Special Report

Amniotic Fluid Embolism: Using the Medical Staff Process to Facilitate Streamlined Care

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ABSTRACT

Amniotic fluid embolism (AFE) is a catastrophic consequence of labor and delivery that often results in maternal and neonatal death. These poor outcomes are related largely to the rarity of the event in a population overwhelmingly biased by overall good health. Despite the presence of national AFE registries, there are no published algorithmic approaches to its management, to our knowledge. The purpose of this article is to share a care pathway developed by a multidisciplinary group at a community teaching hospital. Post hoc analysis of a complicated case of AFE resulted in development of this pathway, which addresses many of the major consequences of AFE. We offer this algorithm as a template for use by any institution willing to implement a clinical pathway to treat AFE. It is accompanied by the remarkable case outcome that prompted its development.

INTRODUCTION

Amniotic fluid embolism (AFE) has remained an enigmatic and catastrophic complication of pregnancy since it was initially described in 1926.[1] Anesthesiologists are often the first physicians to recognize the initial signs of impending cardiovascular collapse and to coordinate the care of the critically ill mother and fetus. Maternal death directly attributed to AFE was not well known until the seminal publication by Steiner and Lushbaugh[2] in 1941. To date, the exact pathophysiology of AFE remains incompletely understood. Early reports postulated that the syndrome was embolic in nature.[3] Contemporary thinking suggests an immunologic etiology[4] because amniotic fluid contains proinflammatory, vasospastic, and coagulative substances that cause acute lung injury, ventricular dysfunction, and activation of clotting factors predisposing to disseminated intravascular coagulation (DIC).[5] The syndrome frequently manifests the following symptoms: maternal hypoxia, hypotension, DIC, seizure activity, and fetal distress.[4,6] Mortality rates ranging from 20% to 60% have been reported recently.[7]

The incidence of AFE ranges from approximately 1 case per 15,200 deliveries in North America to 1 per 53,800 deliveries in Europe.[8] The sporadic occurrence of AFE means most anesthesiologists, obstetricians, and delivery units are not prepared for the herculean efforts that are necessary to achieve both maternal and neonatal survival. Table 1 lists the most frequent elements of the clinical presentation that should alert the anesthesiologist and obstetrician to the possibility of AFE. The triad of hypotension, hypoxemia with respiratory failure, and DIC should prompt immediate implementation of the proposed AFE management pathway described later in this article. It was developed following the successful outcome of the case reported here. Clearly, the classic triad is not always present, and milder cases of AFE may not include all common manifestations. A high index of suspicion is critical for a favorable outcome.

CASE ILLUSTRATION

A 33-year-old pregnant woman, gravida 1, para 0, was admitted at 41 weeks gestation for a scheduled induction of labor because she was past her due date. Her medical history included glomerulonephritis during childhood, which resolved after 1 year of prednisone treatment. Her obstetric history was unremarkable with an uncomplicated pregnancy. After admission, the patient was given 2 doses of misoprostol; she experienced spontaneous rupture of membranes and entered active labor. Approximately 2 hours after an uneventful epidural placement, the patient became hypotensive, and fetal monitoring documented severe bradycardia. Fetal distress prompted emergent cesarean delivery. Maternal seizures began during the cesarean delivery, with subsequent

Table 1. Clinical presentation of amniotic fluid embolism[a]

Symptom or sign	Frequency of occurrence, %
Hypotension	100
Fetal distress	100
Pulmonary edema or ARDS	93
Cardiopulmonary arrest	87
Coagulopathy	83
Dyspnea	49
Seizure	48

[a] Excerpted and reprinted with kind permission from: American Journal of Obstetrics and Gynecology, 172(4 Pt 1), Clark SL, Hankins GD, Dudley DA, Dildy GA, Porter TF. Amniotic fluid embolism: analysis of the national registry, p 1158-67: Table V, with permission from Elsevier.

ARDS = acute respiratory distress syndrome.

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cardiac arrest requiring cardiopulmonary resuscitation. This maternal collapse was consistent with AFE.

Five minutes into the resuscitation, a live female infant was delivered via cesarean delivery. After 75 minutes of cardiopulmonary resuscitation, the patient remained in cardiopulmonary arrest and experienced DIC. The massive transfusion protocol was initiated, and a cardiac surgeon was recruited. Appropriate cannulae in the right femoral artery and vein were placed to establish full cardiopulmonary support (CPS) via extracorporeal membrane oxygenation (ECMO). After the initiation of CPS, massive abdominal distention was noted, suspicious for active intraabdominal hemorrhage. Exploratory laparotomy by the obstetrician and on-call general surgeon revealed 3 L of intraabdominal blood. The left uterine artery was ligated, and the abdomen was closed.

In the intensive care unit (ICU), a temperature control protocol for brain cooling was initiated in an attempt to preserve brain function. The patient remained on CPS and a regimen of vasopressors as needed. DIC persisted, as manifested by hemorrhage and progressive abdominal distention. Embolization of the uterine arteries by an interventional radiologist was attempted, but during the attempt, the right lower extremity developed critical limb ischemia as a consequence of femoral cannulation for CPS. The patient was returned emergently to the operating room, where groin cannulation was replaced by ascending aorta and right atrial cannulation for CPS. Arterial flow to the ischemic right lower extremity was reestablished but resulted in compartment syndrome treated with a four-compartment fasciotomy by the vascular surgery team. A total hysterectomy and left salpingo-oophorectomy were necessary to control hemorrhage. Raw bleeding surfaces in the pelvis were treated by packing maneuvers.

The patient returned to the ICU, where transfusion was continued. Once the DIC resolved, packing was removed from the pelvis. After stabilization, CPS was discontinued. During the entire resuscitation, the patient received a total of 154 U of packed red blood cells, 78 U of fresh frozen plasma, 25 U of platelets, 12 U of cryoprecipitate, and 2 doses of Factor VII to control the DIC.

After resuscitation, cardiopulmonary stabilization, and resolution of coagulopathy, the patient recovered. She was discharged from the hospital on postpartum Day 26. The infant was discharged 9 days after birth. Mother and baby are doing well, with no deficits at 3-year follow-up.

DISCUSSION

The successful outcome in this case prompted a post hoc analysis by a multidisciplinary task force to clarify emergent processes that might improve future outcomes. Despite recent advances in prenatal care, AFE remains a most perplexing and frequently fatal consequence of parturition. Major risk factors predisposing to AFE include maternal age older than 35 years, cesarean delivery, vacuum or forceps-assisted delivery, placenta previa or abruption, eclampsia, and fetal distress.[8] There have been previously published reports analyzing complex treatment modalities for maternal support in the immediate postpartum setting when AFE is encountered.[7,8] The proinflammatory pathology of AFE manifests as the clinical scenario of respiratory failure, cardiovascular collapse, coagulopathy, and occasionally seizure activity. The circulatory and respiratory support following maternal collapse can include the use of ventricular assist devices, ECMO, inhalation of nitrous oxide, and cardiopulmonary bypass with or without intra-aortic balloon pump.[4,9,10] This illustrative case demonstrates the benefit of a multidisciplinary approach to the complex care required to treat AFE. Larger multispecialty integrated health care organizations are in a pivotal position to champion refinements in clinical care pathways. Other authors have suggested that multidisciplinary teamwork offers the most effective strategy for maternal and fetal survival.[11] However, an interdisciplinary decision tree is difficult for the anesthesiologist and obstetrician to assimilate in the frenetic environment that accompanies AFE. Rapid information dissemination for recruitment of resources and specialty providers is critical for a successful outcome.

On the basis of the experience with a ruptured abdominal aortic aneurysm and fetal distress protocols already implemented at our institution, an AFE algorithm was developed. The algorithm was vetted through the medical staff process, approved, and promoted in the hopes of clarifying the emergent management of AFE (Figure 1). In this care pathway, the On-Call Nursing Supervisor serves as the initial multidisciplinary coordinator during the "mobilization of resources" phase of treatment. This allows the attending anesthesiologist and obstetrician to focus on the mother with the full knowledge that a previously vetted algorithm will facilitate coordination of all essential aspects of care, including that of the neonate. Separate subalgorithms for anesthesiologists, obstetricians, cardiac surgeons, intensivists, general surgeons, and neonatologists are integrated into the one-page AFE algorithm to streamline the processes and to maximize the chance that smaller but critical decisions are accomplished in rapid sequence. We postulate that a similar AFE algorithm could be easily adopted in any hospital willing to merge the best aspects of its own facility's previously established protocols, such as those for emergent fetal distress, massive transfusion, or ruptured abdominal aortic aneurysm.

The ultimate goal of the algorithm is to decrease variability in care and to streamline care pathways, which are likely to optimize outcomes. The rarity of this event makes proof of this hypothesis extremely difficult, but we contend that drills similar to mass casualty exercises or treatment of malignant hyperthermia are useful. We note that during the period of time required to obtain clinical acceptance of this care pathway by multiple departments, an interval maternal death caused by AFE occurred. This adverse outcome, which occurred in the absence of a defined clinical pathway, attests to the need for a streamlined approach to the management of AFE. Our institution is currently in the process of implementing proactive AFE training for our anesthesiologists. We also firmly support the concept of debriefing following each event to modify processes as needed.

Once the anesthesiologist or obstetrician recognizes cardiopulmonary collapse,

the AFE algorithm can be implemented by a single phone call to the Nursing Supervisor. Figure 1 outlines in detail the AFE algorithm now in place at our institution. Each subalgorithm provides a checklist to be considered by the individual specialty services. Limiting the document to one page provides simplicity for rapid information transfer and streamlined implementation. This algorithm is not an attempt to comprehensively address each variable that may present in an individual case. It is an overarching document designed to limit major oversights in care. There are areas of controversy in the blood product ratios used to manage massive transfusion, in the use of ECMO for CPS, and in the levels for targeted temperature control (see Figure 1, Blood Bank, Cardiac Surgery, and Anesthesia). Individual institutions can tailor recommendations to regional preferences (practice standards) with appropriate support from the literature.

Intensivists rapidly assume ongoing management of the multiple organ failure and hemodynamic instability on the patient's arrival in ICU. Recruitment of specialists early in the chain of events facilitates the transition from the labor deck to the ICU. The added expertise of those critical care specialists makes it less likely that maternal and fetal stabilization efforts will fail.

While the obstetrician focuses on delivery of the infant and control of maternal DIC and uterine hemorrhage with the assistance of the general surgeon, the anesthesiologist and cardiac surgeon can manage cardiopulmonary failure. In addition to securing the airway, performing advanced cardiac life support on the mother, pediatric advanced life support on the infant, and administering blood products via the massive transfusion protocol, the anesthesiologist(s) may perform transesophageal echocardiography. Transesophageal echocardiography can be useful at identifying amniotic debris in the atrium, facilitating removal on cardiopulmonary bypass.[12] ECMO/CPS using extracorporeal bypass or left ventricular assist devices has been described as a means to treat acute cardiopulmonary failure. Ecker and associates[13] recently reported in the *New England Journal of Medicine* a similar case requiring extensive CPS.

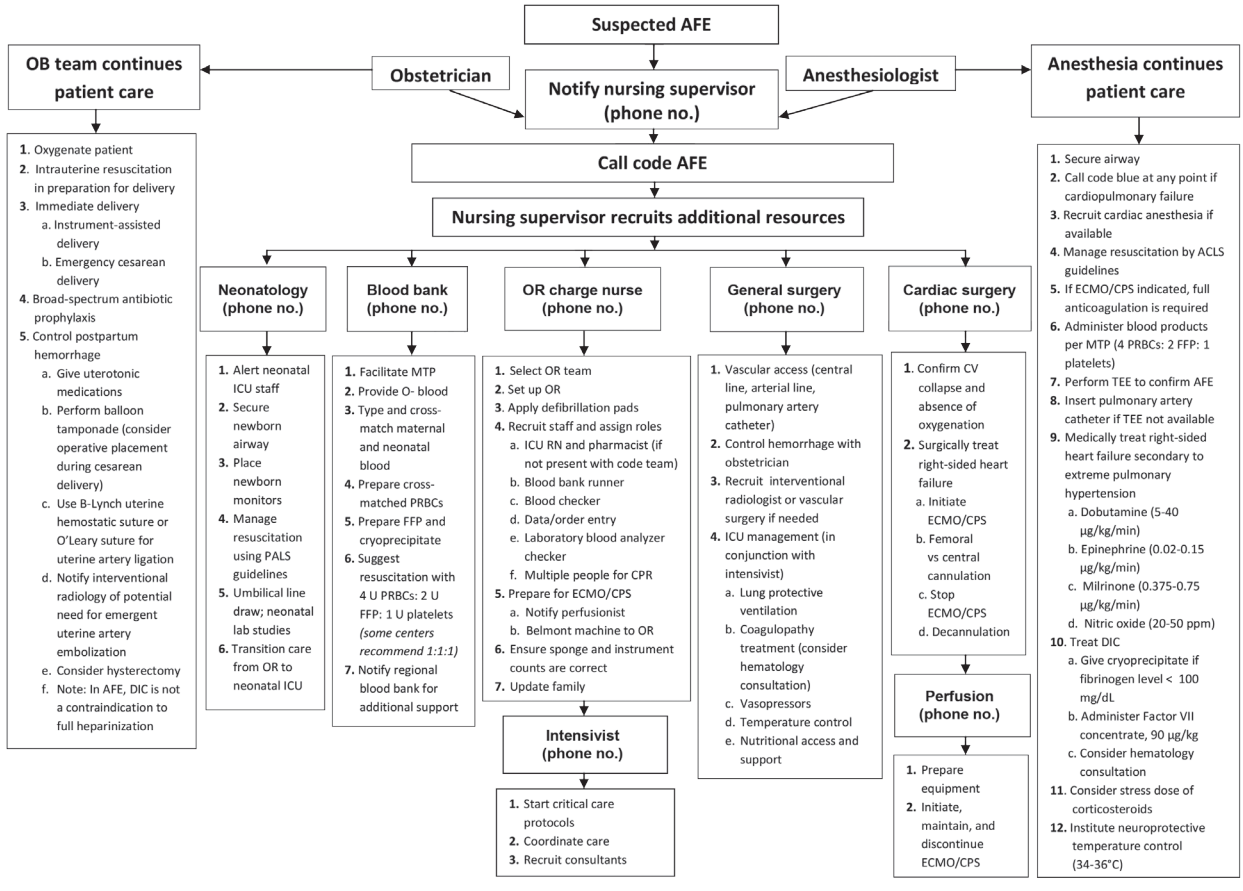

Figure 1. Algorithmic management of amniotic fluid embolism (AFE).

ACLS = Advanced Cardiac Life Support; CPR = cardiopulmonary resuscitation; CV = cardiovascular; DIC = disseminated intravascular coagulation; ECMO/CPS = extracorporeal membrane oxygenation/cardiopulmonary support; FFP = fresh frozen plasma; ICU = intensive care unit; lab = laboratory; MTP = massive transfusion protocol; OB = obstetrics; OR = operating room; PALS = Pediatric Advanced Life Support; PRBC = packed red blood cell; RN = registered nurse; TEE = transesophageal echocardiography.

Diagnosis and management of AFE is elegantly outlined in their report. The CESAR trial suggested that ECMO for treatment of reversible respiratory failure was superior to conventional ventilation because it increased survival without severe disability.[14] Some investigators have challenged the CESAR trial results and methods. Other articles also promote the use of ECMO for treatment of reversible respiratory failure and acute respiratory distress syndrome, but all suggest that validation and prospective studies are necessary to determine the optimal timing of initiation and specific indications to standardize the use of ECMO in such settings.[15-19] As in this case, the use of ECMO to treat cardiopulmonary failure in the setting of AFE has been described by other investigators.[4,5,7,9,10,13] The cardiac surgeon will determine whether to initiate CPS on the basis of general indications demonstrated in the Sidebar: Extracorporeal Membrane Oxygenation Checklist. In the ICU, the general surgeon or surgical intensivist may adopt management strategies that include use of lung protective ventilation, targeted temperature control for preservation of neurologic function,[20] and early enteral vs parenteral nutritional support.

When such a checklist is in place before the acute event occurs, lessons learned from prior experience are not forgotten in the protracted interim. Each subspecialty can be automatically and seamlessly integrated to provide a unique and critical service in management of the multisystem organ failure associated with AFE. This article combines our experience and knowledge gained from the excellent work of others[5-7,13] into a one-page document that is posted in the labor and delivery suites, in the main operating rooms, and at selected critical locations for easy visibility and accessibility. We are in the process of developing drills to facilitate implementation. Ideally, such drills will be incorporated in periodic training in a manner similar to mass casualty exercises. Regional practice variations in other institutions will mandate changes at the individual hospital level, but the general principles outlined herein constitute a best practice model approved by our institution and based on the current literature. Similar algorithmic decision trees have shown utility in the management of malignant hyperthermia, acute coronary syndromes, and acute stroke.[21-25]

CONCLUSION

The establishment of a multidisciplinary care pathway for the management of AFE is designed to improve maternal and neonatal survival. After a successful maternal and neonatal outcome following a case of AFE at our institution, the course of events and components of care were reviewed, and the parties involved were questioned in an effort to ascertain the elements necessary to reproduce such a monumental success in future cases of AFE. Our analysis suggests that the collaborative effort between multidisciplinary care providers, including early initiation of the massive transfusion protocol and implementation of appropriate CPS, were the critical components for success. Algorithmic treatment is intended to decrease variability, mitigate physician stress, and streamline responses. We offer this report as a template for management of AFE and to encourage other institutions to be proactive in their modifications and implementation of similar algorithmic approaches to AFE. ❖

Extracorporeal Membrane Oxygenation Checklist[1]

Algorithmic management of amniotic fluid embolism

(Start ECMO consideration if *Carrico Index:* PaO2/FIO2 < 150)

Indications for ECMO

- Acute Respiratory Distress Syndrome (ARDS) present
- Severe hyoxemia (PaO2/FIO2) < 80 despite PEEP 15 cm-20 cm H_2O
- (PaO2/FIO2) < 50 consider early ECMO
- Uncompensated hypercarbia (pH < 7.15)
- Excessively high plateau airway pressure on ventilator
- Hypercarbic respiratory failure

Contraindications to ECMO

Relative Contraindications

- High-pressure ventilation (peak inspiratory pressure > 30 cm of water) for > 7 days
- High FIO2 requirements (> 0.8) for > 7 days
- Limited vascular access
- Refusal to accept blood products
- Any condition or organ dysfunction that would limit the likelihood of overall benefit from ECMO such as severe, irreversible brain injury or untreatable metastatic cancer

Absolute Contraindications

- Contraindication to anticoagulation
- ECMO as bridge to lung transplantation if transplantation will not be considered

[1] New York Presbyterian Center for Acute Respiratory Failure [Internet]. New York, NY: New York-Presbyterian/Allen Hospital; 2016 [cited 2016 Jun 9]. Available from: http://nyp.org/services/carf/for-physicians/indications-for-ecmo.html.

ECMO = extracorporeal membrane oxygenation; PEEP = positive end-expiratory pressure.

Disclosure Statement

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A Discipline

Medicine is a discipline, in which the effort is made to use knowledge procured in various ways in order to effect certain practical ends. … It harbors no preconceptions as to diseases or their cure. … It has progressively become less cocksure and more modest. It distrusts general propositions, a priori explanations, grandiose and comforting generalizations. It needs theories only as convenient summaries in which a number of ascertained facts may be used tentatively to define a course of action. It makes no effort to use its discoveries to substantiate a principle formulated before the facts were even suspected.

— Abraham Flexner, 1866-1959, American educator,
reformer of medical and higher education in the US and Canada