed in a supine position, the gravid uterus places pressure on the inferior vena cava resulting in decreased venous return to the heart, decreased cardiac output with concomitant maternal hypotension, and decreased placental perfusion. Hence, the patient should be positioned in the left lateral decubitus whenever possible to minimize compression of the vena cava[3,18].

The open technique for abdominal access can reduce the risk for uterine and other abdominal organ injury. However, using a Veress needle for insufflation or optical trocar can be done safely if the site of initial abdominal access is adjusted according to fundal height and the abdominal wall is elevated[15,17,19].

Adjustments in trocar placement must be made to avoid uterine injury and improve visualization. An angled laparoscope may help in better viewing of areas around the uterus.

Pneumoperitoneum remains a concern amongst surgeons because of its effect on uterine blood flow and pulmonary function]. It is recommended that intraabdominal insufflation pressures be maintained at less than 12 mmHg to avoid worsening pulmonary physiology in the pregnant women[3]. However, insufflation less than 12 mmHg may not provide adequate visualization of the intra-abdominal cavity. Furthermore, pressures of 15 mmHg have been used during laparoscopy in pregnant patients without increasing adverse outcomes to the patient or her fetus[20]. Because CO2 exchange occurs with intraperitoneal insufflation there has been concern for deleterious effects to the fetus from CO2 absorption. However, despite the large experience with the use of laparoscopy pregnancy, there are no data showing detrimental effects to human fetuses from CO2 pneumoperitoneum. Additionally, pneumoperitoneum promotes lower extremity venous stasis already present in pregnant woman, and along with the hypercoagulable state that is induced by pregnancy and associated hormones, there is an ever further increased risk of Deep Vein Thrombosis. Therefore, pneumatic compression devices are used whenever possible and DVT prophylaxis should be considered when indicated[21].

Fetal respiratory acidosis with subsequent fetal hypertension and tachycardia has been observed in gravid animal models, but the effect was lessened by maintaining maternal respiratory alkalosis[22]. Fetal acidosis with insufflation has not been documented in the human fetus, but concerns over potential detrimental effects of acidosis have led to the recommendation of intra-operative maternal CO2 monitoring. That can be done either by maternal blood gas or end-tidal carbon dioxide monitoring[23].

A preoperative obstetrics consultation should be obtained for all pregnant women who will be undergoing surgical therapy, but should not delay definitive surgical treatment as that may increase the risk of morbidity to the mother and fetus. It is recommended to perform preoperative and postoperative monitoring of the fetal heart rate when possible[17]. It is generally recommended that post-operative patients should undergo cesarean sections for delivery of child so as not to disrupt any surgically placed materials such as sutures or staples[9]. The role of the obstetrician post-operatively is to monitor the fetus in a strict setting until both the mother and fetus are stable with sufficient pain control, care of wounds, and fetal monitoring.

**Common surgical procedures in surgery**

***Appendectomy***

Acute appendicitis is the most common non-obstetric indication for surgical intervention in pregnant women occurring as often as 1 in 500 pregnancies per year and most commonly presents in the 2nd trimester[5,6,24]. Accurate and timely diagnosis of appendicitis in the gravid patient may minimize the risk of fetal loss and optimize outcomes. Rupture of the appendix during pregnancy increases the risk for perinatal morbidity and mortality. Therefore, it is crucial to make an early diagnosis and proceed with timely surgical intervention.

Presentation of appendicitis in pregnancy is similar to the nonpregnant population with a few caveats. Most common complaints are anorexia, emesis, nausea, fever, and pain, which depending on the gestational age of the fetus can be right lower quadrant, right upper quadrant or flank, as the pain migrates further superior as the appendix gets displaced upwards secondary to the growing uterus. Also since there is an increased separation of the peritoneum from the abdominal organs, peritoneal signs such as rebound tenderness and involuntary guarding are less likely to be present.

Multiple retrospective studies consistently showed it is safe to use the laparoscopic approach with very low rates of preterm delivery and, in most series, no reports of fetal demise[16]. In 2010, a large hospital-based series evaluated laparoscopic *vs* open approach for pregnant patients with presumed acute appendicitis in which the authors concluded that laparoscopy is a safe, feasible, and efficacious approach for pregnant women[25].A meta-analysis by Walsh *et al*[26] published in 2008 using 27 studies, looked at 637 women undergoing laparoscopic appendectomy and 4193 women undergoing appendectomy by open approach. There was an increased risk of fetal loss using laparoscopy, with fetal loss rate of 5.6% (35/624) in the laparoscopic group and 3.1% (128/4193) in the open group, which was statistically significant (*P* = 0.001). Preterm delivery was however increased in the open group with a risk of 8.1% (346/4193) *vs* 2.1% (13/624) in the laparoscopic group, also statistically significant. A population-based study published in 2007 by McGory *et al*[27] retrospectively reviewed all cases of women undergoing appendectomy between the years 1995 and 2002. Four hundred and four pregnant patients underwent laparoscopy and 2679 underwent laparotomy for suspected appendicitis. Once again, there was significantly higher rate of fetal loss (7%, 31/454) with laparoscopy compared with laparotomy (3%, 88/2679) (OR = 2.31). Preterm birth was 1% (1/454) in the laparoscopic group *vs* 8% (216/2679) in the laparotomy group. Another meta-analysis published in 2012 by Wilasrusmee *et al*[28] evaluated eleven studies comparing laparoscopic and open appendectomy in pregnancy from January 1990 to July 2011. A total of 3415 women (599 in laparoscopic and 2816 in open group) were included in the analysis. After weighted and pooled analysis fetal loss was significantly worse in those who underwent laparoscopy compared with open appendectomy (pooled RR = 1.91). No significant difference was found for wound infection, birth weight, preterm labor, length of hospital stay, duration of operation or Apgar score. Preterm birth is a very morbid condition which if extreme (23-27 wk GA) can lead to high rates of infant mortality, autism and low educational attainment (Table 1).

**Cholecystectomy**

Presentation of acute cholecystitis, similar to appendiceal disease, is similar to the nonpregnant population. Unlike the nonpregnant population however, most gallstones are found incidentally without symptoms during routine imaging for obstetric health maintenance. There are no confounding differences in location of pain or symptoms between the two populations, but there are many alternative diagnoses in patients with right upper quadrant pain and pregnancy, so a thorough differential of diagnoses must be done.

Up to 10% of women have been shown to have gallstones on routine imaging during pregnancy[29-31]. However, the incidence of symptomatic cholelithiasis during pregnancy is similar to the incidence in age-related non-pregnant woman. Early surgical management of gravid patients with symptomatic gallstones is supported by data showing that 92% of patients managed non-operatively have recurrent symptoms after presenting in the first trimester, 64% of patients who present in the second trimester, and 44% of patients who present in the third trimester[32]. The incidence of gallstone pancreatitis is 13% in any pregnant patient diagnosed with gallstones at any point during their pregnancy. Studies comparing conservative to operative management for biliary disease, find that up to 50% of patients conservatively managed will have recurrent symptoms *vs* roughly 10% in the surgically treated group. Considering that up to 60% of cases of gallstone pancreatitis in the pregnant patient lead to fetal demise it is generally agreed that surgery should be performed. A delay in surgical management by way of conservative therapy results in increased rates of hospitalizations, spontaneous abortions, preterm labor, and preterm delivery compared to those undergoing cholecystectomy.

The advantages of laparoscopic surgery were mentioned before and apply here as well. There have been no reports of fetal demise for laparoscopic cholecystectomy performed during the first and second trimesters and decreased rates of spontaneous abortion and preterm labor have been reported in laparoscopic cholecystectomy when compared to laparotomy. Laparoscopy is generally agreed to be technically easier during the first and second trimester owing to the fact that there is less of a distorting effect from the uterus on the rest of the viscera and that anatomy is still maintained in regular position without the effect of the gravid uterus.

If an intra-operative or endoscopic cholangiogram is done it is recommended to shield the lower abdomen with lead[15].

**Adnexal Disease**

During the course of pregnancy, the incidence of adnexal masses is 1%-2%[33]. Most of the masses discovered during pregnancy are functional cysts and resolve spontaneously by the end of the pregnancy. These patients can be observed as long as they are asymptomatic, the mass is smaller than six centimeters, there are no concerning ultrasound findings, and tumor markers are within acceptable ranges (CA-125 normally elevated slightly during pregnancy). However, 5%-20% of masses do not resolve or are symptomatic and require operative intervention[33,34]. The use of laparoscopy for removal of any of these lesions has the same outcome in all trimesters of pregnancy[35]. A retrospective review of 88 pregnant women undergoing surgical intervention for adnexal pathology demonstrated equivalent maternal and fetal outcomes in adnexal masses managed laparoscopically compared to laparotomy and concluded that laparoscopy is safe for gynecologic surgery and should be considered if technically feasible[36].

**DISCUSSION**

It is not uncommon that a pregnant woman requires a surgical procedure. The etiologies and indications for surgery still usually just the ones common for the patient’s age group and are unrelated to pregnancy. The clinical presentation and physical examination of these patients may be atypical and the evaluation of the patient can be challenging. Changes in the anatomy and physiology of the pregnant woman and the care for the fetus need to be considered when deciding whether or not to perform surgery on these patients. In the past, laparoscopic surgery was considered hazardous and was contraindicated for a number of reasons. The significant developments in laparoscopic techniques encouraged surgeons to seek advancements in the surgical treatment of the pregnant woman. The advantages of laparoscopic surgery in the pregnant patient are similar to non-pregnant, with the additional advantage of rapid localization of abdominal organs that may shift during pregnancy, and the ability to manage conditions through smaller incisions and less organ manipulation. Current literature comparing laparoscopy and open techniques for surgical management of common diseases lacks randomized trials, but consistent outcomes seen in the available studies show that minimally invasive surgery in the pregnant woman is feasible and safe in any trimester and should not be postponed when indicated. Patient selection and surgeon experience are important for successful laparoscopic surgery and a consultation with an obstetrician is recommended when available. It is also important to look long term after the fetus has been delivered but there are few studies looking at outcomes after surgery. A study looking at 29 patients undergoing laparoscopic appendectomy show that there was no motor, sensory or social deficits in the child by age 3[37]. As laparoscopy is further adopted, even longer follow up is possible to examine the effects of laparoscopic surgery on the fetus’ development.

**CONCLUSION**

Laparoscopy is emerging as the standard approach for pregnant patients requiring surgery. While it is essential to have a thorough discussion with the patient regarding the risks and benefits of surgical intervention, the current literature suggests that laparoscopy for pregnant patients is a safe and favorable technique when performed by an experienced surgeon.

**REFERENCES**

1 **Firstenberg MS**, Malangoni MA. Gastrointestinal surgery during pregnancy. *Gastroenterol Clin North Am* 1998; **27**: 73-88 [PMID: 9546085 DOI: 10.1016/S0889-8553(05)70348-4]

2 **Fallon WF**, Newman JS, Fallon GL, Malangoni MA. The surgical management of intra-abdominal inflammatory conditions during pregnancy. *Surg Clin North Am* 1995; **75**: 15-31 [PMID: 7855715]

3 **Chesnutt AN**. Physiology of normal pregnancy. *Crit Care Clin* 2004; **20**: 609-615 [PMID: 15388191 DOI: 10.1016/j.ccc.2004.06.001]

4 **RM Anesthesia in Obstetrics**. Miller’s Anesthesia, 8ed. 2014: 2328-2337

5 **Kort B**, Katz VL, Watson WJ. The effect of nonobstetric operation during pregnancy. *Surg Gynecol Obstet* 1993; **177**: 371-376 [PMID: 8211581]

6 **Gilo NB**, Amini D, Landy HJ. Appendicitis and cholecystitis in pregnancy. *Clin Obstet Gynecol* 2009; **52**: 586-596 [PMID: 20393411 DOI: 10.1097/GRF.0b013e3181c11d10]

7 **Cunningham FG**, McCubbin JH. Appendicitis complicating pregnancy. *Obstet Gynecol* 1975; **45**: 415-420 [PMID: 1121371]

8 **Ueberrueck T**, Koch A, Meyer L, Hinkel M, Gastinger I. Ninety-four appendectomies for suspected acute appendicitis during pregnancy. *World J Surg* 2004; **28**: 508-511 [PMID: 15085399 DOI: 10.1007/s00268-004-7157-2]

9 **Mazze RI**, Källén B. Reproductive outcome after anesthesia and operation during pregnancy: a registry study of 5405 cases. *Am J Obstet Gynecol* 1989; **161**: 1178-1185 [PMID: 2589435 DOI: 10.1016/0002-9378(89)90659-5]

10 **Reedy MB**, Källén B, Kuehl TJ. Laparoscopy during pregnancy: a study of five fetal outcome parameters with use of the Swedish Health Registry. *Am J Obstet Gynecol* 1997; **177**: 673-679 [PMID: 9322641 DOI: 10.1016/S0002-9378(97)70163-7]

11 **Jackson H**, Granger S, Price R, Rollins M, Earle D, Richardson W, Fanelli R. Diagnosis and laparoscopic treatment of surgical diseases during pregnancy: an evidence-based review. *Surg Endosc* 2008; **22**: 1917-1927 [PMID: 18553201 DOI: 10.1007/s00464-008-9989-6]

12 **Curet MJ**, Allen D, Josloff RK, Pitcher DE, Curet LB, Miscall BG, Zucker KA. Laparoscopy during pregnancy. *Arch Surg* 1996; **131**: 546-550; discussion 550-551 [PMID: 8624203 DOI: 10.1001/archsurg.1996.01430170092017]

13 **Oelsner G**, Stockheim D, Soriano D, Goldenberg M, Seidman DS, Cohen SB, Admon D, Novikov I, Maschiach S, Carp HJ, Anderman S, Ben-Ami M, Ben-Arie A, Hagay Z, Bustan M, Shalev E, Carp H, Gemer O, Golan A, Holzinger M, Beyth Y, Horowitz A, Hamani Y, Keis M, Lavie O, Luxman D, Oelsner G, Stockheim D, Rojansky N, Taichner G, Yafe C, Zohar S, Bilanca B. Pregnancy outcome after laparoscopy or laparotomy in pregnancy. *J Am Assoc Gynecol Laparosc* 2003; **10**: 200-204 [PMID: 12732772 DOI: 10.1016/S1074-3804(05)60299-X]

14 **Gurbuz AT**, Peetz ME. The acute abdomen in the pregnant patient. Is there a role for laparoscopy? *Surg Endosc* 1997; **11**: 98-102 [PMID: 9069135 DOI: 10.1007/s004649900306]

15 **Pearl J**, Price R, Richardson W, Fanelli R. Guidelines for diagnosis, treatment, and use of laparoscopy for surgical problems during pregnancy. *Surg Endosc* 2011; **25**: 3479-3492 [PMID: 21938570 DOI: 10.1007/s00464-011-1927-3]

16 **Affleck DG**, Handrahan DL, Egger MJ, Price RR. The laparoscopic management of appendicitis and cholelithiasis during pregnancy. *Am J Surg* 1999; **178**: 523-529 [PMID: 10670865 DOI: 10.1016/S0002-9610(99)00244-5]

17 **Rollins MD**, Chan KJ, Price RR. Laparoscopy for appendicitis and cholelithiasis during pregnancy: a new standard of care. *Surg Endosc* 2004; **18**: 237-241 [PMID: 14691706 DOI: 10.1007/s00464-003-8811-8]

18 **Clark SL**, Cotton DB, Pivarnik JM, Lee W, Hankins GD, Benedetti TJ, Phelan JP. Position change and central hemodynamic profile during normal third-trimester pregnancy and post-partum. *Am J Obstet Gynecol* 1991; **164**: 883-887 [PMID: 2003555 DOI: 10.1016/S0002-9378(11)90534-1]

19 **Lemaire BM**, van Erp WF. Laparoscopic surgery during pregnancy. *Surg Endosc* 1997; **11**: 15-18 [PMID: 8994981 DOI: 10.1007/s004649900286]

20 **Andreoli M**, Servakov M, Meyers P, Mann WJ. Laparoscopic surgery during pregnancy. *J Am Assoc Gynecol Laparosc* 1999; **6**: 229-233 [PMID: 10226140 DOI: 10.1016/S1074-3804(99)80110-8]

21 **Melnick DM**, Wahl WL, Dalton VK. Management of general surgical problems in the pregnant patient. *Am J Surg* 2004; **187**: 170-180 [PMID: 14769301 DOI: 10.1016/j.amjsurg.2003.11.023]

22 **Hunter JG**, Swanstrom L, Thornburg K. Carbon dioxide pneumoperitoneum induces fetal acidosis in a pregnant ewe model. *Surg Endosc* 1995; **9**: 272-277; discussion 272-277 [PMID: 7597597]

23 **Bhavani-Shankar K**, Steinbrook RA, Brooks DC, Datta S. Arterial to end-tidal carbon dioxide pressure difference during laparoscopic surgery in pregnancy. *Anesthesiology* 2000; **93**: 370-373 [PMID: 10910483 DOI: 10.1097/00000542-200008000-00014]

24 **Guttman R**, Goldman RD, Koren G. Appendicitis during pregnancy. *Can Fam Physician* 2004; **50**: 355-357 [PMID: 15318670]

25 **Sadot E**, Telem DA, Arora M, Butala P, Nguyen SQ, Divino CM. Laparoscopy: a safe approach to appendicitis during pregnancy. *Surg Endosc* 2010; **24**: 383-389 [PMID: 19551438 DOI: 10.1007/s00464-009-0571-7]

26 **Walsh CA**, Tang T, Walsh SR. Laparoscopic versus open appendicectomy in pregnancy: a systematic review. *Int J Surg* 2008; **6**: 339-344 [PMID: 18342590 DOI: 10.1016/j.ijsu.2008.01.006]

27 **McGory ML**, Zingmond DS, Tillou A, Hiatt JR, Ko CY, Cryer HM. Negative appendectomy in pregnant women is associated with a substantial risk of fetal loss. *J Am Coll Surg* 2007; **205**: 534-540 [PMID: 17903726 DOI: 10.1016/j.jamcollsurg.2007.05.025]

28 **Wilasrusmee C**, Sukrat B, McEvoy M, Attia J, Thakkinstian A. Systematic review and meta-analysis of safety of laparoscopic versus open appendicectomy for suspected appendicitis in pregnancy. *Br J Surg* 2012; **99**: 1470-1478 [PMID: 23001791 DOI: 10.1002/bjs.8889]

29 **Machado NO**, Grant CS. Laparoscopic appendicectomy in all trimesters of pregnancy. *JSLS* 2009; **13**: 384-390 [PMID: 19793481]

30 **Davis A**, Katz VL, Cox R. Gallbladder disease in pregnancy. *J Reprod Med* 1995; **40**: 759-762 [PMID: 8592309]

31 **Dixon NP**, Faddis DM, Silberman H. Aggressive management of cholecystitis during pregnancy. *Am J Surg* 1987; **154**: 292-294 [PMID: 3631407 DOI: 10.1016/0002-9610(89)90613-2]

32 **Swisher SG**, Schmit PJ, Hunt KK, Hiyama DT, Bennion RS, Swisher EM, Thompson JE. Biliary disease during pregnancy. *Am J Surg* 1994; **168**: 576-59; discussion 576-59; [PMID: 7977999]

33 **Bozzo M**, Buscaglia M, Ferrazzi E. The management of persistent adnexal masses in pregnancy. *Am J Obstet Gynecol* 1997; **177**: 981-982 [PMID: 9369862 DOI: 10.1016/S0002-9378(97)70315-6]

34 **Grimes WH**, Bartholomew RA, Colvin ED, Fish JS, Lester WM. Ovarian cyst complicating pregnancy. *Am J Obstet Gynecol* 1954; **68**: 594-605 [PMID: 13180567]

35 **Parker WH**, Levine RL, Howard FM, Sansone B, Berek JS. A multicenter study of laparoscopic management of selected cystic adnexal masses in postmenopausal women. *J Am Coll Surg* 1994; **179**: 733-737 [PMID: 7952486]

36 **Soriano D**, Yefet Y, Seidman DS, Goldenberg M, Mashiach S, Oelsner G. Laparoscopy versus laparotomy in the management of adnexal masses during pregnancy. *Fertil Steril* 1999; **71**: 955-960 [PMID: 10231065 DOI: 10.1016/S0015-0282(99)00064-3]

37 **Choi JJ**, Mustafa R, Lynn ET, Divino CM. Appendectomy during pregnancy: follow-up of progeny. *J Am Coll Surg* 2011; **213**: 627-632 [PMID: 21856183 DOI: 10.1016/j.jamcollsurg.2011.07.016]

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**S-Editor:** Qiu S **L-Editor: E-Editor:**

Table 1 Comparing laparoscopy and open appendectomy fetal loss and preterm birth rates

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Ref.** | **Fetal loss rate laparoscopic** | **Preterm delivery rate laparoscopic** | **Fetal loss rate open** | **Preterm delivery rate open** |
| Sadot *et al*[25] | 2.0% (1/41) | 29% (12/41) | 0.0% (0/16) | 19% (3/16) |
| Walsh e*t al*[26] | 6.0% (35/624) | 2.1% (13/624) | 3.1% (128/4193) | 8.1% (346/4193) |
| Mcgory *et al*[27] | 7.0% (31/454) | < 1.0% (1/454) | 3.0% (88/2679) | 8.0% (216/2679) |