



## Anesthesia for Interventional Radiology in Obstetrics: A Public Health Perspective on Maternal Safety and Health Systems

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### ABSTRACT

Interventional radiology (IR) has emerged as a transformative modality in obstetric care, particularly in the management of life-threatening conditions such as postpartum hemorrhage (PPH), placenta accreta spectrum (PAS), and uterine vascular abnormalities. The anesthetic management of obstetric patients undergoing IR procedures is complex and requires careful consideration of maternal physiology, fetal safety, and procedural demands. From a public health perspective, integrating anesthesia services within IR suites provides an opportunity to significantly improve maternal outcomes, particularly in low- and middle-income countries (LMICs), where maternal mortality remains disproportionately high.

This review provides a comprehensive evaluation of anesthetic techniques used in obstetric IR, including local anesthesia with sedation, regional anesthesia, general anesthesia, and monitored anesthesia care. It examines physiological challenges, safety considerations, and procedural requirements specific to pregnant patients. Additionally, the paper explores health system barriers such as workforce shortages, inadequate infrastructure, and delayed referrals, which limit the implementation of IR services in resource-constrained settings.

Evidence from clinical studies demonstrates that IR procedures, particularly uterine artery embolization, are associated with high success rates, reduced morbidity, and preservation of fertility when compared to traditional surgical approaches. However, their effectiveness is closely linked to the availability of skilled anesthesia providers and multidisciplinary care teams.

The paper concludes that strengthening anesthesia services, investing in infrastructure, and integrating IR into maternal health policies are essential steps toward reducing maternal mortality and improving global health equity.

**KEYWORDS:** Obstetric anesthesia, interventional radiology, postpartum hemorrhage, maternal mortality, uterine artery embolization, public health

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### INTRODUCTION

Maternal mortality remains a significant global health challenge, particularly in low- and middle-income countries (LMICs), where access to timely and effective obstetric care is limited. According to global estimates, postpartum hemorrhage (PPH) accounts for nearly one-quarter of maternal deaths worldwide and remains the leading direct cause of maternal mortality [1]. Despite advances in obstetric care, many regions continue to rely on conventional management strategies such as uterotonics, surgical ligation, and hysterectomy, which are often associated with high morbidity and permanent loss of fertility.

In recent decades, interventional radiology (IR) has emerged as a powerful alternative in the management of obstetric complications. Techniques such as uterine artery embolization (UAE), pelvic arterial embolization, and prophylactic balloon occlusion have revolutionized the treatment of severe hemorrhage and abnormal placentation [2,3]. These minimally invasive procedures allow targeted control of bleeding, reduce surgical trauma, and preserve reproductive potential.

However, the successful implementation of IR in obstetrics is highly dependent on effective anesthetic management. Obstetric patients present unique physiological challenges, including increased cardiac output, reduced functional residual capacity, airway edema, and a hypercoagulable state. These changes increase the risk of hemodynamic instability, hypoxia, and difficult

airway management during anesthesia. Furthermore, IR procedures are often performed outside conventional operating rooms, creating additional challenges related to monitoring, equipment availability, and emergency preparedness.

From a public health perspective, the integration of IR into obstetric care pathways represents an opportunity to significantly reduce maternal mortality. However, this requires a systems-based approach that includes strengthening anesthesia services, training healthcare providers, and improving infrastructure. In many LMICs, the lack of trained anesthesiologists and limited access to IR facilities remain major barriers to implementation.

This paper aims to provide a comprehensive review of anesthesia for interventional radiology in obstetrics, with a focus on maternal safety and health systems. It examines physiological considerations, anesthetic techniques, safety challenges, and the broader public health implications of integrating IR into obstetric care.

### **Physiological Considerations**

Pregnancy induces profound physiological changes that significantly influence anesthetic management. These changes affect multiple organ systems and must be carefully considered when planning anesthesia for IR procedures.

#### **Cardiovascular System**

Cardiac output increases by 30–50% during pregnancy due to increased stroke volume and heart rate. Systemic vascular resistance decreases, leading to relative hypotension. During hemorrhage, these compensatory mechanisms may rapidly fail, resulting in severe hemodynamic instability. Additionally, aortocaval compression by the gravid uterus can reduce venous return, necessitating positioning strategies such as left lateral tilt.

#### **Respiratory System**

Respiratory changes include increased oxygen consumption and decreased functional residual capacity. These adaptations predispose pregnant women to rapid desaturation during apnea, making airway management particularly critical. Even brief periods of hypoventilation during sedation can result in hypoxia.

#### **Airway Changes**

Airway edema and increased vascularity increase the risk of difficult intubation. Failed airway remains one of the leading causes of anesthesia-related maternal morbidity and mortality.

#### **Hematological Changes**

Pregnancy is associated with a hypercoagulable state, characterized by increased clotting factors and reduced fibrinolysis. While this protects against hemorrhage, severe bleeding can lead to coagulopathy, complicating the use of regional anesthesia.

#### **Implications for IR**

These physiological changes require individualized anesthetic planning, vigilant monitoring, and readiness for rapid intervention. The choice of anesthetic technique must balance maternal stability, procedural requirements, and fetal safety.

#### **Interventional Radiology Procedures**

Key IR procedures in obstetrics include uterine artery embolization, balloon occlusion techniques, and embolization for vascular abnormalities.

UAE is the most widely used procedure for PPH, with success rates exceeding 90% in many studies. Balloon occlusion techniques are used prophylactically in placenta accreta spectrum to reduce intraoperative blood loss. Embolization is also effective in managing arteriovenous malformations and selected cases of ectopic pregnancy.

These procedures are minimally invasive but require precise coordination between radiologists and anesthesiologists.

#### **Anesthetic Techniques**

- **Local Anesthesia with Sedation**

This technique is commonly used in stable patients undergoing UAE. It avoids airway manipulation and allows faster recovery. However, careful monitoring is required to prevent respiratory depression.

- **Regional Anesthesia**

Regional techniques provide excellent analgesia and reduce systemic drug exposure. They are useful in elective procedures but are contraindicated in coagulopathy.

- **General Anesthesia**

General anesthesia is essential in unstable patients. It allows airway control and aggressive resuscitation but carries risks such as difficult intubation and aspiration.

- **Monitored Anesthesia Care**

This approach combines sedation with continuous monitoring and requires experienced providers.

### Safety Considerations

Safe anesthesia in IR requires:

- Continuous monitoring
- Airway preparedness
- Blood transfusion availability
- Radiation protection
- Infection control

Radiation exposure is minimized through shielding and limiting exposure time, with fetal doses typically below harmful thresholds.

### Public Health Perspective

Maternal mortality remains a major global health concern, with the highest burden observed in low- and middle-income countries (LMICs). Despite significant progress in maternal health over recent decades, disparities persist due to inequities in access to timely and effective obstetric care. Postpartum hemorrhage continues to be the leading cause of maternal death worldwide, particularly in resource-limited settings where delays in diagnosis and management are common. These delays are often multifactorial, involving barriers at the community, transport, and facility levels.

Interventional radiology (IR) has emerged as a promising solution for managing obstetric hemorrhage, offering minimally invasive, fertility-preserving techniques such as uterine artery embolization (UAE). Compared to conventional surgical interventions, IR procedures are associated with reduced blood loss, lower complication rates, shorter hospital stays, and preservation of reproductive function. From a public health standpoint, the integration of IR into obstetric care pathways has the potential to significantly reduce maternal morbidity and mortality, particularly when implemented as part of comprehensive emergency obstetric care systems.

However, the implementation of IR services in LMICs is constrained by several systemic challenges. One of the most significant barriers is the lack of infrastructure. IR procedures require specialized equipment, including fluoroscopy units, angiography suites, and embolization materials, which are often unavailable in peripheral or district-level hospitals. Even in tertiary care centers, limited availability of functioning equipment and maintenance issues can restrict service delivery. This creates a situation where life-saving interventions are theoretically available but practically inaccessible to a large proportion of the population.

Another critical challenge is the shortage of trained healthcare professionals, particularly anesthesiologists and interventional radiologists. Safe delivery of IR procedures relies heavily on the presence of skilled anesthesia providers who can manage hemodynamic instability, airway complications, and rapid clinical deterioration. In many LMICs, the density of anesthesiologists is extremely low, with some regions relying on non-physician providers with limited training. This workforce gap directly impacts the feasibility of establishing IR services, as anesthesia support is essential for both procedural success and patient safety.

In addition to workforce shortages, there are gaps in training and capacity building. Even where healthcare providers are available, they may lack specific training in obstetric anesthesia for IR procedures. Simulation-based training, multidisciplinary drills, and continuous professional development programs are essential to build competency and confidence among providers. Investment in training programs not only improves clinical outcomes but also strengthens health systems by creating a sustainable workforce.

Referral systems and delays in care further contribute to poor maternal outcomes. The “Three Delays Model” highlights delays in seeking care, reaching healthcare facilities, and receiving appropriate treatment. In many LMICs, women experiencing obstetric emergencies face significant barriers in accessing tertiary care centers where IR services are available. Poor transportation networks, financial constraints, and lack of awareness contribute to delayed presentation, often resulting in advanced disease and increased risk of mortality. Strengthening referral pathways and establishing regional centers of excellence for IR can help address these challenges.

Health financing and resource allocation also play a crucial role in determining access to IR services. In many settings, healthcare systems are underfunded, and priority is often given to basic services rather than advanced interventions. However, investing in IR can be cost-effective in the long term by reducing the need for extensive surgical procedures, decreasing hospital stays, and minimizing complications. Policymakers must recognize the value of IR as part of essential maternal health services and allocate resources accordingly.

Another important aspect is the integration of IR into national maternal health policies and guidelines. While many high-income countries have incorporated IR into standardized obstetric hemorrhage protocols, its inclusion in LMIC guidelines remains limited. Developing context-specific protocols that incorporate IR alongside medical and surgical management can improve decision-making and ensure timely escalation of care. Collaboration between policymakers, clinicians, and professional organizations is essential for the successful implementation of such strategies.

Equity in access to care is a fundamental principle of public health. Currently, access to IR services is often limited to urban tertiary centers, leaving rural populations underserved. Addressing this urban-rural disparity requires innovative approaches, such as mobile IR units, telemedicine support, and decentralization of services. Strengthening primary and secondary healthcare systems can also facilitate early identification and referral of high-risk cases.

Multidisciplinary collaboration is another key component of effective IR implementation. Successful management of obstetric emergencies requires coordination between obstetricians, anesthesiologists, interventional radiologists, nursing staff, and blood bank services. Establishing structured team-based care models and standardized protocols can significantly improve outcomes. Evidence suggests that hospitals with well-developed obstetric hemorrhage bundles, including IR components, have lower rates of maternal morbidity and mortality.

Furthermore, community-level interventions play an important role in improving maternal outcomes. Increasing awareness about the importance of institutional deliveries, early recognition of complications, and timely healthcare-seeking behavior can reduce delays and improve access to care. Public health campaigns, education programs, and engagement with community health workers are essential in bridging the gap between communities and healthcare systems.

Technological advancements also offer opportunities to expand access to IR services. Telemedicine platforms can facilitate remote consultations, allowing specialists to guide procedures and decision-making in resource-limited settings. Additionally, the development of cost-effective and portable imaging technologies may enable wider implementation of IR in the future.

Despite its potential, the widespread adoption of IR in obstetrics requires careful consideration of ethical and equity issues. Ensuring that all women, regardless of socioeconomic status or geographic location, have access to life-saving interventions is a key challenge. Health systems must strive to balance the introduction of advanced technologies with the need to provide basic essential services.

## Discussion

The integration of interventional radiology into obstetric care has significantly transformed the management of severe maternal complications, particularly postpartum hemorrhage and placenta accreta spectrum. Evidence from multiple observational and cohort studies demonstrates that uterine artery embolization achieves high success rates, often exceeding 85–90%, in controlling hemorrhage while preserving fertility. Compared with traditional surgical approaches such as hysterectomy, IR techniques are associated with reduced morbidity, shorter recovery times, and improved reproductive outcomes.

The choice of anesthetic technique remains variable across studies. In hemodynamically stable patients, local anesthesia with sedation has been shown to be safe and effective, minimizing airway-related complications and facilitating rapid recovery. However, in cases of massive hemorrhage or instability, general anesthesia remains essential due to the need for airway control and aggressive resuscitation. This aligns with findings from multiple clinical studies emphasizing a case-based approach to anesthetic management.

Regional anesthesia, although less frequently utilized, offers significant advantages in selected patients undergoing planned procedures. Studies suggest improved analgesia and reduced systemic drug exposure, though its use is limited by concerns regarding coagulopathy and hypotension. The underutilization of regional techniques reflects both clinical caution and infrastructural limitations within IR suites.

Maternal safety outcomes associated with IR are generally favorable. Complication rates are low when procedures are performed in well-equipped settings with experienced providers. Anesthesia-related complications are rare but underscore the importance of vigilant monitoring and preparedness for emergencies. Radiation exposure, a commonly cited concern, has been shown to remain within safe limits when appropriate protective measures are employed.

From a health systems perspective, significant disparities exist in access to IR services. High-income countries have well-established IR programs, whereas low- and middle-income countries face challenges related to workforce shortages, infrastructure deficits, and delayed referrals. These barriers contribute to continued reliance on surgical management and higher maternal morbidity.

Comparative studies consistently demonstrate superior outcomes with IR compared to surgical interventions in appropriate cases. However, IR is not universally available, and its success depends on timely access and multidisciplinary coordination. The integration of obstetric hemorrhage protocols, including IR and anesthesia components, has been shown to improve outcomes and reduce mortality.

Policy-level interventions are crucial for expanding access to IR services. Investment in infrastructure, training of anesthesia providers, and development of referral networks are essential components of health system strengthening. Incorporating IR into national maternal health strategies could significantly reduce maternal mortality.

Future research should focus on randomized trials comparing anesthetic techniques, cost-effectiveness analyses, and data from low-resource settings. Emerging technologies and telemedicine may further enhance access and improve outcomes.

## CONCLUSION

Anesthesia for interventional radiology in obstetrics is a critical component of modern maternal care. Effective anesthetic management enhances procedural success and significantly improves maternal outcomes. From a public health perspective, strengthening anesthesia services within interventional radiology frameworks is essential for reducing maternal mortality and achieving global health equity. Multidisciplinary collaboration, infrastructure development, and policy integration are key to

realizing the full potential of interventional radiology in obstetric care.

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