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Intraoperative fetal heart monitoring for non-obstetric surgery: a systematic review

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ABSTRACT

Limited data are available on fetal monitoring during non-obstetric surgery in pregnancy. We performed a systematic review to evaluate the incidence of emergent cesarean delivery performed for non-reassuring fetal heart rate patterns during non-obstetric surgery. Electronic databases were

searched from their inception until October 2018 without limit for language. We included studies evaluating at least five cases of intraoperative fetal heart rate monitoring -either with ultrasound or cardiotocography- during non-obstetric surgery in pregnant women at ≥22 weeks of gestation. The primary outcome was the incidence of intraoperative cesarean delivery performed for non-reassuring fetal heart rate monitoring. Non-reassuring fetal heart rate monitoring was defined by attendant personnel, meeting NICHD criteria for category II or III patterns. Data extracted regarded type of study, demographic characteristics, maternal and perinatal outcomes. Statistical analysis was performed for continuous outcomes by calculating mean and standard deviations for appropriate variables. Of 120 studies identified, 4 with 41 cases of intraoperative monitoring met criteria for inclusion and were analyzed. Most (66%) surgeries were indicated for neurological or abdominal maternal issues and were performed under general anesthesia (88%) at a mean gestational age of 28 weeks. Minimal or absent fetal heart variability was noted in most cases and a 10-25 beats per minutes decrease in fetal heart rate baseline was observed in cases with general anesthesia. No intraoperative cesarean deliveries were needed. The incidence of non-reassuring fetal heart rate monitoring was 4.9% (2/41) and were limited to fetal tachycardia during maternal fever. Two (4.9%) cases of non-reassuring fetal heart rate monitoring were noted within the immediate 48 hours after surgery, necessitating cesarean delivery. A single case of intrauterine fetal demise occurred four days postoperatively in a woman who had neurosurgery and remained comatose. In conclusion, limited data exist regarding the clinical application of fetal heart rate monitoring at viable gestational ages during non-obstetric surgical procedures. Fetal heart rate monitoring during non-obstetric surgery at ≥22 weeks was not associated with need for intraoperative cesarean delivery, but two (4.9%) cesarean deliveries were performed for non-reassuring fetal heart rate monitoring within 48 hours after surgery.

Key words: intraoperative fetal monitoring; non-obstetric surgery; non-reassuring fetal monitoring during non-obstetric surgery; emergency cesarean delivery during non-obstetric surgery.

INTRODUCTION

Non-obstetric surgery is required in approximately 1-2% of pregnancies.[1] In the United States alone, this equates to about 40,000-80,000 pregnant women undergoing antepartum surgical procedures yearly. The evaluation of fetal well-being during non-obstetric surgery is often an area of divergent clinical practice due to the limited evidence. While the need for pre- and postoperative assessment of fetal heart rate (FHR) has been proposed,[2] there is no consensus regarding intraoperative fetal heart rate monitoring (iFHRM). The American College of Obstetricians and Gynecologists (ACOG) has stated that the decision to use iFHRM should be individualized, based on factors such as gestational age, type of surgery, and available resources.[3]

Many studies and case reports have described management and outcomes of non-obstetric surgery in pregnancy,[4-11] but there is an absence of randomized controlled trials, and to our knowledge, no systematic review has evaluated the use of iFHRM on obstetric and neonatal outcomes in pregnant women who underwent non-obstetric surgery at a viable gestational age (≥22 weeks).

Objective

The aim of this systematic review was to evaluate the incidence of intraoperative cesarean delivery for non-reassuring iFHRM (NRiFHRM) during non-obstetric surgery ≥22 weeks.

MATERIALS AND METHODS

Search strategy

This review was performed according to a protocol designed a priori and recommended for systematic review.[12] Electronic databases (MEDLINE, clinicaltrials.gov and Cochrane Library, PROSPERO, Scopus, Science direct) were searched from their inception until October 2018 without restrictions on publication language. Employed search terms included: "fetal heart rate monitoring", "intraoperative fetal monitoring", "non-obstetric surgery" and "emergency cesarean delivery during non-obstetric surgery". In addition, the bibliographies of all identified articles were reviewed to identify studies not captured by electronic searches. Eligibility of the studies was assessed independently by two authors (GP, CO); differences were resolved through discussion with a third author (VB).

Study selection

We included randomized controlled trials, cohort studies, case-control studies, and case series evaluating use of iFHRM during non-obstetric surgery in pregnant women. Case reports and studies describing fewer than five cases, all previable cases (<22 weeks of gestation), studies without defined gestational ages, and studies without details about intraoperative fetal monitoring were excluded.

Data extraction

Data extraction was completed by 2 independent investigators (GP, CO); disparities were resolved by consensus with a third reviewer (VB). Before data extraction, the review was registered with the PROSPERO International Prospective Register of Systematic Reviews (registration no.: CRD42018114205). The review was reported according to the Preferred Reporting Item for Systematic Reviews and Meta-analyses statement.[13]

Assessment of risk of bias

Two reviewers (GP, GS) independently assessed the risk of bias of the included studies via the Methodological Index for Non-Randomized Studies.[14] Seven domains that are related to risk of bias were assessed in each study: (1) aim (i.e., clearly stated aim), (2) rate (i.e., inclusion of consecutive patients and response rate), (3) data (i.e., prospective collection of data), (4) bias (i.e., unbiased assessment of study end points), (5) time (i.e., follow-up time appropriate), (6) loss (i.e., loss to follow-up), (7) size (i.e., calculation of the study size). Review authors' judgments were categorized as "low risk," "high risk" or "unclear risk of bias." Discrepancies were resolved by discussion with a third reviewer (VB).

Outcomes

The primary outcome was the incidence of cesarean delivery performed for non-reassuring iFHRM (NRiFHRM). Secondary outcomes were incidence of NRiFHRM during surgery in absence of maternal vital sign changes, rate of cesarean delivery performed postoperatively (within 48 hours after surgery), rate of preterm birth, and neonatal outcomes, including birthweight, APGAR score <7 at 5 minutes, intrauterine fetal demise, neonatal death, respiratory distress syndrome, cerebral palsy and admission to the neonatal intensive care unit (NICU).

In principle, NRiFHRM was defined as NICHD category II or III characteristics[15] when iFHRM was performed using CTG and as refractory bradycardia (<110/minute) or tachycardia (>160/minute) when iFHRM was performed exclusively via ultrasound. Minimal or absent fetal heart rate variability was not considered as criteria for NRiFHRM since induction and maintenance of general anesthesia is commonly associated with these phenomena.[16] Maternal vital sign changes were defined as sustained maternal tachycardia (>100/minute), blood pressure <90/40 mmHg, hyperthermia (> 38˚C) and hypoxemia (defined as SaO_2 <95% oxygen saturation).

Statistical analysis

Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) v. 19.0 (IBM Inc., Armonk, NY, USA). Data are shown as means ± standard deviation (SD), or as medians (range), or as number (percentage). Univariate comparisons of dichotomous data were performed with the use of the chi-square or Fisher exact test. Comparisons between groups were performed with the use of the Mann-Whitney U test, to test group medians with range; and with the use of the T-test or the One-way ANOVA to test group means with SD.

RESULTS

Study selection and study characteristics

We identified 120 publications with primary subject of non-obstetric surgery in pregnancy (Figure 1). Eighty-nine (74.2%) reported about iFHRM during non-obstetric surgery, and 50 (56.2%) reported specific information on iFHRM. Four (3.3% of the total)[17-20] were case series including ≥5 cases with details of iFHRM during non-obstetric surgery performed at ≥22weeks. The quality of the studies included in our review was assessed by the Methodological Index for Non-Randomized Studies' tool[14] for assessment of the risk of bias (Figure 2). All studies had low risk of bias in "aim" and "time". Three of them were retrospective case series;[17, 19, 20] 1 study had prospective design.[18] One author provided subsequent additional unpublished data (CR).[20]

The four included studies reported a total of 155 non-obstetric surgical procedures in pregnancy, of which 148 (95.5%) were performed at ≥22 weeks gestation (Table 1). Of these, 41 (27.7%) had iFHRM recorded. The mean gestational age at surgery was 28.6 ± 4.2 weeks.

Characteristics of the surgeries are shown in Table 2. The most common indications for surgery were neurological (34.1%) and abdominal (31.7%) pathology, and most women (87.8%)

underwent general anesthesia, for elective (58.5%) procedures, lasting approximately one hour and 40 minutes.

Maternal monitoring during surgery is shown in Table 3. Most (73.2%) women were placed in a left lateral position. Details of any changes in maternal heart rate, blood pressure and pulse oximetry were reported exhaustively only for 7 women, with 2 reported to have fever during episodes of concurrent fetal tachycardia.

Synthesis of results

Primary outcome

Details of iFHRM during surgery are reported in Table 4. iFHRM was done by either CTG (21, 51.2%) or ultrasound (15, 36.6%); in 5 cases the exact type of iFHRM was not recorded. Specific information about FHR patterns was available only for 15 cases (36.6%): 14 with CTG and 1 with ultrasound. Overall, 2 (4.9%) had NRiFHRM: these were 2 cases of fetal tachycardia, one detected with CTG (>180 beats per minute for 25 minutes) and the other with ultrasound.

The case of tachycardia registered with CTG occurred in a febrile patient at 23 4/7 weeks during an exploratory laparotomy for removal of a right adnexal mass under epidural anesthesia; fetal tachycardia resolved immediately after the surgical procedure was completed. The case of fetal tachycardia detected by ultrasound occurred in a patient at 24 3/7 weeks during an emergent laparotomy for acute appendicitis under general anesthesia. Maternal blood pressure, heart rate, and pulse oximetry remained stable during the surgery, but hyperthermia (38.1°C) was reported. The fetal heart rate baseline returned to 125/minute at the end of the surgical procedure; after the patient was extubated and transferred to the transport bed, refractory fetal bradycardia was noted and emergent cesarean delivery performed.

Two of the included studies with details of iFHRM reported minimal or absent FHR variability in 13/15 patients (86.7%), most pronounced with general anesthesia; four of which (30.8%) occurred in the second trimester. Variability of the FHR returned to moderate with emergence from the anesthesia in 9 cases and persisted for 95-180 minutes in 4 cases. Among 11 cases under general anesthesia, 9 (81.8%) reported a decrease in FHR baseline by 10-25/minute. There were no other cases of NRiFHRM, and all other reported cases had stable maternal vital parameters intraoperative. No cases necessitated cesarean for NRiFHRM (Table 5).

Secondary outcome:

Tocolysis was employed in 7 (25.9%) cases (Table 5); 6 cases occurred in the third trimester, 5 were abdominal procedures (3 appendectomies, 1 cholecystectomy, 1 removal of an adnexal mass) and 2 were mastectomies. All of these women delivered at term.

Obstetrical and perinatal outcomes are shown in Table 6. Data on gestational age at delivery were complete in only two studies, reporting a mean gestational age at delivery of 34.2 ± 6 and 36 ± 8.1 weeks, respectively. Preterm birth occurred in 9/36 (25%) cases, of which 5/9 (55.6%) occurred within 48 hours after abdominal surgery. Three of these were cesarean deliveries performed (1) for fetal bradycardia immediately after surgery at 24 3/7 weeks (case described above), (2) for intra-abdominal hemorrhage with maternal hypotension on postoperative day 1 after hepatic resection at 26 6/7 weeks, and (3) for non-reassuring fetal non-stress test on post-operative day 2 after a skin graft for burn at 24 2/7 weeks. The other two were spontaneous preterm births occurring after abdominal surgery within 48 hours post-operative (one operative vaginal delivery secondary to a placental abruption at 32 2/7 weeks and one spontaneous vaginal delivery at 28 3/7 weeks).

Preterm births occurred greater than 48 hours postoperative in 4 (44.4%) patients; 2 occurred in patients who underwent neurosurgery: 1 delivery at 31 weeks (7 days postoperative) occurred

following surgery for a closed head injury subsequent to a motor vehicle accident, with low neonatal Apgar scores recorded at birth (no further information available), and the other case was an intrauterine fetal demise with spontaneous onset of labor at 26 4/7 weeks after craniotomy for a spontaneous intracerebral hemorrhage 4 days before (no further information available). Both patients presented and remained in comatose status at the time of surgery. The remaining preterm births occurred at 32 3/7 and 35 2/7 weeks, 10 days after a cystoscopy with stent placement and 5 weeks after an appendectomy, respectively.Among overall spontaneous preterm births, 3 cases of preterm delivery followed abdominal procedures, 2 occurred after neurologic procedures and 1 after a urologic procedure.

Two cases (8.3 %) of low APGAR scores at birth and 1 (3.1%) intrauterine fetal demise occurred in patients who underwent neurosurgery (as described above). No other adverse neonatal outcomes were reported.

COMMENT

Main findings

This systematic review of women undergoing antepartum non-obstetric surgery at ≥22 weeks gestation in which intraoperative fetal monitoring was performed identified three findings:

- Cesarean delivery was not performed in any case for NRiFHRM.
- In cases where NRiFHRM was identified, this was explicable secondary to a maternal etiology. No cases of NRiFHRM occurred with stable maternal vital signs.
- Delivery for NRiFHRM was required within 48 hours postoperative in about 5% of women.

As no cases of intraoperative NRiFHRM were described with stable maternal vital parameters, the risk of a pathologic fetal heart pattern appears to be confined to intraoperatively febrile or hemodynamically unstable patients. The preterm birth rate in this cohort was high (25%); the majority of preterm deliveries in the first 48 hours postoperative were consequent to cesarean delivery. Adverse neonatal outcomes, including the only stillbirth, were limited to patients who underwent neurosurgical procedures while comatose.

Comparison with prior literature

To our knowledge, this may be the first systematic review to review iFHRM at ≥22 weeks during non-obstetrics surgery. Other reviews[21, 22] evaluated obstetric and perinatal outcomes after non-obstetric surgery without iFHRM, and therefore are unable to address the incidence of intraoperative NRiFHRM, FHR patterns and the rate of cesarean delivery for NRiFHRM during surgery. A previous review[23] evaluated the practice of iFHRM, including 9 pregnant women at various gestational ages (including non-viable pregnancies) who underwent non-obstetric surgical procedures; as no instances of fetal demise were encountered, the authors concluded there was no evidence-based benefit to the practice.[23]

FHR patterns can be affected directly by anesthetic medication crossing the placenta or indirectly by changing in maternal hemodynamics as a result of anesthesia and surgery.[24] In our review, the only intraoperative NRiFHRM registered was tachycardia, and every case occurred in association with maternal fever, a known cause. A previous study[25] reported that elevated FHR baseline can also represent a side-effect of maternal drug administration (e.g. atropine). Both cases of NRiFHRM occurred under general anesthesia. Unfortunately, the sample size of our study is too limited for further evaluation regarding effects of different types of anesthesia on the incidence of NRiFHRM, but another author[21] previously demonstrated no association between the type of

anesthesia and adverse fetal and neonatal outcomes in pregnancy of any gestational age following non-obstetric surgery.

Temporary decreases in the FHR baseline and variability is a well-described effect of anesthetic drugs,[16, 25-27, 30] confirmed also in our review. FHR variability always returned to moderate with discontinuation of inhalation anesthesia. Our study supports the fact that minimal/absent variability during general anesthesia without decelerations is not a sign of fetal compromise.

The preterm birth rate in the current study was higher than in the general population of the United States (9.9%)[28] and 50% of cases of spontaneous preterm labor happened after abdominal surgery. Previous studies have found divergent results regarding the risk of preterm birth following non-obstetric surgery during pregnancy.[21, 22, 29] For each study, it was impossible to definitively conclude if preterm labor was caused by the operative procedure itself or provoked by the disease process necessitating the surgery. Indeed surgery, manipulation of the uterus, as well as inflammatory diseases (e.g. appendicitis) could potentially activate similar pathophysiological pathways of cortisol and cytokine release leading to preterm birth.[30]

Another review, including 12,542 pregnant women who underwent surgery during pregnancy from 1966-2001,[29] showed an increased risk of fetal loss (2.5%). In our study, although the stillbirth rate (3.1%) was similar, this occurred in a comatose patient thus we cannot exclude that the fetal demise could be related to the clinical scenario instead of the surgery. In a retrospective study including 5,405 women, Mazze et. al[21] demonstrated that the rates of low birthweight infants and early neonatal death were significantly increased in women who had had surgery. Unfortunately, we were not able to evaluate birthweight due to limitations in source data, however no immediate neonatal deaths were noted.

Strengths and limitations

Our systematic review has several strengths. It is the first evaluating cesarean delivery rate for NRFHRM in pregnant women undergoing non-obstetric surgery at ≥22 weeks of gestation. We included only case series with 5 patients or more in order to reduce publication bias.

Limitations of our study are inherent to the limitations of the included studies. The bias assessment, shows that most of the included studies had moderate risk of bias. Our systematic review retrieved no randomized trials. All of the included studies were case series without controls, with limited number of patients and different objectives; indeed only two of them sought to specifically evaluate FHR changes during maternal surgery. Most of the cases included in this review underwent high-acuity surgical procedures and this could have influenced the type of post-operative fetal monitoring and also obstetric outcomes. Unfortunately, no information regarding the types of post-operative monitoring were available. Furthermore, two of the studies were not recent[17,18] and may not reflect contemporary obstetric practice. Some outcomes (e.g. mean gestational age at delivery, birthweight, maternal vital sign changes) were not reported. Although all authors of the included studies were contacted, only 1 provided the missing information. We were not able to find any eligible case series of pregnant women undergoing cardiac surgery with iFHRM. Finally, the small number of patients did not allow us to perform sub-analysis for the different types of surgery or techniques (e.g. laparoscopic or open surgery).

Implications

During non-obstetric surgery, in limited data, NRiFHRM or stillbirth appear to occur only in presence of maternal vital sign changes. Therefore, iFHRM seems most beneficial in situations where unstable maternal vital signs are anticipated, and it is practically feasible to temporarily suspend the primary procedure to permit emergent cesarean delivery to be performed.

Conclusion

Non-reassuring fetal heart patterns during non-obstetric surgery at ≥22 weeks were limited to fetal tachycardia due to maternal fever and did not require intraoperative cesarean delivery in any case. As in 5% of cases cesarean deliveries were necessary for non-reassuring fetal heart rate monitoring within 48 hours after surgery, postoperative fetal monitoring should be considered, especially in cases where unstable vital signs are anticipated. Recognizing that at present there is minimal existent data regarding the practice of intraoperative fetal monitoring during antepartum non-obstetric surgery, the current study represents the most comprehensive review to date.

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TABLES

Table 1. Study and demographic characteristics

Author	Type of study	Primary outcome	Total operative procedures (N)	Operative procedures ≥ 22 weeks (N)	Procedure with FHRM ≥ 22 weeks (N)	Maternal age, mean ± SD (years)	GA at surgery, mean ± SD (weeks)
Liu 1985	Retrospective case series	FHR changes and uterine activity during maternal surgery	5	5	5	28.2 ± 8.6	31.8 ± 2.9
Kendrick 1994	Prospective case series	FHR changes and uterine activity during maternal surgery	10	8	8	24.8 (range 19-36)	27.6 ± 4.2
Cohen-Gadol 2009	Retrospective case series	Identifying optimal management strategies for intracranial pathological entities in pregnant women	19	14	14	26.9 ± 3.8	27.3 ± 4.4
Baldwin 2015	Retrospective case series	Incidence of preterm delivery after non-obstetric surgical procedures performed at viable fetal gestational ages.	121	121	14	27.2 ±4.6	29.4 ± 3.9
Total	1 (25%) prospective case series 3 (75%) retrospective case series	-	155	148/155 (95.5%)	41/148 (27.7%)	27.2 ±4.9	28.6 ± 4.2

GA, gestational age; FHR, fetal heart rate

Table 2. Surgery characteristics

Author	Type of surgery, N (%)	Characteristics of surgery (emergent/urgent/ elective), N (%)	Duration of surgery in minutes (mean)	Type of anesthesia, N (%)
Liu 1985	3 Abdominal (2 appendectomy, 1 lysis of adhesions) 1 Thoracic (mastectomy) 1 Other (debridement and skin grafting)	1 Elective 3 Urgent 1 Emergency	126.6± 77.3	5 General
Kendrick 1994	3 Abdominal (1cholecystectomy, 1 appendectomy, 1 removal of an adnexal mass) 1 Urologic (urolithiasis) 2 Thoracic (mastectomy) 1 Orthopedic 1 Other (cervical conization)	6 Elective 2 Urgent	82.8 ±54.6	6 (75) General 2 (25) Neuraxial
Cohen-Gadol 2009	14 Neurosurgery (7 vascular lesions, 4 tumors, 3 trauma and hemorrhage)	12 Elective 2 Emergent	Not reported	14 (100) General anesthesia
Baldwin 2015	7 Abdominal (3 appendectomy, 2 intestinal resection, 1 LPS cholecystectomy, 1 hepatic surgery) 3 Urologic (3 cystoscopy and stent placement) 2 Thoracic (mastectomy, VATS) 1 Orthopedic 1 Other (parathyroid)	5 Elective 5 Urgent 4 Emergent	Not reported	11 (79) General 3 (21) Neuraxial
Total	14 (34.1) Neurosurgery 13 (31.7) Abdominal 4 (9.8) Urologic 5 (12.2) Thoracic 2 (4.9) Orthopedic 3 (7.3) Other	24 (58.5) Elective 10 (24.4) Urgent 7 (17.1) Emergent	99.6 ± 65*	36 (87.8) General 5 (12.2) Neuraxial

LPS, laparoscopic; VATS, video-assisted thoracoscopic surgery
** Data available for 13 women*

Table 3. Maternal monitoring during surgery

Author	Maternal position, N (%)	Changes in maternal heart rate	Changes in maternal blood pressure	Changes in maternal temperature	Changes in maternal pulse oximetry
Liu 1985	5 Left lateral tilt	None	None	None	None
Kendrick 1994	8 Left lateral tilt	Not reported	Not reported	One case of fever during fetal tachycardia	Not reported
Cohen-Gadol 2009	14 Lateral decubitus	Not reported	Not reported	Not reported	Not reported
Baldwin 2015	3 Left lateral 5 Dorso-lithotomy 6 Not recorded	Not reported	Not reported	One case of fever during fetal tachycardia	Not reported
Total	30 (73.2) Lateral 5 (12.2) Dorso-lithotomy 6 (14.6) Not recorded	Not reported	Not reported	Not reported	Not reported

Table 4. Details of fetal heart rate monitoring during surgery

Author	Type of monitoring	FHR patterns recorded, N (%), details	Number of NRiFHRM	Details of NRiFHRM	Type of surgery during NRiFHRM	Type of anesthesia during NRiFHRM	NRiFHRM in absence of maternal VS changes
Liu 1985	5 CTG (uterine activity not evaluated in 4 procedures)	5/5 (100) reduced/absent variability with the administration of general anesthesia, in 3 cases decreased FHR baseline	0	Not applicable	Not applicable	Not applicable	Not applicable
Kendrick 1994	8 CTG (uterine activity evaluated with palpation in 3 procedures)	8/8 (100) Loss of variability, decrease of 10-25 bpm with general anesthesia, decrease of 5 bpm with spinal anesthesia	1	Tachycardia	Exploratory laparotomy with excision of an adnexal mass	1 Neuraxial anesthesia	No (tachycardia was believed a fetal response to maternal fever)
Cohen-Gadol 2009	14 US continuous or intermittent	Not reported	0	Not reported	Not reported	Not reported	Not reported
Baldwin 2015	8 CTG (7 Continuous /1 Intermittent) 1 US intermittent (appendectomy) 5 Not recorded	2/14 (14.3), One category I CTG, one tachycardia at the US	1	Tachycardia	Exploratory laparotomy with appendectomy	1 General anesthesia	No (tachycardia occurred during maternal fever)
Total	21 (51.2) CTG (19 continuous/2 intermittent) 15 (36.6) US 5 (12.2) Not recorded	15/41 (36.6)	2/41 (4.9%)	Tachycardia	Abdominal procedures	1/2 (50) Neuraxial anesthesia 1/2 (50) General anesthesia	No

FHR: Fetal heart rate; NRiFHRM: Non-reassuring intraoperative fetal heart rate monitoring; US, ultrasound.

Table 5. Intraoperative and post-operative intervention for maternal-fetal complications

Author	Intraoperative CD performed for NRiFHRM, N (%)	Emergent CD performed for NRFHRM within 48 hours post-operative, N (%)	Type of surgery when emergent CD for NRFHRM was performed	Need for tocolysis, N (%)	Type of surgery when tocolysis was used
Liu 1985	0 (0)	1/5 (20)	Skin graft subsequent a burn	3/5 (60)	2 abdominal and 1 mastectomy
Kendrick 1994	0 (0)	0/8	-	4/8 (50)	3 abdominal and 1 mastectomy
Cohen-Gadol 2009	0 (0)	0/14	-	Not reported	Not reported
Baldwin 2015	0 (0)	1/14 (7.1)	Appendectomy	0/14	None
Total	0 (0)	2/41 (4.9)	1 skin graft, 1 appendectomy	7/27 (25.9)*	5 abdominal and 2 mastectomy

CD, Cesarean delivery; NRiFHRM, Non-reassuring intraoperative fetal heart rate monitoring; NRFHRM, Non-reassuring fetal heart rate monitoring.

* Data available for 27 patients

Table 6. Obstetrics and perinatal outcomes

Author	GA at delivery, mean ±SD	PTB, N (%)	PTB within 48 hours post-operative, N (%)	Details of PTB within 48 hours post-operative	BW (gr)	APGAR < 7 at 5 minutes, N (%)	Stillbirths, N (%)	Other adverse perinatal outcomes, N (%)*
Liu 1985	36 ± 8.1	1/5 (20)	1/1 (100)	1 emergent CD for NRFHRM on post-operative day 2 after a skin graft for a burn at 24 2/7 weeks.	3167±1006	0/5 (0)	0/5 (0)	0/5 (0)
Kendrick 1994	All at Term (not reported GA in weeks)	0/8 (0)	0 (0)	None	3374 (2764-4791)	Not reported	0/8 (0)	0/8 (0)
Cohen-Gadol 2009	Not reported	2/12**(16.7)	0 (0)	None	Not reported	2/12 (16.7)**	1/12 (8.3)**	0/12**
Baldwin 2015	34.2 ± 6	6/11***(54.5)	4/6 (66.7)	1 emergent CD for refractory fetal bradycardia immediately after appendectomy at 24 3/7 weeks; 1 emergent CD for intra-abdominal hemorrhage with maternal hypotension on postoperative day 1, after hepatic resection at 26 6/7 weeks; 1 FAVD secondary to a placental abruption at 32 2/7 weeks on post-operative day 2, after an intestinal resection; 1 SVD at 28 3/7 weeks on post-operative day 2, after a subtotal colectomy and ileostomy.	Not reported	0/7 (0)†	0/7 (0)†	0/7 (0)†
Total	-	9/36 (25)	5/9 (55.6)	3 emergent CD; 2 spontaneous preterm labors	-	2/24 (8.3)	1/32 (3.1)	0/32 (0)

GA, gestational age; PTB, preterm birth; BW, birth weight; CD, cesarean delivery; NRFHRM, non-reassuring fetal heart rate monitoring; FAVD, forceps-assisted vaginal delivery; SVD, spontaneous vaginal delivery.
*Including neonatal death, respiratory distress syndrome, cerebral palsy and admission to neonatal intensive care unit
** One ongoing pregnancy, one case with unknown pregnancy outcome.
***Three patients lost at follow-up
†Data available for 7 women

FIGURES

Figure 1. Flow diagram of studies identified in the systematic review. Preferred Reporting Item for Systematic Reviews and Meta-analyses (PRISMA) template. *Definition of terms: FHRM: fetal heart rate monitoring; iFHRM: intraoperative fetal heart rate monitoring.*

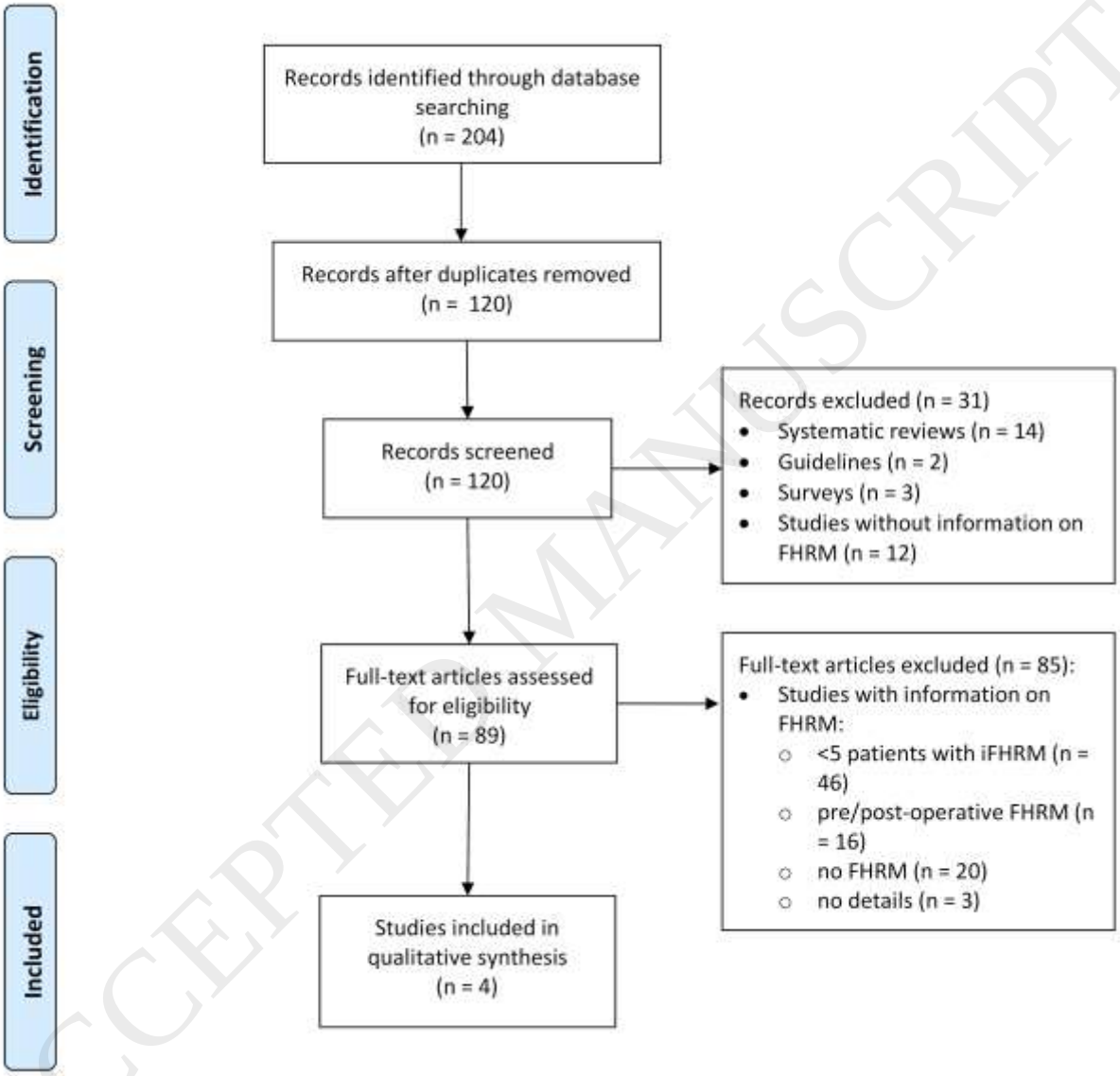

Figure 2. Assessment of risk of bias. *Definition of terms: Aim, clearly stated aim; Rate, inclusion of consecutive patients and response rate; Data, prospective collection of data; Bias, unbiased assessment of study endpoints; Time, follow-up time appropriate; Loss, loss to follow-up; Size, calculation of the study size.*