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Monitored Anesthesia Care versus General Anesthesia for Intrauterine Fetal Interventions: Analysis of Conversions and Complications for 480 Cases

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Abstract
Introduction: Fetal intervention/surgery constitutes a relatively new field of maternal-fetal medicine in which monitored anesthesia care (MAC) or general anesthesia (GA) are utilized as anesthetic techniques when feasible. In this study, we sought to calculate the usage of MAC and GA in various fetal procedures as well as investigate any anesthetic complications and conversions from MAC to GA. ***Methods:*** All intrauterine fetal intervention cases performed at the Texas Children's Hospital Pavilion for Women from 2012 to 2016 were retrospectively analyzed and categorized by mode of anesthesia. Anesthetic complications, conversions to GA, preoperative patient physical status, average number of intraoperative medications required, and average duration of procedure were compared between the MAC and GA groups. ***Results:*** A total of 480 fetal interventions were performed with 432 under MAC (90%) and 37 under GA (7.7%). There were 11 conversions from MAC to GA (2.3%). These conversions were due to poor visualization with ultrasound and change of surgical approach to laparoscopic-assisted technique ($n = 5$), inability to lay flat due to back pain ($n = 3$), persistent vomiting ($n = 2$), and unresponsiveness after a spinal block ($n = 1$). One anesthetic complication occurred due to a medication administration error and did not require conversion to GA. The average preoperative American Society of Anesthesiologists (ASA) physical status classification was 1.97 for the MAC group and 1.87 for the GA group ($p = 0.23$). Duration of the interventions averaged 129 min under MAC and 138 min under GA ($p = 0.23$). An average of 7.8 different medications were administered during MAC cases compared to 13.1 during GA cases ($p < 0.0001$). ***Discussion:*** This analysis suggests that MAC is the most commonly used anesthetic option for fetal interventions with a low complication rate and minimal conversion rates to GA. It is therefore preferable to use MAC when feasible due to the low complication rate and decreased drug exposure.

Introduction

Complex birth defects are present in about 2% of all babies born in the United States [1]. While many of these defects are traditionally treated after delivery, improved technology and diagnostic capabilities have

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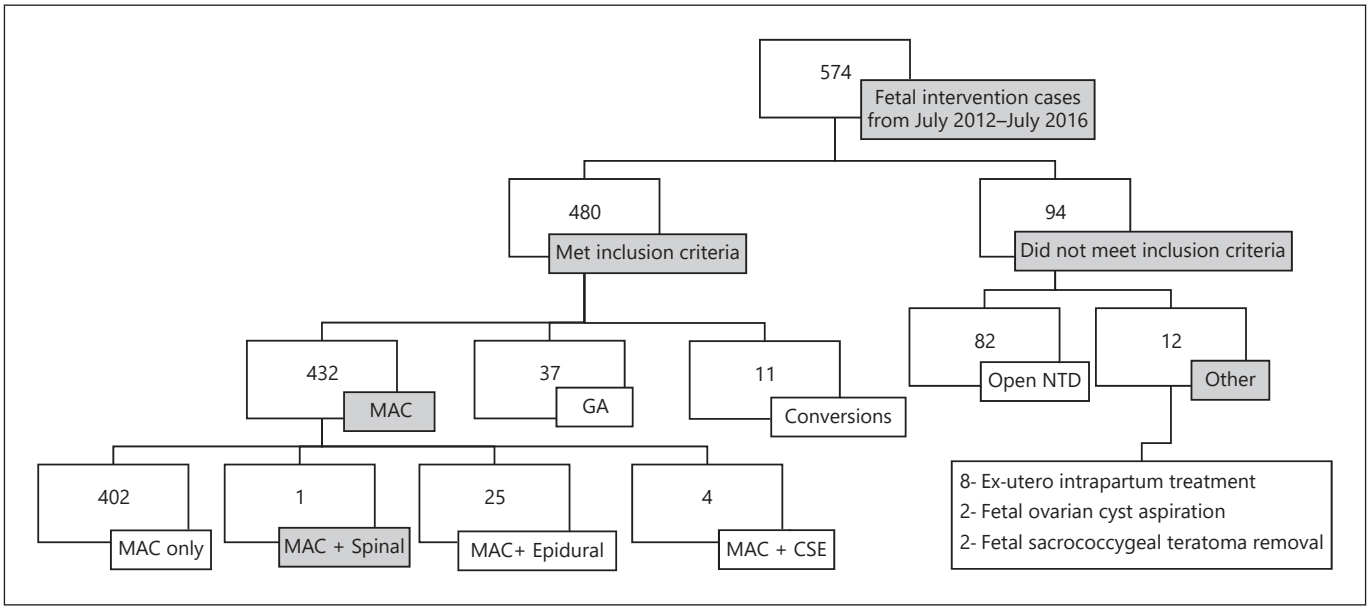

Fig. 1. Flowchart of fetal intervention cases performed by anesthetic technique from July 2012 through July 2016. MAC, monitored anesthesia care; GA, general anesthesia; CSE, combined spinal epidural; NTD, neural tube defect.

allowed for potential interventions to be performed prenatally. Fetal intervention/surgery constitutes a relatively new and continuously advancing section of maternal-fetal medicine in which midgestation fetal related procedures are performed. Many of these fetal interventions are complex surgical procedures that can be high risk for both the mother and the baby. Monitored anesthesia care with intravenous sedation and local anesthetic infiltration (MAC) as well as general anesthesia (GA) are two anesthetic techniques utilized for these interventions. Depending on the nature of the fetal intervention and other indicated procedures, neuraxial anesthesia in the form of a spinal, epidural, or combined spinal epidural (CSE) block may be performed to augment MAC or GA.

There is significant variability in anesthetic management for different procedures amongst fetal centers as well as within institutions [2–5]. The anesthetic regimen is determined based on the planned surgical intervention as well as the accompanying maternal-fetal risk. Considering the concern for relatively high anesthetic related maternal morbidity and mortality during the second and third trimesters of pregnancy coupled with the growing concern for fetal anesthetic neurotoxicity, efforts have been made to utilize MAC and/or regional anesthesia [6, 7]. However, the use of MAC is not without inherent risk, specifically the risk of gastric aspiration in a sedated parturient with an unprotected airway [8]. As the majority of fetal procedures involve only the placenta and the fetus, with very minor maternal skin incisions, MAC is often utilized despite the described increased maternal risk of possible aspiration with sedation or the need for a conversion to GA.

The purpose of this retrospective chart review was to observe the utilization trends of MAC and GA in various fetal procedures and also to investigate the occurrence of anesthetic complications. Secondarily, we sought to determine the number of patients requiring intra-procedure conversion from MAC to GA.

Methods

We performed a single-institution retrospective study that reviewed all anesthetic records of fetal intervention cases performed at the Texas Children's Hospital Pavilion for Women from July 2012 through July 2016 (Fig. 1). Interventions that could only be performed under GA (e.g., open neural tube defects) were excluded from the study. The anesthetic technique was categorized as GA, MAC, MAC plus neuraxial (epidural, spinal, or CSE), or converted cases. Converted cases include any instance of conversion from MAC to GA where the anesthetic technique at the start and end of the case differed. All anesthetics were performed by board certified pediatric anesthesiologists on the fetal subspecialty team at Texas Children's Hospital. The anesthetic plan was determined by the attending anesthesiologist after analysis of the surgical pro-

Table 1. Procedural and anesthetic characteristics for patients included in the analysis

Procedure type[a]	MAC	MAC with regional			GA	Conversions	Total
		spinal	epidural	CSE			
Fetoscopic-guided laser photocoagulation of placental anastomoses	163	0	0	1	29	10	203
Shunt placement	87	0	1	0	2	0	90
Vesico-amniotic	38	0	0	0	0	0	38
Thoraco-amniotic	28	0	1	0	2	0	31
Peritoneal-amniotic	17	0	0	0	0	0	17
Vesico-amniotic and peritoneal-amniotic	4	0	0	0	0	0	4
Intrauterine transfusion	72	0	0	0	0	0	72
Intravascular	67	0	0	0	0	0	67
Intraperitoneal	4	0	0	0	0	0	4
Intracardiac	1	0	0	0	0	0	1
Fetoscopic endoluminal tracheal related	40	1	1	1	3	0	46
Fetal endoscopic tracheal occlusion (FETO)	21	1	1	1	1	0	25
Fetal endoscopic tracheal unplugging	19	0	0	0	2	0	21
Cardiac	0	0	23	2	0	1	26
Aortic valve balloon valvuloplasty	0	0	13	0	0	0	13
Balloon atrial septostomy	0	0	10	2	0	1	13
Selective bipolar cord coagulation and radiofrequency ablation of acardiac twin	13	0	0	0	0	0	13
Fluid drainage	11	0	0	0	0	0	11
Thoracocentesis	8	0	0	0	0	0	8
Vesicocentesis	2	0	0	0	0	0	2
Thoracentesis and paracentesis	1	0	0	0	0	0	1
Amnioreduction	7	0	0	0	0	0	7
Fetoscopic release of amniotic bands	3	0	0	0	2	0	5
Congenital cystic adenomatoid malformation cyst aspiration	2	0	0	0	0	0	2
Fetoscopic-guided laser photocoagulation of feeder vessels to large placental tumor (chorioangioma)	1	0	0	0	1	0	2
Laser photocoagulation of vasa previa vessels	1	0	0	0	0	0	1
Posterior urethral valve fulguration	1	0	0	0	0	0	1
Retrieval of rocket shunt from the uterine wall	1	0	0	0	0	0	1
	402	1	25	4	37	11	480

[a] Procedure type defined as the primary intervention for encounter. MAC, monitored anesthesia care; GA, general anesthesia; CSE, combined spinal epidural.

cedure, patient medical status, airway evaluation, appropriateness of MAC, and input from the surgical team regarding anatomical aberrations and specific surgical considerations. All patients were preprocedurally consented for both MAC and GA.

There were instances in which multiple procedures were performed during the same anesthetic. While all anesthetic data was reviewed, we report the primary procedure as listed in the record. Multiple surgeries with the same patient were treated as independent events. In addition to reviewing the charts for intra- and postoperative complications (e.g., aspiration), and conversions in the MAC and GA cases, the anesthetic methods were also compared using patients' preoperative physical status (determined by ASA classification), number of intraoperative medications required, and duration of procedures.

Results

In total, 574 fetal interventions were performed with anesthesia in 499 patients from July 2012 through July 2016 (Fig. 1). Of the cases performed under a form of anesthesia, 480 interventions met inclusion criteria and were included in the final analysis. Out of the included interventions, 402 were performed under MAC, 4 were under MAC and CSE, 1 was under MAC with a spinal block, 25 were under MAC with an epidural catheter, and 37 were under GA. There were also 11 conversions in which cases were completed under GA but began with a

Table 2. Procedural and patient characteristics of patients requiring unplanned conversion from MAC to GA for fetal surgical interventions

Procedure type	Original anesthetic technique	Indication for conversion	Number of procedures
Fetoscopic-guided laser photocoagulation of placental anastomoses	MAC	Ultrasound provided poor visualization with surgical plan changed to laparoscopic-assisted procedure requiring general anesthesia	5
		Patient with significant back pain who is unable to lay flat for duration of procedure	3
		Patient with persistent nausea and vomiting and anesthesiologist desire to protect airway	1
	Spinal	Patient with spinal began vomiting and complained of breathing (100% SpO_2 throughout); she then became unresponsive and the anesthesiologist decided to intubate	1
Balloon atrial septostomy	Epidural	Patient with persistent nausea and vomiting and anesthesiologist desire to protect airway	1
			11

Table 3. Noted anesthetic specific complications during fetal surgical interventions from July 2012 through July 2016

Procedure type	Anesthetic technique	Description of complication	Number of procedures
Selective bipolar cord coagulation and radiofrequency ablation of acardiac twin	MAC	Patient noted to be apneic with oxygen desaturation to 60's following medication error – patient inadvertently received 500 μg of remifentanil; dose of infusion entered was 0.8 μg/kg/min instead of 0.08 μg/kg/min; the case continued with MAC after oxygen saturation improved after 2 min with bag-mask ventilation	1
			1

different anesthetic technique. The surgical procedure and accompanying anesthetic techniques used can be seen in Table 1.

There were 11 procedures that began under MAC and required conversion to GA. Details regarding the reasons for conversion are summarized in Table 2. There was one anesthetic complication noted in our cohort, a medication dosing error resulting in respiratory depression (Table 3).

The preoperative American Society of Anesthesiologists (ASA) patient physical status (PS), number of intraoperative medications required, and duration of procedures were then analyzed (Table 4). The MAC group here includes MAC, MAC with spinal block, MAC with epidural catheter, and MAC with CSE. These neuraxial anesthesia cases were not separated because of the low number of cases between both groups. An average of 7.8 different medications were administered during MAC cases compared to 13.1 during GA cases ($p < 0.0001$). Duration of the interventions averaged 129 min under MAC and 138 min under GA ($p = 0.23$). There was an average ASA PS of 1.97 for patients who received MAC and 1.87 for patients who received GA ($p = 0.23$).

In order to analyze differences by holding the procedure constant, 29 selective fetoscopic laser photocoagulation (SFLP) cases that were performed under GA were

Table 4. Comparison of various metrics under MAC and GA

	MAC (n = 432)	GA (n = 47)	p value
Number of meds administered	7.82±2.32	13.1±5.54	<0.0001
Duration of procedure, min	129.4±43.4	138.1±73.1	0.23
ASA Physical Status Class	1.97±0.53	1.87±0.62	0.23

Values are expressed as mean ± SD. The MAC group here includes MAC and MAC plus regional.

Table 5. Comparison of 29 GA cases with 29 MAC cases of SFLP fetal intervention

	MAC	GA	p value
Maternal age, years	30.8±5.8	31.2±6.5	0.8056
Gestational age, days	132±16	131±18	0.8239
ASA class	1.92±0.68	1.88±0.56	0.8077
Quintero staging	2.8±1.1	2.6±1.1	0.4916
Surgical duration, min	145±78	196±52	0.0049
Medications administered	6.12±2.18	12.90±4.81	<0.001
Postoperative days until discharge	2.6±0.6	3.4±1.0	0.0005
Complications	0	0	

compared with a selected group of 29 SFLP cases under MAC. This group was selected for by controlling for maternal age, gestational age at time of intervention, ASA class, and Quintero stage. A decrease in the surgical duration, number of medications administered, and number of postoperative days before discharge was observed in the MAC group (Table 5).

Discussion

The primary purpose of this study was to observe the usage of MAC and GA in fetal interventions in which MAC anesthesia is an option. Out of the 480 total procedures in this study, 90% were performed under MAC and 7.7% under GA. The remaining 2.3% were cases that began under MAC and were converted to GA. This demonstrates that a high number of cases were performed and completed under MAC when that option existed. Excluded cases include procedures in which MAC anesthesia was not an option such as myelomeningocele repairs. The high proportion of cases that were performed under MAC in the 23 procedure types listed (Table 1) demonstrates that MAC is already being used when feasible.

Complication rates in the MAC cases were of particular interest. Just because a certain procedure can be performed under MAC anesthesia does not mean that it will have the same safety profile or patient comfort and compliance when performed under GA. The chart review revealed one anesthetic complication out of the 480 procedures (0.2%), and this was in a MAC case. However, this was due to a medication error resulting in respiratory depression requiring bag mask ventilation for 2 min, but no endotracheal intubation. No gastric aspiration or other complications were noted. Using MAC in these procedures appears to be safe given the low number of complications over the 4-year study period. However, safety cannot be accurately assessed without further investigation controlling for long-term effects and randomization.

The number of conversions is also an important marker indicating the viability of MAC anesthesia for certain procedures. A low conversion rate would suggest that the decision to use MAC was appropriate and efficacious. There were 11 conversions in our study. Five conversions occurred before the surgery commenced, during the dedicated time for ultrasound examination. In these cases, MAC was the preferred anesthetic technique but early conversion occurred due to poor visualization. It is important to note that certain reasons for conversion cannot be anticipated ahead of time until surgery has progressed and are therefore difficult to avoid.

Back pain was a reason for conversion ($n = 3$). In the pregnant population, the prevalence of back pain is higher than in the general population. Therefore, these patients are more likely to express difficulty lying flat for the duration of the procedure [9, 10]. Vomiting ($n = 2$) and the concern for airway protection was another reason for conversion. This indication is a more serious risk for the patient compared to back pain as aspiration risk is high in the pregnant population and more so in the sedated, pregnant patient. Ten of the conversions occurred during fetoscopic-guided laser photocoagulation of placental anastomoses, but this may be because of the high frequency in which this type of procedure is performed in our patient cohort and in general.

The similarity between ASA PS classification in the MAC and GA groups suggests that patient physical status was not a huge factor in deciding whether a patient required one anesthetic method over the other. This suggests that there may have been less of an influence from maternal comorbidities than approach to surgery with regards to mode of anesthesia.

Given that many medications have untoward or unknown effect on the fetus, it is preferable to reduce the number of medications administered when safe to do so. In our study, patients undergoing procedures with MAC received six fewer medications compared with those requiring GA. This is likely because fetal intervention procedures requiring GA often warrant specific medication administration for the fetus, maternal muscle relaxation and subsequent reversal, as well as multimodal pain management.

It is preferable to decrease duration under anesthesia as longer times are correlated with increased postoperative complication risk. Decreased procedure time is also preferable to decrease overall operating room expenses as each minute of operating room time is estimated to be approximately USD 368 [11]. On average, the MAC cases were shorter by 9 min, but this difference was not found to be statistically significant. Duration of procedure is likely more a consequence of procedure type than the anesthetic technique used.

The above results do not directly compare similar patients receiving the same fetal intervention. When SFLP groups were compared by anesthesia type there were statistically significant reductions in surgical duration, medications administered, and days in hospital. This specific comparison serves to highlight the advantages of MAC over GA for fetal procedures when there is a choice.

There are several limitations to this study. This is a retrospective study and patients were not randomized to MAC or GA groups. Furthermore, it would be impossible to randomize patients for a mode of anesthesia while maintaining blinding for the purposes of timing and medication administration. Another limitation is that all procedures were performed at a single institution. The Texas Children's Fetal Program performs approximately 235 fetal cases per year with four fetal surgeons, fetal cardiac interventionalists (as applicable), and maternal fetal medicine specialists each, and the cases performed here may not be representative of the cases and resources at other institutions.

This analysis suggests that MAC is a safe alternative to GA for amenable fetal interventions even in the midgestation pregnant mother, with a low complication rate. MAC affords reduced maternal and subsequently fetal medication exposure. Finally, conversion rate to GA is very low. Measures to reduce patient anxiety and enhance position-related comfort should be employed to potentially reduce the risk of conversion. Overall, this study demonstrates that MAC has been used with relative success in amenable fetal interventions.

Statement of Ethics

This research complies with the guidelines for ethics. It was a retrospective database analysis that did not require special approval for human studies. This study design was approved by the Institutional Review Board at Baylor College of Medicine.

Disclosure Statement

The authors have no conflicts of interest to declare.

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Author Contributions

Deep Patel compiled the data and analyzed the different complications and conversions in the fetal interventions. Dr. Hassanpour, Dr. Adler, Dr. Olutoye, and Dr. Chandrakantan contributed to the study design and format. All authors participated in editing and revision of the final article.

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