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Perioperative management of surgical procedure during pregnancy: a systematic review

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Background: Approximately 1–2% of pregnant women undergo non-obstetric surgery under anaesthesia during their pregnancy. This review specifically targets anaesthesia management for pregnant women undergoing non-obstetric surgery in resource-limited settings.

Methods: Following the delineation of primary questions, scope, and inclusion criteria, a comprehensive search strategy utilizing advanced techniques was implemented across electronic sources, databases, and websites to identify relevant articles. A rigorous screening process was applied during the literature evaluation. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement guided the conduct of this review, ensuring adherence to standardized reporting practices.

Results: A total of 240 articles were initially identified from databases and websites. After screening titles and abstracts, 85 papers were excluded, and an additional 43 were removed due to duplication. Subsequently, 68 items were subjected to eligibility screening. Finally, 30 papers that specifically addressed anaesthetic considerations for pregnant women undergoing non-obstetric operations were reviewed.

Conclusion: Thorough preoperative evaluation is essential for all patients, with particular attention to modifications in anaesthetic management to accommodate physiological changes during pregnancy. Urgent and emergent surgeries should proceed promptly during pregnancy to optimize outcomes for both the mother and foetus. Maintaining uteroplacental perfusion generally involves avoiding maternal hypoxaemia, hypotension, hyper- and hypocapnia, temperature extremes, and stress. When deemed safe, regional anaesthesia may offer favourable outcomes for both the mother and foetus.

Keywords: anaesthesia, incidental surgery, pregnancy, teratogenicity

Introduction

Approximately 1–2% of pregnant women undergo non-obstetric surgery under anaesthesia during their pregnancy[1–3]. The occurrence of surgical procedures in pregnant women unrelated to gestation itself has become relatively common and has increased over the years. Diagnosing and managing non-obstetric abdominal pathologies during pregnancy pose clinical challenges for both obstetricians and anaesthetists[4].

The pregnancy outcomes following non-obstetric surgical intervention indicate that maternal death is rare, miscarriage (5.8%), elective termination (1.3%), premature labour (3.5%), foetal loss (2.5%), and prematurity (8.2%). Studies specifically focusing on appendectomy during pregnancy reveal a high rate of surgery-induced labour. Foetal loss (2.6%) during appendectomy and (10.9%) peritonitis[5].

During anaesthetic and perioperative surgical care in pregnant women, strict selection and careful timing are crucial factors when deciding to perform non-obstetric surgical procedures[6]. Pregnant mothers are considered as higher perioperative risk group due to physiological and anatomical changes during pregnancy. These changes, influenced by hormonal factors and the mechanical effects of the enlarged uterus, carry important implications for both surgeons and anaesthetists[7].

Anaesthetists must take into account the effects of the disease process itself, aiming to inhibit uterine contractions and prevent preterm labour and delivery. Ensuring foetal safety involves avoiding potentially harmful medications and ensuring the

HIGHLIGHTS

- Urgent and emergent surgeries proceed promptly during pregnancy to optimize outcomes for both the mother and foetus.
- Maintaining uteroplacental perfusion is crucial.
- Regional anaesthesia may offer favourable outcomes for both the mother and foetus.

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maintenance of adequate uteroplacental perfusion[1]. Optimizing and maintaining maternal homoeostasis, minimizing the risk of teratogenic effects of anaesthetic drugs, preventing preterm labour, avoiding changes in uteroplacental perfusion that could harm the foetus, and preventing foetal asphyxia are major concerns for anaesthetists in ensuring the safety of both patients[8].

Surgery may be necessary at any stage of pregnancy depending on the urgency of the medical indication[9]. The decision to proceed with surgery during pregnancy should involve a multidisciplinary team consisting of anesthesiologists, obstetricians, surgeons, and perinatologists[1]. Surgery is typically reserved for pregnancy when it is deemed absolutely necessary for the well-being of either the mother, foetus, or both[9].

The most common indications for surgery during pregnancy include both pregnancy-related issues, such as cervical incompetence and surgical management of ovarian cyst problems, as well as non-pregnancy-related acute abdominal problems, maternal trauma, and maternal malignancies[10]. Appendicitis, cholecystitis, ovarian torsion, maternal malignancies, and trauma are indeed among the more common indications for surgical interventions during pregnancy[1,3].

The purpose of this review was to ensure the provision of safe and high-quality anaesthesia services for pregnant women undergoing non-obstetric operations. This goal is achieved by prioritizing maternal safety through a comprehensive understanding of the physiological and pharmacological changes that occur during pregnancy.

Methods

Search strategy

After establishing the key questions, scope, and eligibility criteria for the review, a thorough search strategy of electronic sources was implemented. Keywords such as 'anesthesia management', 'surgery', 'pregnancy', and 'teratogenicity' were identified as central to the review question. Synonyms of these keywords were obtained from the National Library of Medicine through the Medical Subject Headings (MeSH) browser. The keywords were then combined using Boolean operators "AND" or "OR" as appropriate. The search terms were applied in combinations such as: 'anesthesia management' OR 'consideration' AND 'surgery' OR 'incidental surgery' AND 'pregnancy' AND 'teratogenicity'.

The literature was sourced using advanced search methods from databases including the Cochrane Library, PubMed, Scopus, Embase, and websites like Google Scholar to gather articles on anaesthesia management for pregnant women undergoing non-obstetric surgery. The electronic literature search was conducted from 12 February 2023, to 15 March 2023. All studies published in the English language from inception up to 15 March 2023, were considered for inclusion in the review.

The removal of duplicate literature was facilitated by EndNote. Subsequently, further screening of the remaining literature was conducted through a comprehensive appraisal of the title, abstract, and full text of the articles. A total of 26 articles underwent review. This work has been reported in line with AMSTAR (Assessing the methodological quality of systematic reviews) Guidelines[11].

The reporting of this review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement guidelines[12] (Fig. 1). This review was registered in the research registry.

Eligibility criteria

Articles pertaining to anaesthetic management for pregnant women undergoing incidental surgery, reported in the English language, with full text available, and conducted globally were included in this systematic review. Exclusion criteria encompassed duplicated sources, unrelated research, case reports, and articles lacking full-text availability.

Study selection

Three authors independently screened the candidate articles for the review, which were then exported into EndNote reference manager software to eliminate duplicates. Subsequently, they independently assessed the titles and abstracts. In case of any disagreements, resolutions were achieved through discussions led by a third author.

Study quality assessment

The two independent authors appraised the quality of the articles using the AMSTAR 2 methodological quality appraisal checklist. This critical analysis checklist comprises 16 parameters[11]. The quality of this review after a critical assessment of its method was reported as high.

Results

Study selection

From the databases and websites, a total of 240 articles were initially identified through electronic search. After removing 43 articles due to duplication and excluding 85 studies based on title and abstract review, 68 articles remained for further evaluation of eligibility. Finally, 25 studies related to anaesthesia management for pregnant women undergoing incidental surgery were included in the review (Fig. 1).

Characteristics of included studies

Out of the 68 articles retrieved, 25 met the eligibility criteria and were included in the final systematic review. Among these included articles, 9 were systematic reviews, 6 were systematic reviews with meta-analyses, 2 were randomized controlled trials, 2 were cross-sectional studies, 3 were guidelines, and 3 were cohort studies.

Discussion

Physiological changes of pregnancy

The primary physiological changes occurring during pregnancy are influenced by pregnancy hormones. These changes are crucial to ensure an adequate supply of oxygen and nutrients to the foetus and to prepare the mother's body for childbirth[13]. Secondary changes occur due to the mechanical effects of the enlarged pregnant uterus[3]. Understanding the adaptations of the central nervous system (CNS), respiratory, gastrointestinal, cardiovascular, and haematologic systems during pregnancy can help in selecting the most appropriate anaesthetic technique and

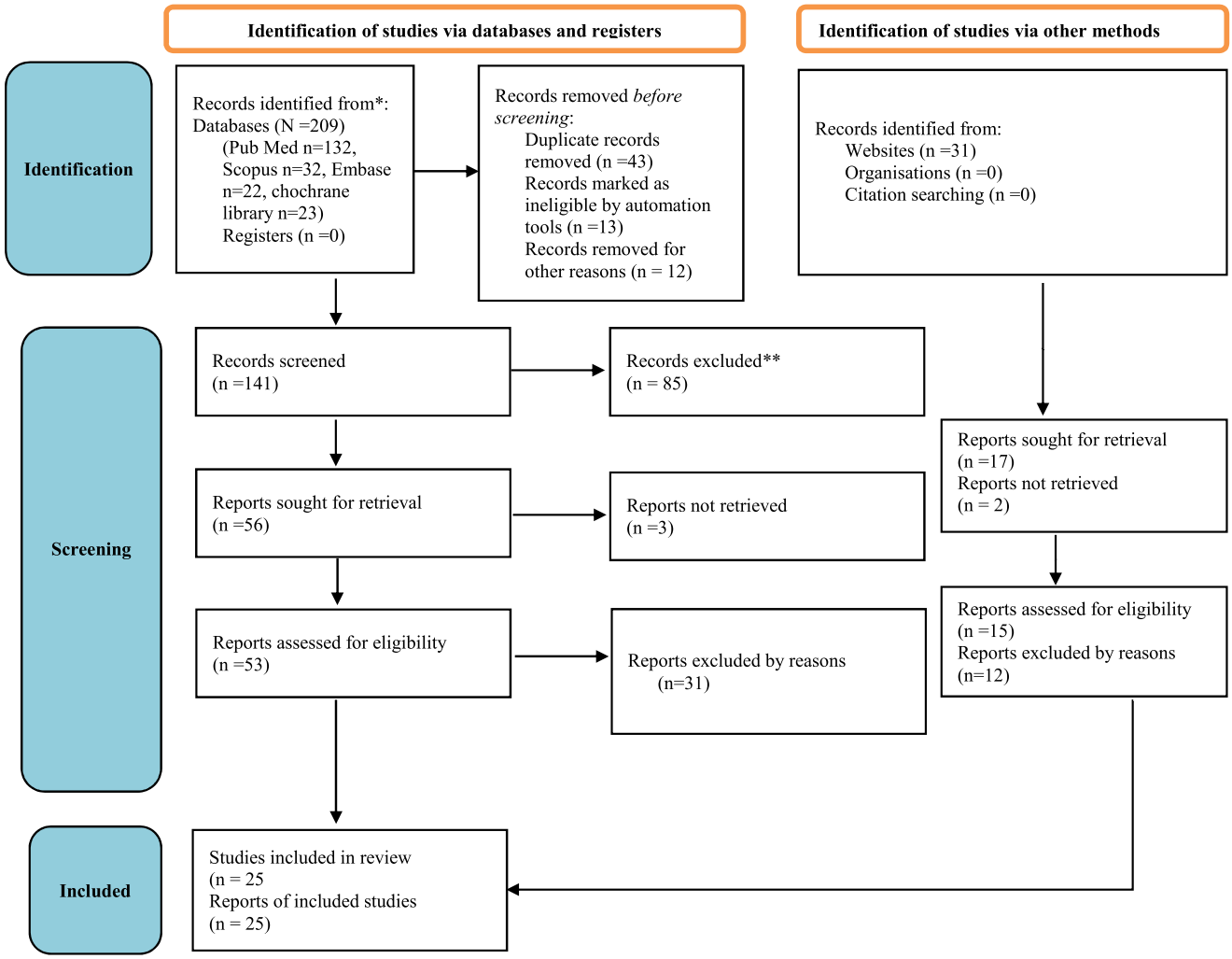

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).

optimize maternal hemodynamics intraoperatively[14] (Table 1). Common signs and symptoms experienced during pregnancy, including tachypnea, dyspnoea, heart murmurs, and benign electrocardiogram changes, can potentially complicate the anaesthetic management of patients[6].

CNS changes

Pregnant patients undergo changes in pain perception and pain threshold, exhibit decreased anaesthetic requirements, and rely more on the sympathetic nervous system (SNS). The minimum alveolar concentration (MAC) for volatile agents decreases by 28% during 8–12 weeks of gestation, reaches 40% of non-pregnant levels as pregnancy advances, and returns to baseline by post-partum day 3[14].

Respiratory system changes

Airway changes can manifest from the mid-trimester onward and are particularly pronounced near the end of pregnancy. These changes involve swelling of oropharyngeal tissues and a reduced calibre of the glottic opening, potentially resulting in challenges during ventilation and intubation of unconscious pregnant patients[6].

Anatomic and hormonal changes, along with increased metabolic demands, lead to various alterations in respiratory mechanics during pregnancy. The upward displacement of the diaphragm due to uterine growth results in decreases in expiratory reserve volume and residual volume. Consequently, functional residual capacity significantly decreases after 5 months of gestation[14].

Cardiovascular system (CVS) changes

During pregnancy, a substantial increase in cardiac output is observed due to elevations in both heart rate and stroke volume. This rise in cardiac output commences early in pregnancy, with a resulting 35% increase by the conclusion of the first trimester. As cardiac output increases, there is a simultaneous decrease in both systemic vascular resistance and pulmonary vascular resistance[15]. Pregnancy induces a hypercoagulable state characterized by an elevation in most clotting factors. While the platelet count may decrease, there is typically an increase in both platelet production and

Table 1

Physiological changes of pregnancy and their perioperative implications

System	Physiological changes	Perioperative implications
CVS	Decreased BP, SVR	Increased incidence of hypotension after anaesthesia
	Lack of auto regulation of uterine vasculature,	Foetal blood supply depends on maternal BP
	Aortocaval compression after 20 weeks of gestation	Supine hypotension syndrome is common. Left uterine lateral tilt (15°) to reduce aortocaval compression
	Gallop rhythm, left axis deviation, systolic murmur, mild ST-T changes	Misleads the clinician to a cardiac disease
	Increased blood volume and cardiac output	Decompensation of structural cardiac diseases (valvular lesions)
Airway	Increased soft tissue in the neck, weight gain, and breast engorgement	Difficult mask ventilation, laryngoscopy, and intubation
	Increase in Mallampatti grading as pregnancy progresses	Difficult intubation. Smaller sized endotracheal tubes should be used
	• Increased oedema of the airway and vocal cord	Epistaxis with nasal intubation
	• Increased vascularity of mucous membranes	
Respiratory system	Reduced FRC (20%), increased oxygen demand (20%)	Tendency for early desaturation. Careful preoxygenation is a must
	Mild respiratory alkalosis (PaCO2 28–32 mmHg)	Maintain PaCO2 at normal pregnancy levels
	Increased minute ventilation	Faster inhalational induction
Blood and coagulation	Basal tachycardia and hemodilution	Delay in the onset of classical signs of hypovolemia
	Hypercoagulability	Perioperative DVT prophylaxis
Gastrointestinal system	Reduced lower oesophageal sphincter tone	• Consider all pregnant patients as full stomach. • Mandates rapid sequence induction
	• Altered gastric and pyloric anatomy • Increased gastric volume and acidity	Preoperative antiaspiration prophylaxis and antacids after 16 weeks
Central nervous system	Engorged epidural veins	Increased incidence of bloody tap
	Reduced epidural space volume	More extensive spread of LA
	Increased CSF pressure	Reduced dosage requirements
	Increased sensitivity to opioids and inhalational agents	Faster induction with inhalational agents

BP, blood pressure; CSF, cerebrospinal fluid; CVS, cardiovascular system; DVT, Deep venous thrombosis; FHR, foetal heart rate; LA, Local Anesthetics; SVR, Systemic vascular resistance.

consumption. Pregnancy poses a significant risk factor for thromboembolism; hence, thromboprophylaxis is crucial in the postoperative period[16].

Gastrointestinal changes

The risk of gastric content aspiration is heightened during pregnancy. While recent research indicates that gastric emptying remains normal during pregnancy and immediately before labour, the risk of aspiration is still increased due to reduced pressure at the level of the lower oesophageal sphincter tone[9].

Indications for operation during pregnancy and approaches

A pregnant woman should never be denied indicated surgery, regardless of the trimester[17]. The most common non-obstetric operations during pregnancy include appendectomy (44%) and cholecystectomy (22.3%). In the USA, 64.8% of these intraperitoneal procedures are performed via laparoscopy[7]. In practice, surgery during pregnancy might be elective surgery, urgent surgery/non-elective/essential, emergent /category 1 / life threatening surgery[18,19].

Perioperative anaesthetic considerations for non-obstetric surgery during pregnancy

The incidence of non-obstetric surgery during pregnancy was reported as 0.48%, with a majority performed during the second trimester (44%) and under general anaesthesia (81%). When surgery was conducted under general anaesthesia, a higher frequency of low birth weight was observed (22% vs. 6%) and the preterm birth rate secondary to surgery was higher for interventions during the third trimester compared to other trimesters (10% vs. 0%)[20].

A systematic review of literature in Colombia suggests that the assessment and approach to a pregnant patient undergoing non-obstetric surgery should involve a multidisciplinary group to ensure the well-being of both the mother and foetus[18].

An 11-year retrospective study conducted in Austria on non-obstetric surgery during pregnancy stated that ninety-seven percent of operations were performed under general anaesthesia. The median skin-to-skin time was 50 (37–80) min, with a median in-hospital stay of 4 (3.5–6) days. Additionally, 5% of patients required postoperative intensive care admissions, Preterm labour occurred in 15% of cases and miscarriage in 7%[4].

A meta-analysis of cohort and case-control studies conducted in Toronto, Canada, found no association between foetal exposure to benzodiazepines and the risk of major malformations or oral cleft. However, pooled data from case-control studies indicated a significantly increased risk for major malformations or oral cleft alone[21].

A systematic review and meta-analysis on maternal drug use and the risk of anorectal malformations conducted in Germany indicated that certain medications, such as anti-asthma medication, hypnotics, and benzodiazepines were associated with increased risks of anorectal malformations[22].

A multisite, population-based case-control study in Atlanta, Georgia, on the use of benzodiazepine medications during pregnancy and their potential risk for birth defects, suggests that benzodiazepine use is rare and may be associated with a risk for certain birth defects[23].

A community-based cohort study in the United Kingdom concluded that there is no evidence for an increase in major congenital anomalies in children exposed to benzodiazepines and non-benzodiazepine hypnotics during the first trimester of pregnancy[24].

A nationwide cohort study conducted on Norwegian mothers and children reported that there was no substantial determinative risk to a child fine motor skills and ADHD symptoms after prenatal exposure to benzodiazepines and hypnotics alone or in combination with opioids or antidepressants[25].

A cohort study conducted at Columbia University examining the association of panic disorder, generalized anxiety disorder, and benzodiazepine treatment during pregnancy with the risk of adverse birth outcomes concluded that maternal treatment with a serotonin reuptake inhibitor is also associated with hypertensive disease of pregnancy and caesarean delivery[26].

A systematic review and meta-analysis conducted at the University of Toronto, Canada, on the effects of cocaine use during pregnancy on low birth weight and preterm birth revealed that prenatal cocaine exposure is significantly associated with preterm birth, low birth weight, and small for gestational age infants[27].

A systematic review conducted in the US on maternal use of opioids during pregnancy and congenital malformations revealed that among the case-control studies, associations with oral clefts and ventricular septal defects/atrial septal defects were the most frequently reported specific malformations[28].

A cohort study conducted at the University of Helsinki, Finland, revealed that the use of opioids during pregnancy was associated with an increased risk for deliveries by caesarean sections and the need for respiratory treatment among the offspring during the first week of life[29]. Guidelines in the US recommend that opioids and acetaminophen can be used as treatment for mild to moderate pain during pregnancy. However, non-steroidal anti-inflammatory drugs (NSAIDs) should be avoided due to potential risks to the foetus[15].

A prospective cohort study conducted in Oslo, Norway, on exposure to non-steroidal anti-inflammatory drugs (NSAIDs) during pregnancy and the risk of selected birth defects found that exposure to NSAIDs during the first 12 weeks of gestation does not appear to be associated with an increased risk of the selected birth defects[30].

A population-based cohort study conducted in Oakland, California, USA, on exposure to non-steroidal anti-inflammatory drugs (NSAIDs) during pregnancy and the risk of miscarriage reported that prenatal use of NSAIDs and aspirin increased the risk of miscarriage[31].

A case-control study on the use of non-aspirin non-steroidal anti-inflammatory drugs (NSAIDs) during pregnancy and the risk of spontaneous abortion in Canada concluded that gestational exposure to any type or dosage of non-aspirin NSAIDs may increase the risk of spontaneous abortion. These findings suggest that these drugs should be used with caution during pregnancy[32].

A systematic review conducted in the US reported that 5% of cases require caesarean deliveries for non-reassuring foetal heart rate monitoring within 48 hours after surgery. Postoperative foetal monitoring should be considered, especially in cases where unstable vital signs are anticipated. Non-reassuring foetal heart patterns during non-obstetric surgery at 22 weeks gestation or beyond were limited to foetal tachycardia due to maternal fever and did not require intraoperative caesarean delivery in any case[33].

A review conducted in the USA recommended that timing is a crucial factor in surgeries during pregnancy. Whenever possible, surgery should be performed in the second trimester, accompanied by perioperative foetal monitoring to assess foetal well-being, detailed preoperative evaluation, and a preference for regional over general anaesthetic techniques to maintain hemodynamic stability, uteroplacental perfusion, and uterine relaxation, all of which are essential for sustaining pregnancy[15].

Anaesthesia consideration

The risks of surgery during pregnancy are influenced by several factors, including physiological changes, potential adverse effects of anaesthetic medications, gestational age, the type, duration, and location of the surgery, anaesthetic technique, and the general condition of the patient[18]. Both general and regional anaesthesia can be used[3].

Every pregnant patient should undergo assessment by an anaesthetist to evaluate her general condition, potentially associated pathologies, foetal viability, and gestational age. An individualized plan should be developed for each case to ensure maternal and foetal safety, control teratogenicity, avoid intrauterine foetal asphyxia, and prevent preterm labour[18].

Despite meticulous attention to maternal and foetal well-being, women exposed to surgery and anaesthesia during pregnancy may still experience major complications[14]. These can include pneumonia, sepsis, venous thromboembolism (VTE), and even death, as well as foetal loss, preterm labour, and the birth of low birth-weight infants.

Non-obstetric cases undergo surgery, and there is heightened awareness regarding several key concerns like ensuring safety during general anaesthesia, understanding the potential neurotoxic effects of anaesthetics, and addressing the unique challenges associated with airway management in pregnant women[34] (Fig. 2).

Preoperative assessment and anaesthetic consideration

Pregnant patients who require surgery should undergo preoperative evaluation in a manner similar to non-pregnant patients. In addition to standard preoperative procedures, preparation for pregnant women also considers specific risks such as aspiration, difficult intubation, thromboembolism, and the well-being of the foetus. This comprehensive approach ensures the safety and well-being of both the mother and the unborn child[1].

Higher Mallampati classes (III and IV), indicating potential difficulty with intubation, were observed in 12% of women during the first trimester of pregnancy. This percentage increased to 20% during the second trimester, which is considered the preferred time for non-urgent surgery. This highlights the importance of careful airway assessment and preparation, particularly in pregnant patients, to ensure safe anaesthesia management[34].

Appropriate selection of pain medication is crucial, especially during pregnancy. Drugs such as non-steroidal anti-inflammatory drugs (NSAIDs) and opioids should generally be avoided due to potential risks to the developing foetus. In contrast, acetaminophen is considered to be safe for use during pregnancy and is preferred for pain management, as it does not have known teratogenic effects.

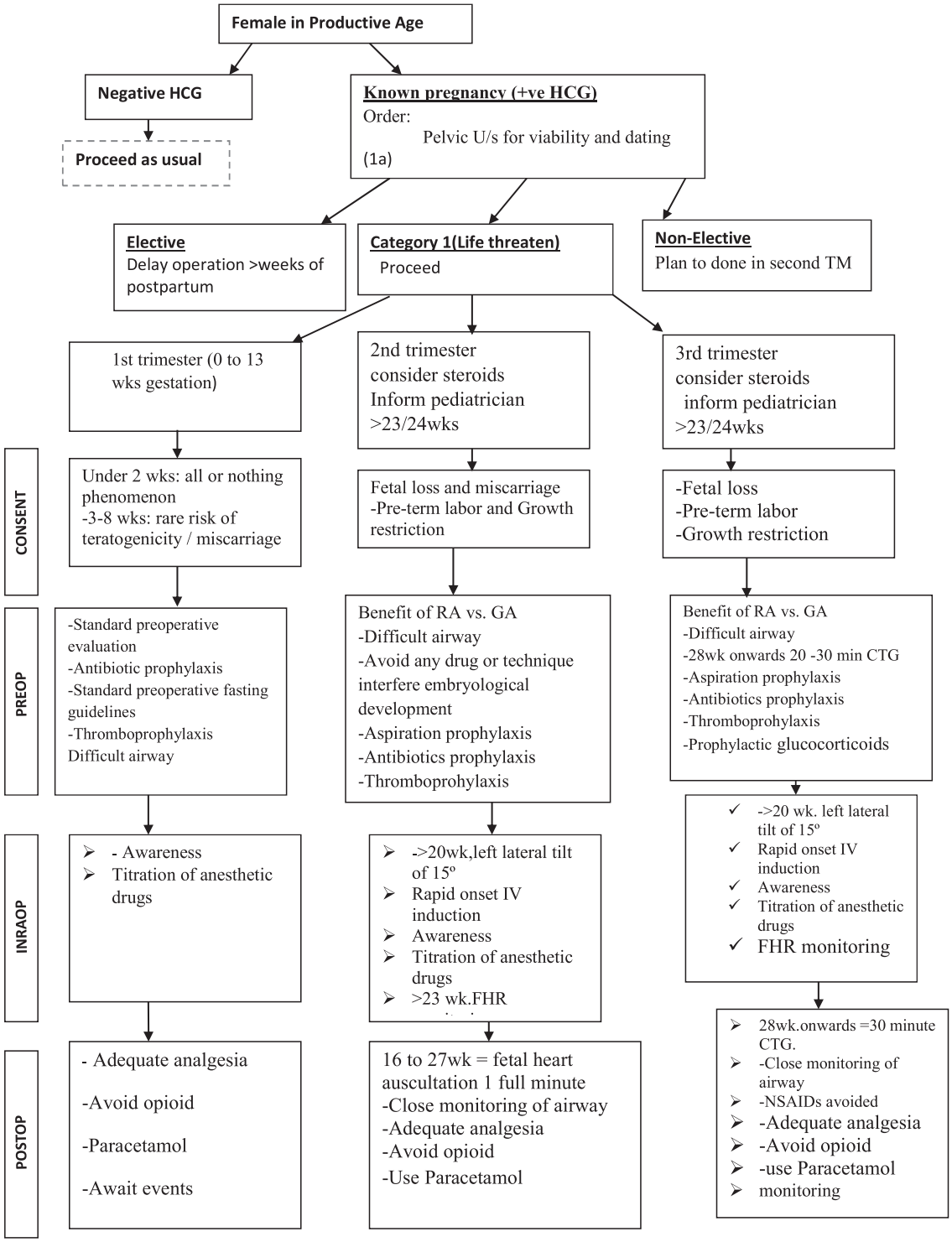

Figure 2. Flow diagram of perioperative management surgical procedure during pregnancy. CTG, Cardiotocography; GA, General Anesthesia; HCG, Human chorionic gonadotropin; NSAIDs, non-steroidal anti-inflammatory drugs; RA, Regional Anesthesia; TM, Trimester.

This cautious approach to pain medication selection helps ensure the well-being of both the mother and the unborn child[6].

In the preoperative period for pregnant patients, verbal reassurance is often preferred over pharmacological premedication. Antacid prophylaxis is recommended after 14 weeks of gestation, and deep venous thrombosis prophylaxis should always be considered. A standard preoperative assessment is conducted with careful attention to gestational age, as well as the possibility of miscarriage and preterm labour. The mother should be informed about the low risks of teratogenicity associated with anaesthetic

agents currently in use. Additionally, the involvement of the obstetric team is essential, and consideration should be given to involving a paediatrician if preterm labour is anticipated. This comprehensive approach helps ensure the safety and well-being of both the mother and the unborn child during the perioperative period[35].

One of the paramount considerations regarding surgery in pregnant patients is the urgency of the procedure. Surgery carries inherent risks to the developing foetus that should be minimized whenever possible. Reported miscarriage rates following surgery range up to 5.8%, with rates as high as 10.5% for surgeries performed during the first trimester. Therefore, any surgical procedure that can safely be delayed until after delivery should be postponed for up to 6 weeks post-partum, when feasible, to mitigate risks to both the mother and the unborn child[15].

Standard preoperative evaluation should include appropriate laboratory tests and imaging studies based on the patient's comorbidities. Coordination among the anaesthetic, surgical, obstetric, and paediatric teams is essential. Fasting guidelines prior to surgery should be adhered to. Prophylactic antibiotics should be administered when indicated, with consideration given to the safety profile of antibiotic options. The use of prophylactic tocolytics to prevent preterm labour has not demonstrated effectiveness. However, in the late second and third trimesters, antenatal glucocorticoids administered 24–48 hours before surgery have been shown to reduce perinatal morbidity and mortality in the event of preterm birth. It's important to consider the presence of maternal systemic infection when making decisions about glucocorticoid administration[15].

Intraoperative anaesthetic consideration

Regional anaesthesia offers several advantages for pregnant patients. It typically involves less drug exposure, reducing concerns about teratogenicity, especially in the first trimester, and minimizing anaesthetic effects on foetal monitoring later in pregnancy. Regional techniques often provide superior postoperative pain control, facilitating early mobilization and reducing the risk of thromboembolism. Airway control is maintained, potentially decreasing the risk of aspiration. Additionally, hearing the foetal heart rate on the monitor can be reassuring for the mother if she is awake during the procedure.

However, regional anaesthesia also has its limitations. Patients or surgeons may experience anxiety about the patient being awake during the procedure. Furthermore, not all surgical procedures are suitable for neuraxial blocks, which may restrict the use of regional anaesthesia in certain cases. Despite these limitations, regional anaesthesia remains a valuable option for managing anaesthesia in pregnant patients undergoing surgery[1].

During surgical procedures in pregnant patients, precautions focus on preventing four key risks: hypotension, hypoxaemia, hypovolemia, and hypothermia. It's crucial to carefully titrate anaesthetic drugs as the requirements are typically reduced during pregnancy, both for inhalational and intravenous drugs. This ensures that the mother's physiological changes are appropriately managed and that the anaesthesia remains effective without causing unnecessary risks to the mother or foetus. By addressing these precautions, anaesthesia can be administered safely and effectively during surgery in pregnant patients[36].

Studies have suggested that there may be up to a 30% reduction in the minimum alveolar concentration (MAC) for isoflurane in early pregnancy, which persists into the immediate post-partum period. Pregnant women also appear to be more sensitive to neuromuscular blockers. Although the dose of succinylcholine is not typically reduced, there may be a slight prolongation of neuromuscular block due to a reduction in pseudocholinesterase. Additionally, other studies have indicated a more rapid onset of neuromuscular block with agents such as vecuronium and rocuronium in pregnant patients. These findings underscore the importance of careful titration and monitoring of anaesthetic drugs to ensure optimal anaesthesia management for pregnant patients undergoing surgery[15].

Ketamine has been found to induce uterine contractions similar to ergometrine in early pregnancy, but it does not have this effect in late pregnancy. Therefore, ketamine's excellent analgesic properties can be safely utilized in late pregnancy. Volatile anaesthetics such as halothane, sevoflurane, desflurane, and isoflurane have been shown to inhibit uterine contractility, potentially providing benefits in uterine relaxation and reducing the incidence of preterm labour. During anaesthesia and surgery in pregnant patients, ensuring foetal well-being is paramount. This is best achieved by carefully maintaining stable maternal hemodynamic parameters and oxygenation levels. Additionally, close monitoring of foetal responses for signs of distress is strongly recommended to promptly address any potential concerns and ensure the safety of both the mother and the foetus throughout the perioperative period[1].

Positioning

Pregnant patients beyond 18–20 weeks of gestation should be positioned with a 15° left lateral tilt during surgery. This positioning helps to reduce aortocaval compression and mitigate the risk of supine hypotension syndrome, which can occur due to pressure on the vena cava when the patient is lying flat on her back. By tilting the patient to the left, pressure on the vena cava is alleviated, helping to maintain adequate blood flow and prevent maternal hypotension, which could compromise both maternal and foetal well-being during the surgical procedure[1,15].

Foetal monitoring

The decision to utilize foetal monitoring during surgery in pregnant patients should be made on an individual basis, taking into account factors such as the gestational age, maternal condition, type and duration of surgery, and foetal well-being. It is important to verify the foetal condition and assess for the presence or absence of uterine contractions.

Clinicians must also have a thorough understanding of the effects of anaesthetic drugs on foetal heart rate to avoid misinterpreting variations induced by these drugs. By accurately interpreting foetal heart rate patterns and understanding how anaesthetic agents may influence them, clinicians can effectively monitor foetal well-being and make informed decisions regarding intraoperative management to ensure the safety of both the mother and the foetus[3].

A qualified individual should be readily available to interpret foetal heart rate patterns during surgery in pregnant patients. If the foetus is considered pre-viable, it may be sufficient to ascertain the foetal heart rate using a doppler device before and after the procedure.

For viable foetuses, simultaneous electronic foetal heart rate and contraction monitoring should be performed before and after

the procedure to assess foetal well-being and the absence of contractions. Intraoperative electronic foetal monitoring may be appropriate when certain conditions are met, including the viability of the foetus, feasibility of performing intraoperative electronic foetal monitoring, and the availability of a healthcare provider with obstetric surgery privileges. If necessary, the woman should provide informed consent that allows for emergency caesarean delivery for foetal indications. Additionally, the planned surgery should allow for the safe interruption or alteration of the procedure to provide access for emergency delivery if needed to ensure the safety of both the mother and the foetus[37].

During non-obstetric surgery, when foetal heart rate patterns are non-reassuring at more than or equal to 22 weeks of gestation, the need for intraoperative caesarean delivery is typically limited. This is often observed in cases of foetal tachycardia due to maternal fever. However, postoperative foetal monitoring should be considered, and non-reassuring foetal heart rate patterns should be monitored within 48 h after surgery. This monitoring is particularly important in cases where unstable vital signs are anticipated, ensuring timely detection of any foetal distress and appropriate intervention if necessary to safeguard the well-being of both the mother and the foetus[33].

Foetal heart rate monitoring is feasible starting from ~18–22 weeks of gestation. However, from around 25 weeks onward, heart rate variability becomes more readily observable. This variability in heart rate patterns provides valuable information about foetal well-being and can aid in assessing foetal health during pregnancy and labour[1].

The American College of Obstetricians and Gynecologists (ACOG) guideline recommends continuous monitoring of foetal heart rate (FHR) in all viable foetuses greater than 23 weeks' gestational age throughout surgery. Additionally, regardless of gestational age, FHR should be documented both before and after the surgical procedure. It is essential to have an obstetrician readily available in case an emergency caesarean delivery is indicated. Furthermore, it's important to note that general anaesthetic agents can cross the placenta and may cause absent FHR variability. This underscores the importance of careful monitoring and prompt intervention to ensure the safety and well-being of both the mother and the foetus during surgery[37].

In addition to minimal or absent variability in foetal heart rate (FHR) tracings, other criteria such as persistent tachycardia, recurrent or prolonged FHR decelerations, recurrent late decelerations, or a sinusoidal pattern should also be considered before determining the need for an emergent delivery during surgery. These patterns may indicate foetal distress and require prompt evaluation and intervention. Moreover, it's important to be aware that certain anaesthetic agents can cause changes in FHR tracings. Common examples include opioids, beta-blockers, atropine, and magnesium sulfate. Careful consideration of these factors is essential to ensure the safety of both the mother and the foetus during surgical procedures[15].

Postoperative anaesthetic considerations

If deemed appropriate, analgesic modalities such as continuous peripheral or neuraxial blocks with infusions are optimal for providing postoperative analgesia and achieving optimal pain relief. Ensuring adequate analgesia in the postoperative period is crucial, as studies have demonstrated that pain can increase the risk of premature labour. By effectively managing postoperative pain, clinicians can help mitigate this risk and promote better outcomes for both the mother and the foetus[1].

After surgery and anaesthesia, recovery involves obstetric expertise, with patients typically being recovered on the labour floor unless intensive care is necessary. During recovery, ensuring adequate oxygenation and respiration is paramount, and promoting left uterine displacement helps optimize maternal and foetal well-being. In cases of preterm labour in a viable foetus, aggressive treatment with interventions such as intravenous fluids, magnesium, and/or indomethacin may be warranted. Early mobilization is encouraged to reduce the risk of deep vein thrombosis, and for patients who cannot ambulate effectively, antiembolic massage devices and prophylactic anticoagulation are recommended measures. These strategies aim to support maternal recovery while safeguarding foetal health during the post-surgical period[38].

Regional nerve or plexus blockade, as well as epidural analgesia, are effective options for providing postoperative pain relief and can help minimize the risk of opioid-induced hypoventilation compared to intravenous opioids. While opioids can still be used as necessary to manage postoperative pain, these regional techniques offer excellent analgesia with potentially fewer systemic side effects. Paracetamol (acetaminophen) is generally considered the analgesic of choice for treating mild to moderate pain at any stage of pregnancy due to its safety profile. However, NSAIDs should be avoided, particularly after 32 weeks of gestation, as they may lead to premature closure of the foetal ductus arteriosus if used for more than 48 hours. Additionally, NSAIDs are associated with complications such as oligohydramnios and reduced foetal renal function, and they can inhibit uterine contractions, making them unsuitable for pain management in pregnant patients, especially in the later stages of pregnancy[1].

Common drugs and teratogenicity

In the first 15 days of pregnancy, an "all of or nothing" phenomenon occurs: there is foetal loss, or on the contrary, the foetus is unharmed. During organogenesis (from day 15 to 56), there are structural abnormalities, and then after this period, functional abnormalities occur depending on the particulars of the case[18]. Teratogenesis can manifest as structural abnormalities (e.g., growth restriction or congenital malformation) or as functional behavioural or cognitive delays[14].

The FDA introduced drug risk to the foetus; from Category A (safest) to Category X (known danger)[16] (Table 2), commonly used anaesthetic agents[36] (Table 3). FDA has also listed some common drugs used in anaesthetic practice and in intensive care that is safe for pregnancy[36] (Table 4).

Drugs given during pregnancy could have a deletery effect on the foetus depending on the dose, the route of administration, and the timing of exposure. Despite years of animal studies and observational studies in humans, no anaesthetic drug has been shown to be clearly dangerous to the human foetus, and there is no optimal anaesthetic technique[3]. The anaesthetics like the induction agents, inhaled or intravenous agents, muscle relaxants, local anaesthetics, benzodiazepines and opioids, used under normal clinical conditions, have been demonstrated to be safe and non-teratogenic[18].

Nitrous oxide inhibits methionine synthetase, and could affect DNA synthesis in the developing foetus and teratogenic during peak organogenesis in rodents. Ketamine increases uterine tone and foetal asphyxia and should not be used in the first two trimesters. Benzodiazepines have been associated with a cleft lip and palate in animal studies, but a single dose has not been associated with teratogenicity[16].

Table 2

FDA classification of foetal harm risk from drugs

Category A	Adequate and well controlled studies have failed to demonstrate a risk to the foetus in the first trimester of pregnancy (and there is no evidence of risk in later pregnancies).
Category B	Animal reproduction studies have failed to demonstrate a foetal risk but there are no controlled studies in pregnant women, OR animal reproduction studies have shown an adverse effect, but adequate well controlled studies in pregnant women have failed to demonstrate a risk to the foetus in any trimester
Category C	Animal reproduction studies have shown an adverse effect on the foetus and there are no adequate well controlled studies in humans, or studies in animals and humans are not available. Potential benefits of drugs may warrant use of drug in pregnant women despite potential risks
Category D	There is positive evidence of human foetal risk, but the benefits from use in pregnant women may be acceptable despite the risk (e.g. life threatening situation or serious disease for which safer drugs are not available).
Category X	Studies in animals or humans have demonstrated foetal abnormalities, or evidence based on human experience, and the risk of use of the drug in pregnant women clearly outweighs any possible benefit. The drug is contraindicated in women who are or may become pregnant

FDA, United States Food and Drug Administration.

Table 3

FDA list of common anaesthetic drugs and their classification and category

Drug	FDA category
Bupivacaine	C
Lignocaine	B
Butorphanol/nalbuphine	C (in small doses)/D (in high doses
Succinylcholine	C
Rocuronium	C
Thiopentone sodium	C
Propofol	B
Morphine/meperidine/fentanyl	B (in small doses)/D (in high doses)
Sufentanyl/remifentanil	C

FDA, United States Food and Drug Administration.

Table 4

List of some common drugs, which can be used safely in pregnancy and relevant to anesthesiologists and intensivists

Safe drugs
Insulin, glyburide, metformin
Ranitidine, cimetidine
Chlorpheniramine, diphenhydramine
Acetaminophen
Methyldopa
Levothyroxine
Azthitromycin, cepaholosporins, clindamycin, erythromycin, penicillins,
Metronidazole
Metoclopramide
Magnesium sulphate

Table 5

Known teratogens in human

List of common teratogens in human
Captopril
Carbamazepine
Cocaine
Enalapril
Fluconazole (high dose)
Lithium
Phenobarbital
Retinoic acid
Tetracyclines
Thalidomide
Valproic acid

NSAIDs are contraindicated, particularly in late pregnancy, due to concerns for premature closure of the ductus arteriosus. While most antibiotics including penicillins, cephalosporins, clindamycin, and azithromycin, tetracyclines are avoided because of adverse effects on bone and teeth development[14]. Anticholinesterases can increase the uterine tonus during pregnancy, and administered slowly is recommended[18].

Sugammadex's ability to encapsulate progesterone and reduce progesterone levels in pharmacologic simulation studies. There may be some effect on endometrial decidualization and uterine growth in early pregnancy and myometrial quiescence and cervical integrity later in pregnancy[15]. There are some anaesthetic agents and other drugs that have a considerable risk of teratogenicity in humans[14] (Table 5).

Conclusion

Thorough preoperative evaluation is essential for all patients, with particular attention to modifications in anaesthetic management to accommodate physiological changes during pregnancy. Urgent and emergent surgeries should proceed promptly during pregnancy to optimize outcomes for both the mother and foetus. Maintaining uteroplacental perfusion generally involves avoiding maternal hypoxaemia, hypotension, hyper- and hypocapnia, temperature extremes, and stress. When deemed safe, regional anaesthesia may offer favourable outcomes for both the mother and foetus.

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Conflicts of interest disclosure

The authors declare no conflicts of interest.

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Data availability statement

The datasets used and analyzed during the study are available from the corresponding author on reasonable request.

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