Case Reports

Emergent Surgical Pulmonary Embolectomy in a Pregnant Woman:

Case Report and Literature Review

Giovanni Saeed, MD
Michael Möller, MD
Jörg Neuzner, MD, PhD
Rainer Gradaus, MD, PhD
Werner Stein, MD
Uwe Langebrake, MD
Thomas Dimpfl, MD, PhD
Meradjoddin Matin, MD
Ali Peivandi, MD, PhD

Acute pulmonary embolism is a leading cause of death during pregnancy and delivery in the United States. We describe the case of a 25-year-old woman who presented in cardiogenic shock in week 38 of her first pregnancy. After the emergent cesarean delivery of a healthy male neonate, the mother underwent immediate surgical pulmonary embolectomy. We confirmed the diagnosis of pulmonary embolism intraoperatively by means of transesophageal echocardiography and removed large clots from the patient's pulmonary arteries. Mother and child were doing well, 27 months later. In addition to presenting our patient's case, we discuss the other relevant reports and the options for treating massive pulmonary embolism during pregnancy. ***(Tex Heart Inst J 2014;41(2):188-94)***

Key words: *Cesarean section; embolectomy/methods; pregnancy complications, cardiovascular/diagnosis/surgery; pregnancy outcome; pregnancy trimester, third; pulmonary embolism/complications/surgery; risk assessment; thrombosis/surgery; treatment outcome; ventricular dysfunction, right/etiology*

From: *Departments of Cardiovascular Surgery (Drs. Matin, Peivandi, and Saeed), Internal Medicine II and Cardiology (Drs. Gradaus, Möller, and Neuzner), Gynecology and Obstetrics (Drs. Dimpfl and Stein), and Anesthesiology and Intensive Care Medicine (Dr. Langebrake), Klinikum Kassel GmbH, 34125 Kassel, Germany*

Address for reprints: *Giovanni Saeed, MD, Untere Königsstraße 50, D-34117 Kassel, Germany*

E-mail: *dr.gsaeed@web.de*

The prevalence of pulmonary embolism (PE) in pregnant women is 5 times greater than that in nonpregnant women.[1,2] Pooled data from 1991 through 1999 reveal that PE accounted for 20% of maternal deaths in the United States[3,4]—more than for hemorrhage (17%) or pregnancy-induced hypertension (16%).[4] The optimal management of acute PE during pregnancy, especially in the presence of unstable cardiopulmonary status, is challenging and poses severe risks for the mother and fetus.[1] Options include anticoagulation with heparin, thrombolytic therapy, transcatheter embolectomy, and surgical pulmonary embolectomy (SPE).[5,6] Earlier, SPE was considered to be the "last resort" because of the accompanying high mortality rates.[7] However, reports since 2005 suggest that a more aggressive strategy, involving a multidisciplinary approach, prompt diagnosis, and operative intervention, leads to better outcomes in patients with acute PE.[8-15] Surgical pulmonary embolectomy has undergone a resurgence after having been largely discarded except in cases of cardiogenic shock or cardiopulmonary resuscitation.[16] We report what to our knowledge is the 13th case of SPE in a pregnant woman.

Case Report

In December 2011, a 25-year-old woman at week 38 in her first pregnancy was hospitalized because of knee joint luxation after a fall at home. She had undergone open knee-joint repositioning and stabilization with a splint. Postoperatively, she developed sudden dyspnea, tachycardia, intermittent hypotensive episodes, nausea, and vomiting. This raised a suspicion of PE and inferior vena cava compression syndrome, and she was referred to our hospital. Upon admission, her clinical cardiopulmonary status was stable. Her personal and family medical histories were not contributory. Abnormal laboratory findings were high levels of D-dimer, creatine kinase and its MB isoenzyme, cardiac troponin I, and B-type natriuretic peptide (BNP), which suggested myocardial injury and dysfunction. A transthoracic echocardiogram (TTE) showed a markedly dilated, hypocontractile right ventricle (RV) (Fig. 1), pulmonary hypertension, mild-to-moderate tricuspid valve insufficiency, a small left ventricular cavity, and paradoxical interventricular septal movement (Fig. 2). The TTE also showed distinct hypokinesia of the mid-free wall of the RV but normal motion of the apex. Thromboembolic clots were not directly observed. An electrocardiogram revealed evident signs of RV strain. Doppler ultrasonographic images of the lower extremities neither confirmed nor excluded deep vein thrombosis. Cardiac tocography yielded normal results, and the fetus was vital. Chest computed tomographic (CT)

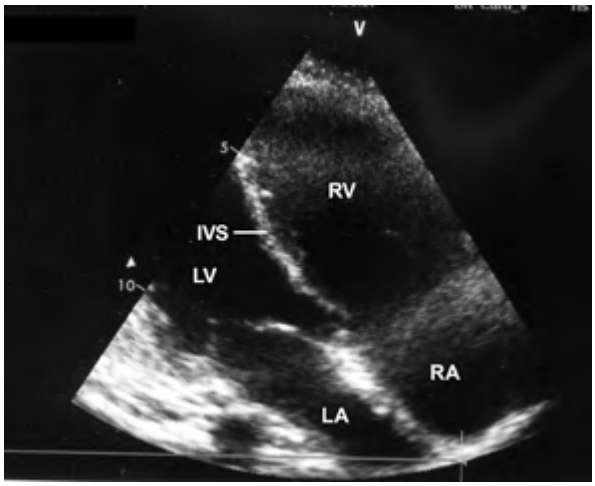

Fig. 1 *Preoperative transthoracic echocardiogram (modified 3-chamber view) shows a markedly dilated, hypocontractile right ventricle and billowing of the interventricular septum into the left ventricle.*

IVS = interventricular septum; LA = left atrium, LV = left ventricle; RA = right atrium; RV = right ventricle

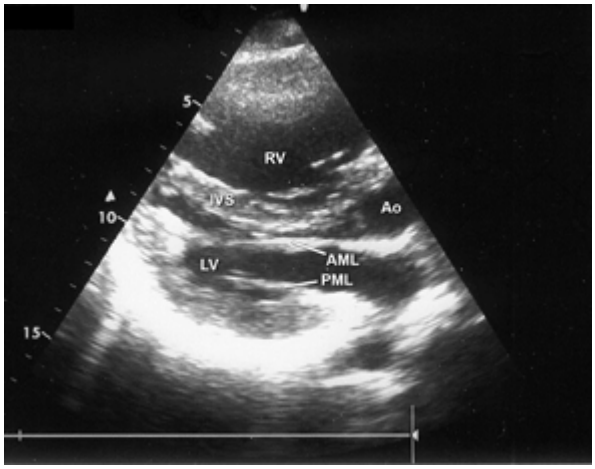

Fig. 2 *Preoperative transthoracic echocardiogram (left parasternal long-axis view) shows deviation of the interventricular septum toward the left ventricle and its small cavity.*

AML = anterior mitral leaflet; Ao = aorta; IVS = interventricular septum; LV = left ventricle; PML = posterior mitral leaflet; RV = right ventricle

and ventilation/perfusion (V/Q) scans of the lungs were intentionally not performed, because of the hazards of ionizing radiation.

The diagnosis of submassive PE was presumed. Heparin was administered as a 5,000-U bolus and then by continuous intravenous infusion. The patient was transferred to the intensive care unit for monitoring. Ten hours after admission, her clinical condition worsened to circulatory collapse with severe respiratory insufficiency, hypoxemia, and cyanosis. Tracheal intubation and mechanical ventilation were promptly initiated. Further circulatory support with catecholamines was necessary. We decided to deliver the infant emergently through a cesarean section and to subsequently perform SPE with the mother under cardiopulmonary bypass (CPB). An intraoperative transesophageal echocardiogram (TEE) confirmed the paradoxical interventricular septal movement, the severely dilated and poorly contractile RV, and tricuspid annular dilation with mild-to-moderate valvular insufficiency. The obstetrics team performed the cesarean delivery of a healthy male neonate. Immediately thereafter, TEE showed a sudden and subtotal occlusion of the mother's main pulmonary artery (PA) by thromboembolic material (Fig. 3). Median sternotomy with aortic and bicaval cannulation was performed, and CPB with mild hypothermia and crystalloid cardioplegic arrest was started. We made bilateral horizontal incisions in the branch PAs. The left PA was occluded with thrombus, and approximately three quarters of the lumen of the right PA was occluded, up to the segmental arteries. We used forceps and suction to remove all the clots (Fig. 4). We removed the clots in the main PA (which we did not open) by means of suction and with use of angulated forceps through the incisions in the branch PAs. The patient was uneventfully weaned from CPB, and her postoperative course was uncomplicated. As of March 2014, she and her child were doing well, and no recurrent PE was detected.

Discussion

The prevalence of PE during pregnancy—0.3 to 3 per 1,000 pregnant women—is 5 times greater than that in nonpregnant women.[2,6,17] During pregnancy, the 3 elements of Virchow for deep vein thrombosis and

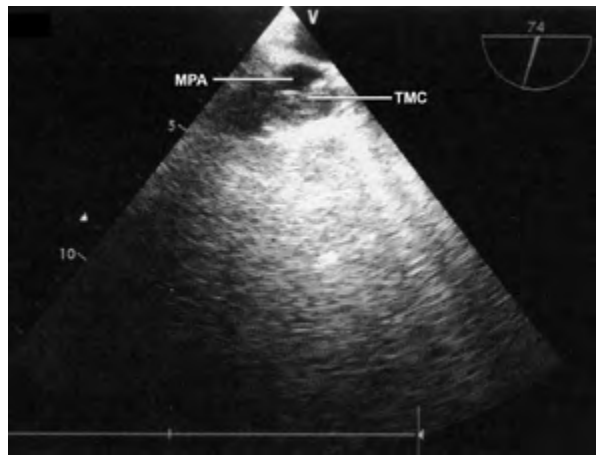

Fig. 3 *Intraoperative transesophageal echocardiogram immediately after cesarean delivery shows subtotal thrombotic occlusion of the mother's main pulmonary artery.*

MPA = main pulmonary artery; TMC = thrombotic clots

Fig. 4 *Photograph shows thrombotic clots removed from the main and branch pulmonary arteries.*

thromboembolic sequelae can occur: hypercoagulability, venous stasis, and vascular damage.[5,6,18,19]

To avoid negative consequences for the pregnant woman and fetus, an early and correct diagnosis of PE is crucial.[1,19] Diagnostic tests include chest radiography, V/Q imaging, spiral computed tomography, and pulmonary angiography.[1,17] The guidelines of the European Society of Cardiology for the diagnosis and management of acute PE state that these tests can be completed safely, because they fall below the minimum radiation dose of 50 mSv (50,000 μGy) that could harm the fetus.[17]

Both TTE and TEE are valuable in the diagnosis of PE.[5,8-10,12,13,20,21] Echocardiograms can show direct views of central thromboemboli and provide indirect evidence of PA obstruction and RV pressure overload, such as RV dysfunction, tricuspid regurgitation, leftward bowing of the interatrial septum, and systolic flattening of the interventricular septum.[17,20,21] Echocardiograms can reveal moderate or severe RV free-wall hypokinesia with preserved apical contractility (the McConnell sign) as indirect evidence of acute PE.[17,20,21] Although D-dimer levels naturally rise during pregnancy, substantial increases have been observed in pregnant women with ongoing thrombosis.[1,17] High levels of BNP and N-terminal pro-BNP biomarkers have been associated with RV dysfunction in patients with acute PE and are significant predictors of all-cause in-hospital or short-term death.[22]

Treating Acute Massive Pulmonary Embolism. Heparin anticoagulation, thrombolytic therapy, transcatheter embolectomy, catheter-directed thrombolytic therapy, and SPE are possible treatments for acute massive PE during pregnancy.[5,6,9,10,18,19,23] Heparin anticoagulation is the chief therapy.[17,23] Either unfractionated or low-molecular-weight heparin is safe in pregnant women, because neither substance crosses the placenta or is found in breast milk in significant amounts.[17,23]

Literature Review. Our review of the English-language medical literature from 1970 through 2012 yielded 12 other case reports that described SPE for massive PE during pregnancy.[6,18,24-33] Table I summarizes the clinical characteristics, presenting symptoms and signs, diagnostic methods, clinical courses, indications for SPE, and fetal and maternal outcomes.

In all 13 patients, (age range, 21–39 yr), the clinical manifestation of PE was not dominated by one symptom or sign, but rather by combinations. The most frequent presentations were respiratory and cardiac: dyspnea in 9 patients, tachycardia in 5, cyanosis in 4, tachypnea in 4, hypoxemia in 2, acute respiratory distress in 1, and palpitations in 1. Heparin at therapeutic doses in 9 patients was insufficient to resolve their unstable hemodynamic conditions. In all 13 patients, SPE was indicated because of rapidly worsening hemodynamic status and the onset of cardiogenic shock. Cardiopulmonary resuscitation was necessary in 2 patients.[30,31] All patients underwent CPB: ours and one other[6] with cardioplegic arrest, and 2 others without it.[32,33] No data were available about cardioplegic arrest in the other 9 cases. The thrombi were removed through an opening in the main PA in all patients but ours. Two maternal deaths[28,31] and 3 fetal deaths[24,26,31] occurred, constituting a 15.4% maternal mortality rate and a 23% fetal mortality rate.

Thrombolytic Therapy. According to data from a meta-analysis of 11 randomized controlled trials,[34] thrombolytic therapy was no more beneficial than heparin in the initial treatment of unselected patients with acute PE. However, thrombolysis was advised in patients who were at highest risk of recurrent PE or death. Although single case reports have documented successful thrombolysis for massive PE in pregnant women,[5,17,19,23] no prospective randomized studies have been conducted to evaluate the efficacy and safety of thrombolytic agents during pregnancy.

Because of the risk of bleeding, thrombolytic agents are not for routine use and should be reserved for pregnant women who are hemodynamically unstable, particularly those with systemic hypotension.[5,17,19,23] With urokinase therapy, there is a risk of bleeding, teratogenicity, and premature abruption of the placenta.[5] In 2009, te Raa and colleagues[35] successfully treated massive PE with streptokinase after intravenous heparin therapy failed, in a 34-year-old woman who had a compromised hemodynamic status, hypoxemia, tachypnea, and tachycardia at 25 weeks of pregnancy. The streptokinase therapy enabled rapid improvement, and she delivered a healthy child at term. In their literature review, those authors found 13 patients who had undergone thrombolysis for PE during pregnancy. The outcomes included no maternal deaths, 4 nonfatal maternal major bleeding sequelae, 2 fetal deaths, and 5 preterm deliveries.[35] Another success was achieved with recombinant

TABLE I. Cases of Massive Pulmonary Embolism in Pregnancy with Treatment by Surgical Pulmonary Embolectomy

Reference	Age of Mother (yr)	Weeks of Gestation	Clinical Presentation	Associated Morbidity	Diagnostic Method
Marcinkevicius A, et al.[24] (1970)	30	24	Unconsciousness, deep cyanosis, tachycardia, tachypnea, and left-leg swelling	No	ECG, chest radiography, and clinical suspicion
Cohn LH and Shumway NE[25] (1973)	21	First trimester	Dyspnea, pleuritic chest pain, and weakness	No	ECG, PA, right-sided heart catheterization, and chest radiography
Duff P and Greene VP[26] (1985)	35	13	Diaphoresis, disorientation, tachypnea, and hypotension	Pancreatic neoplasm	PA
Richards SR, et al.[27] (1985)	25	35	Acute respiratory distress, substernal chest pain, and active labor hypoxemia	No	Clinical suspicion, ECG, BGA, and V/Q scan
Girz BA and Heiselman DE[28] (1988)	31	29	Dyspnea, hypoxia, hypotension, and fetal bradycardia	No	PA
Blegvad S, et al.[29] (1989)	26	28	Dyspnea, palpitations, syncope, chest pain, and cyanosis	No	Right-sided heart catheterization, PA, ECG, and clinical suspicion
Splinter WM, et al.[30] (1989)	27	32	Syncope, tachypnea, cyanosis, tachycardia, and fetal bradycardia	No	V/Q scan
Lau G[31] (1994)	33	8	Left-calf pain and swelling, sudden collapse, and cardiac arrest	DIC	Clinical suspicion and TTE
Woodward DK, et al.[32] (1998)	25	38	Sudden dyspnea, chest tightness, dizziness, cyanosis, tachycardia, and tachypnea	Thrombocyto-penia	Clinical suspicion, ECG, and PA
Funakoshi Y, et al.[18] (2004)	32	38	Dyspnea and swelling of legs	Protein S deficiency and PFO	Chest CT and TEE
Taniguchi S, et al.[33] (2008)	35	18	Dyspnea, tachypnea, tachycardia, and hypoxemia	HIT, anemia, and myelodysplastic syndrome	Chest CT
Hajj-Chahine J, et al.[6] (2010)	39	25	Threatened premature labor, severe dyspnea, and ARDS	HIT and previous history of PE	TEE
Current case	25	38	Dyspnea, intermittent hypotensive episodes, vomiting, nausea, and tachycardia	No	Clinical suspicion, laboratory findings, TTE, and TEE

ARDS = acute respiratory distress syndrome; BGA = blood-gas analysis; CPR = cardiopulmonary resuscitation; CT = computed tomography; DIC = disseminated intravascular coagulopathy; ECG = electrocardiography; HIT = heparin-induced thrombocytopenia; IVC = inferior vena cava; NA = not applicable; NS = not specified; PA = pulmonary angiography; PE = pulmonary embolism; PFO = patent foramen ovale; Postop = postoperative; preop = preoperative; SPE = surgical pulmonary embolectomy; TEE = transesophageal echocardiography; TTE = transthoracic echocardiography; V/Q = ventilation/perfusion

TABLE I (continued). Cases of Massive Pulmonary Embolism in Pregnancy with Treatment by Surgical Pulmonary Embolectomy

Reference	Survival of Mother	Survival of Fetus	Type of Delivery	Initial Heparin Therapy	Indication for SPE	Cardioplegic Arrest	IVC Filter	Postop Follow-Up
Marcinkevicius A, et al.[24] (1970)	Yes	No	Extraction of fetus	Yes	Shock	NS	No; caval ligation	6 mo
Cohn LH and Shumway NE[25] (1973)	Yes	Yes	Abdominal, at term	Yes	Shock	NS	No; partial caval interruption	12 mo
Duff P and Greene VP[26] (1985)	Yes	No	Spontaneous abortion	Yes	Shock	NS	No	NS
Richards SR, et al.[27] (1985)	Yes	Yes	Abdominal, at term	Yes	Shock	NS	No	NS
Girz BA and Heiselman DE[28] (1988)	No	Yes	Cesarean	No	Shock	NS	No	NA
Blegvad S, et al.[29] (1989)	Yes	Yes	Abdominal, at term	No	Shock	NS	No	4 mo
Splinter WM, et al.[30] (1989)	Yes	Yes	Cesarean	Yes	Shock and CPR	NS	No	NS
Lau G[31] (1994)	No	No	Extraction of fetus	NS	CPR and shock	NS	No	NA
Woodward DK, et al.[32] (1998)	Yes	Yes	Cesarean	Yes	Shock	No	Yes (temporary); was removed on postop day 10	10 d
Funakoshi Y, et al.[18] (2004)	Yes	Yes	Cesarean	No	Shock	NS	Temporary; caval ligation	54 mo
Taniguchi S, et al.[33] (2008)	Yes	Yes	Cesarean	Yes	Shock	No	Yes (preop)	NS
Hajj-Chahine J, et al.[6] (2010)	Yes	Yes	Abdominal, at term	Yes	Shock	Yes	No	NS
Current case	Yes	Yes	Cesarean	Yes	Shock	Yes	No	27 mo

ARDS = acute respiratory distress syndrome; BGA = blood-gas analysis; CPR = cardiopulmonary resuscitation; CT = computed tomography; DIC = disseminated intravascular coagulopathy; ECG = electrocardiography; HIT = heparin-induced thrombocytopenia; IVC = inferior vena cava; NA = not applicable; NS = not specified; PA = pulmonary angiography; PE = pulmonary embolism; PFO = patent foramen ovale; Postop = postoperative; preop = preoperative; SPE = surgical pulmonary embolectomy; TEE = transesophageal echocardiography; TTE = transthoracic echocardiography; V/Q = ventilation/perfusion

tissue plasminogen activator (rtPA) in a 26-year-old woman at 24 weeks.[36] The authors found 18 reports of thrombolysis in pregnant women with PE: 10 patients were given rtPA, 6 streptokinase, and 2 urokinase, with beneficial maternal and fetal effects in terms of mortality and complication rates and with acceptable bleeding risks. Major nonfatal bleeding was observed in 4 streptokinase patients. Two patients on rtPA therapy and 3 on streptokinase delivered preterm. The 2 fetal deaths, 1 each in the streptokinase and rtPA groups, were not attributed to fetal hemorrhage.[36]

Catheter-Directed Thrombolytic Therapy. Few reports are available about the successful use of catheter-directed thrombolysis, either alone or with thromboembolic mechanical fragmentation, in treating massive PE peripartum or postpartum.[37-40] Catheter-directed thrombolytic therapy affords potential advantages, such as more rapid clot lysis with consequent improvement in pulmonary blood flow, normalization of hemodynamic status, uterine perfusion, and lower risk of bleeding; however, no clear or strong evidence supports the superiority of local catheter-directed thrombolysis over systemic thrombolysis or heparin anticoagulation.[40]

Transcatheter Thrombectomy. Sato and colleagues[5] reported successful emergent transcatheter thrombectomy for massive PE in a hemodynamically unstable patient after emergent cesarean delivery at 30 weeks, followed by the intravenous administration of heparin and urokinase therapy for 2 weeks.[5] However, transcatheter thrombectomy can fragment the embolic material, which can then propagate into the peripheral pulmonary vasculature and increase the risk of pulmonary hypertension.[13]

Insertion of an Inferior Vena Cava Filter. The indication for inferior vena cava filter placement during pregnancy is the same as in nonpregnant patients.[23] In 1981, Scurr and colleagues[41] reported the first successful use of a filter in a pregnant woman. In 1986, Hux and associates[42] reported good maternal and fetal outcomes after Greenfield filter placement in 6 pregnant patients with thromboembolic disease. In 1997, Thomas and co-authors[43] described good outcomes in 8 pregnant patients after Greenfield filters were prophylactically inserted because of a high risk of PE. Instead of a permanent filter, a retrievable filter—removable within 10 days—might protect the patient in the high-risk period during and after the acute event.[22]

Conclusion

Cooley and colleagues, who in 1961 first used temporary CPB when surgically treating massive PE in a 37-year-old woman after her pelvic surgery, said, "an aggressive attitude toward treatment of these cases should permit the saving of many patients who otherwise are doomed."[44] This aggressive attitude, in diagnosis and treatment, should be applied to every patient who presents with signs and symptoms of life-threatening massive PE.

Acknowledgment

The authors are honored to acknowledge Dr. Denton A. Cooley, a living legend and pioneering cardiac surgeon with 70 years of unprecedented contributions to humanity and patients with heart disease.

References

1. Matthews S. Short communication: imaging pulmonary embolism in pregnancy: what is the most appropriate imaging protocol? Br J Radiol 2006;79(941):441-4.
2. Pabinger I, Grafenhofer H. Thrombosis during pregnancy: risk factors, diagnosis and treatment. Pathophysiol Haemost Thromb 2002;32(5-6):322-4.
3. Leung AN, Bull TM, Jaeschke R, Lockwood CJ, Boiselle PM, Hurwitz LM, et al. American Thoracic Society documents: an official American Thoracic Society/Society of Thoracic Radiology clinical practice guideline--evaluation of suspected pulmonary embolism in pregnancy. Radiology 2012;262(2): 635-46.
4. Chang J, Elam-Evans LD, Berg CJ, Herndon J, Flowers L, Seed KA, Syverson CJ. Pregnancy-related mortality surveillance--United States, 1991--1999. MMWR Surveill Summ 2003;52(2):1-8.
5. Sato T, Kobatake R, Yoshioka R, Fuke S, Ikeda T, Saito H, et al. Massive pulmonary thromboembolism in pregnancy rescued using transcatheter thrombectomy. Int Heart J 2007; 48(2):269-76.
6. Hajj-Chahine J, Jayle C, Tomasi J, Corbi P. Successful surgical management of massive pulmonary embolism during the second trimester in a parturient with heparin-induced thrombocytopenia. Interact Cardiovasc Thorac Surg 2010;11 (5):679-81.
7. Meyer G, Tamisier D, Sors H, Stern M, Vouhe P, Makowski S, et al. Pulmonary embolectomy: a 20-year experience at one center. Ann Thorac Surg 1991;51(2):232-6.
8. Fukuda I, Taniguchi S, Fukui K, Minakawa M, Daitoku K, Suzuki Y. Improved outcome of surgical pulmonary embolectomy by aggressive intervention for critically ill patients. Ann Thorac Surg 2011;91(3):728-32.
9. Sareyyupoglu B, Greason KL, Suri RM, Keegan MT, Dearani JA, Sundt TM 3rd. A more aggressive approach to emergency embolectomy for acute pulmonary embolism. Mayo Clin Proc 2010;85(9):785-90.
10. Kadner A, Schmidli J, Schonhoff F, Krahenbuhl E, Immer F, Carrel T, Eckstein F. Excellent outcome after surgical treatment of massive pulmonary embolism in critically ill patients. J Thorac Cardiovasc Surg 2008;136(2):448-51.
11. Amirghofran AA, Emami Nia A, Javan R. Surgical embolectomy in acute massive pulmonary embolism. Asian Cardiovasc Thorac Ann 2007;15(2):149-53.
12. Leacche M, Unic D, Goldhaber SZ, Rawn JD, Aranki SF, Couper GS, et al. Modern surgical treatment of massive pulmonary embolism: results in 47 consecutive patients after rapid diagnosis and aggressive surgical approach. J Thorac Cardiovasc Surg 2005;129(5):1018-23.
13. Dauphine C, Omari B. Pulmonary embolectomy for acute massive pulmonary embolism. Ann Thorac Surg 2005;79(4): 1240-4.

14. Vohra HA, Whistance RN, Mattam K, Kaarne M, Haw MP, Barlow CW, et al. Early and late clinical outcomes of pulmonary embolectomy for acute massive pulmonary embolism. Ann Thorac Surg 2010;90(6):1747-52.
15. Konstantinov IE, Saxena P, Koniuszko MD, Alvarez J, Newman MA. Acute massive pulmonary embolism with cardiopulmonary resuscitation: management and results. Tex Heart Inst J 2007;34(1):41-6.
16. Goldhaber SZ. Surgical pulmonary embolectomy: the resurrection of an almost discarded operation. Tex Heart Inst J 2013;40(1):5-8.
17. Torbicki A, Perrier A, Konstantinides S, Agnelli G, Galie N, Pruszczyk P, et al. Guidelines on the diagnosis and management of acute pulmonary embolism: the Task Force for the Diagnosis and Management of Acute Pulmonary Embolism of the European Society of Cardiology (ESC). Eur Heart J 2008;29(18):2276-315.
18. Funakoshi Y, Kato M, Kuratani T, Shigemura N, Kaneko M. Successful treatment of massive pulmonary embolism in the 38th week of pregnancy. Ann Thorac Surg 2004;77(2):694-5.
19. de Swiet M. Management of pulmonary embolus in pregnancy. Eur Heart J 1999;20(19):1378-85.
20. Rosenberger P, Shernan SK, Body SC, Eltzschig HK. Utility of intraoperative transesophageal echocardiography for diagnosis of pulmonary embolism. Anesth Analg 2004;99(1):12-6.
21. Torbicki A. Echocardiographic diagnosis of pulmonary embolism: a rise and fall of McConnell sign? Eur J Echocardiogr 2005;6(1):2-3.
22. Cavallazzi R, Nair A, Vasu T, Marik PE. Natriuretic peptides in acute pulmonary embolism: a systematic review. Intensive Care Med 2008;34(12):2147-56.
23. Ahearn GS, Hadjiliadis D, Govert JA, Tapson VF. Massive pulmonary embolism during pregnancy successfully treated with recombinant tissue plasminogen activator: a case report and review of treatment options. Arch Intern Med 2002;162(11):1221-7.
24. Marcinkevicius A, Sirvydis V, Triponis V, Baublys A, Martinkenas G, Matulionis A. Pulmonary embolectomy during pregnancy. J Cardiovasc Surg (Torino) 1970;11(5):355-8.
25. Cohn LH, Shumway NE. Pulmonary embolectomy during pregnancy. Arch Surg 1973;106(2):214-5.
26. Duff P, Greene VP. Pregnancy complicated by solid-papillary epithelial tumor of the pancreas, pulmonary embolism, and pulmonary embolectomy. Am J Obstet Gynecol 1985;152(1):80-1.
27. Richards SR, Barrows H, O'Shaughnessy R. Intrapartum pulmonary embolus. A case report. J Reprod Med 1985;30(1):64-6.
28. Girz BA, Heiselman DE. Fatal intrapartum pulmonary embolus during tocolysis. Am J Obstet Gynecol 1988;158(1):145-6.
29. Blegvad S, Lund O, Nielsen TT, Guldholt I. Emergency embolectomy in a patient with massive pulmonary embolism during second trimester pregnancy. Acta Obstet Gynecol Scand 1989;68(3):267-70.
30. Splinter WM, Dwane PD, Wigle RD, McGrath MJ. Anaesthetic management of emergency caesarean section followed by pulmonary embolectomy. Can J Anaesth 1989;36(6):689-92.
31. Lau G. A case of sudden maternal death associated with resuscitative liver injury. Forensic Sci Int 1994;67(2):127-32.
32. Woodward DK, Birks RJ, Granger KA. Massive pulmonary embolism in late pregnancy. Can J Anaesth 1998;45(9):888-92.
33. Taniguchi S, Fukuda I, Minakawa M, Watanabe K, Daitoku K, Suzuki Y. Emergency pulmonary embolectomy during the second trimester of pregnancy: report of a case. Surg Today 2008;38(1):59-61.
34. Wan S, Quinlan DJ, Agnelli G, Eikelboom JW. Thrombolysis compared with heparin for the initial treatment of pulmonary embolism: a meta-analysis of the randomized controlled trials. Circulation 2004;110(6):744-9.
35. te Raa GD, Ribbert LS, Snijder RJ, Biesma DH. Treatment options in massive pulmonary embolism during pregnancy; a case-report and review of literature. Thromb Res 2009;124(1):1-5.
36. Fasullo S, Maringhini G, Terrazzino G, Ganci F, Paterna S, Di Pasquale P. Thrombolysis for massive pulmonary embolism in pregnancy: a case report. Int J Emerg Med 2011;4:69.
37. Weinberg L, Kay C, Liskaser F, Jones D, Tay S, Jaffe S, et al. Successful treatment of peripartum massive pulmonary embolism with extracorporeal membrane oxygenation and catheter-directed pulmonary thrombolytic therapy. Anaesth Intensive Care 2011;39(3):486-91.
38. O'Keeffe SA, McGrath A, Ryan JM, Byrne B. Management of a massive pulmonary embolism in a pregnant patient with mechanical fragmentation followed by delayed catheter-directed thrombolysis in the early postpartum period. J Matern Fetal Neonatal Med 2008;21(8):591-4.
39. Bechtel JJ, Mountford MC, Ellinwood WE. Massive pulmonary embolism in pregnancy treated with catheter fragmentation and local thrombolysis. Obstet Gynecol 2005;106(5 Pt 2):1158-60.
40. Krishnamurthy P, Martin CB, Kay HH, Diesner J, Friday RO, Weber CA, Droste S. Catheter-directed thrombolysis for thromboembolic disease during pregnancy: a viable option. J Matern Fetal Med 1999;8(1):24-7.
41. Scurr J, Stannard P, Wright J. Extensive thrombo-embolic disease in pregnancy treated with a Kimray Greenfield vena cava filter. Case report. Br J Obstet Gynaecol 1981;88(7):778-80.
42. Hux CH, Wapner RJ, Chayen B, Rattan P, Jarrell B, Greenfield L. Use of the Greenfield filter for thromboembolic disease in pregnancy. Am J Obstet Gynecol 1986;155(4):734-7.
43. Thomas LA, Summers RR, Cardwell MS. Use of Greenfield filters in pregnant women at risk for pulmonary embolism. South Med J 1997;90(2):215-7.
44. Cooley DA, Beall AC Jr, Alexander JK. Acute massive pulmonary embolism. Successful surgical treatment using temporary cardiopulmonary bypass. JAMA 1961;177(5):283-6.