Extracorporeal Cardiopulmonary Resuscitation Treatment of Cardiac Arrest during Pregnancy: Case Report and Mini-review

Fei Lin[1], Yong Cao[1], Ting Fan[1], Qingping Xia[1], Li Deng[1], Minghai Xian[1], Youkuan He[1], Huajian Peng[1], and Haijie He[2]

[1]The People's Hospital of Gaozhou
[2]The Peoples' Hospital of Gaozhou

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Abstract

This paper presents a pregnant woman successfully rescued in cardiac arrest (CA) using extracorporeal cardiopulmonary resuscitation (ECPR) for up to 5.5 hours. We reviewed the literature on the use of ECPR during pregnancy. Published data suggest that extracorporeal membrane oxygenation (ECMO) appears to be a viable treatment option for pregnant women who have experienced critical situations, such as a maternal CA or an amniotic fluid embolism.

1. Introduction

Cardiac arrest (CA) in pregnant women is a rare event with an incidence of approximately 1 in 12,000 cases; however, the mortality rate is exceptionally high, and it represents an urgent problem in obstetrics and gynecology.[1] Maternal CA can occur during the perinatal or postpartum periods of pregnancy. CA's leading causes are massive hemorrhage, amniotic fluid embolism, acute pulmonary embolism (PE), heart failure, and anesthesia-related complications.[2, 3] When CA occurs, rapid intervention and high-quality cardiopulmonary resuscitation (CPR) are the basic rescue measures.[4, 5] However, in about one-third of pregnant women, basic life support is ineffective or the restoration of spontaneous circulation (ROSC) is not achieved.[6] When such circumstances arise, extracorporeal membrane oxygenation (ECMO) should be considered to gain treatment time.[7, 8]

As a "bridge," ECMO is a convenient technology that can quickly establish and provide effective cardiopulmonary support.[9] ECMO plays an essential role in the field of refractory CA.[10, 11] There are few reports on ECMO use in pregnant women who have experienced CA, and even fewer reports on the long-term effects of extracorporeal cardiopulmonary resuscitation (ECPR) rescue of pregnant women. This paper presents a case study of a pregnant woman who underwent CPR for an extended period, but after no response, it was administered ECPR, which successfully resuscitated her (the patient's family's informed consent was obtained). It also reviews 9 cases of pregnant women who were resuscitated via ECPR after CA. The effects of ECPR in critically pregnant women are summarized, and suggestions for clinical treatment are provided.

2. Case presentation

A 31-year-old woman (weight 41 kg, gravida 6,para 1, G6P1) was admitted to a local hospital on May 25, 2019. At admission, the woman was 34 weeks pregnant, and had a temperature of 37.4. An electrocardiogram showed sinus tachycardia. The patient had a heart rate (HR) of 114 beats/min and her blood pressure (BP) was 103/53 mm Hg. Two days after admission, the pregnant woman developed shortness of breath (breathing rate: 30 beats/min), accompanied by a cough with sputum and oxygen saturation (SPO2) of 88.0%. After oxygen inhalation treatment, the patient's SPO2 was 93%. However, her shortness of breath did not improve. At 6:20 PM on May 28, 2019, the pregnant woman's condition deteriorated, and she was placed in a semi recumbent position. She was treated with continuous high-flow oxygen inhalation. Mild cyanosis was observed on her lips. An examination showed reduced breathing sounds in the lungs, an HR of 106 beats/min and a BP of 105 /64 mmHg, while irregular uterine contractions were observed on the fetal monitor. Based on these symptoms, the patient was diagnosed with cardiac dysfunction.

At 7:30 PM, maternal–fetal HR monitoring showed late deceleration, and fetal distress was considered. To rescue the fetus, the pregnant woman signed and agreed to undergo a cesarean section. The baby had an appearance, pulse, grimace, activity, and respiration (APGAR) score of 8 one minute after delivery, and a score of ten some 5 minutes later. After the operation, the patient was sent to the intensive care unit (ICU) for treatment. In the ICU, the patient experienced hypoxia and hypotension. The patient received mechanical ventilation and vasoactive drugs to maintain BP. A large amount of pink foamy sputum was present during sputum suction. and acute heart failure was considered. The cardiac color Doppler ultrasound examination results revealed left heart enlargement, left ventricular systolic insufficiency, moderate mitral valve insufficiency, and an ejection fraction (EF) of 43%, but showed no right heart dilation or pulmonary artery blood clots.

At 7:25 AM on May 30, 2019, the patient experienced CA. In an early stage of resuscitation, the patient had repeated ventricular pulseless electrical activities. Throughout 2 hours of CPR, after repeated electrical defibrillation, an intravenous injection of epinephrine, lidocaine, and atropine, and volume expansion therapy, ROSC could not be achieved. As an ECMO machine was not available at the hospital or anywhere nearby, the doctor contacted our ECMO team and requested an emergency rescue. The distance between the 2 hospitals was more than 100 kilometers. Our ECMO team assembled immediately after receiving the request and arrived at the patient's hospital in approximately 2 hours.

The ECMO procedure was initiated immediately after the patient's family signed an informed consent form. CPR was continued, a cannulation via the femoral vessels was performed (using a 17 Fr arterial cannula and 19 Fr venous cannula; Medtronic, USA),and a 7Fr distal perfusion cannula (DPC) was placed. After 42 minutes, with the help of our ECMO center team,ECMO was carried out and the initial blood flows were set to 3 L/min. CPR has been carried out for five hours. The patient resumed ROSC about 30 minutes after starting the ECMO treatment and had an invasive BP of 79/77 mmHg. An analysis of the patient's blood gas (BG) showed that the patient had a pH of 7.38, Base excess(BE) of 5.1 mmol/L, Bicarbonate standard($HC03^{-}$std) of 28.7 mmol/L, Bicarbonate($HC03^{-}$) of 30.2 mmol/L, and lactate(Lac) $>$ 15 mmol/L. A cardiac color Doppler ultrasound showed that her left ventricular ejection fraction (LVEF) was 16%, which indicated that the patient had developed severe cardiac dysfunction. A right femoral artery intra-aortic balloon pump (IABP) was placed to aid heart function. A continuous renal replacement therapy circuit was connected to the ECMO treatment to adjust the internal environment. Heparin was used for systemic anticoagulation to prevent thrombosis. Figure 1–2 shows the patient's cardiac ultrasound results at different stages of treatment.

Due to the patient's unstable condition, her family did not agree to her being transferred to our hospital. Thus, the patient continued to be treated at the hospital to which she had been admitted. On May 31, the patient showed an eye-opening reaction. A neurological assessment reveled that both sides of her pupils were equal in size and sensitive to light reflection; the patient nodded to calls. Based on these reactions, the patient was thought to be recovering consciousness. However, when the sedative was stopped on June 5, the patient was in a coma and was suspected of having brain complications. Concerned about the risks associated with patient in-hospital transfer and due to inexperience, the medical staff failed to reach a consensus on whether emergency cranial computerized tomography (CT) scans should be taken. During the following days of treatment, the patient's heart function recovered. On June 8, the patient's left ventricular function improved and her LVEF was 35%. She had an invasive BP of 100/77 mmHg, and her BG results were satisfactory. Based on the above evaluation results, ECMO treatment was withdrawn on the ninth day.

After the ECMO treatment was withdrawn, the patient's pupils were conspicuously unequal in size. An urgent cranial CT scan showed an intracranial hemorrhage (ICH) in the patient's right frontal, occipitotemporal temporal lobe. The patient underwent an emergency craniotomy and decompression surgery that night. After the operation, the patient remained in a deep coma, with a high fever, diabetes insipidus, developed hypotension, and a life-threatening pulmonary infection. Our ECMO team recommended that the patient undergo a craniotomy and blood clot removal. However, the local hospital did not accept this recommendation, as the staff were concerned about the risks of surgery. The family of the patient requested that the patient be transferred to our hospital for treatment.

The following morning, an intracranial clot was eliminated during an operation, and 5 ml of dark-red old blood and some clots were removed from the right forehead. An extra ventricular drainage tube was placed. After the operation, the patient was sent to the cardiac surgery ICU. After treatment, the patient's state of consciousness improved. The patient's 2 pupils were equal circles with a diameter of approximately 3.5–4.0 mm, and sensitive to light reflection. During the subsequent recovery, the patient repeatedly had a fever and again fell into a mild coma. The cranial CT results suggested that the patient had less intracranial hemorrhaging than before the operation; however, a midline shift was apparent, and a brain herniation had formed. Our medical team continued to treat the patient. On June 22, the patient began to regain consciousness. The medical team then launched a rehabilitation treatment plan. The patient had been receiving treatment in the ICU since the onset of her illness, and her hospital stay lasted more than 50 days. On July 17, the patient's condition reached the discharge standard. The result of a cardiac ultrasound examination before discharge showed the patient had an EF of 35%. The patient returned to work after a year. Figures A–C show the CT examination images of the patient at different stages of treatment. Figure 3 shows the procedure adopted in this case.

3. Literature review

A search of the PubMed database was conducted using the keywords "pregnant woman," "cardiogenic shock," "ECMO," "peripartum cardiomyopathy," "extracorporeal cardiopulmonary resuscitation," "cardiac arrest," and "postpartum" and 9 articles on ECPR for pregnant and lying-in women were retrieved. All of the 9 patients in the articles underwent ECPR during pregnancy and childbirth. Of these, 8 patients underwent ECPR at hospital, and 1 underwent ECPR outside hospital.

3.1 General information

The cases of ECPR during pregnancy and childbirth were identified, and 9 literature reports were retrieved. The patients were primiparous/menstrual women with an average age of 27.25 ± 5.19 years, and a gestational age of 18–39 weeks. In relation to the cause of the 9 pregnant women's CA, there were 2 cases of peripartum cardiomyopathy, 2 cases of PE, 2 cases of amniotic fluid embolism, 1 case of spontaneous coronary artery dissection, and 2 cases of other causes (see Table 1).

3.2 ECPR support situation

All of the pregnant women underwent CPR and conventional resuscitation after CA. If CPR and conventional resuscitation were ineffective, an urgently ECMO for ECPR was initiated. Notably, 2 cases did not mention the specific ECPR time (i.e., the time from CPR to ECMO activation). In the case study, the duration of continuous recovery reached 5.5 hours. In relation to the other 9 cases, 6 cases of ECPR occurred during the pregnancy process, and 3 cases had a sudden onset during pregnancy. In 1 case, an ECMO rescue out of hospital was requested. Two cases occurred because of Harlequin syndrome and were converted to the ECMO mode.

3.3 Patient outcomes

The time from CPR to ECMO ranged from 30 to 120 minutes. The average time was 69.71 ± 30.15 minutes, and the ECMO support time was 4.79 ± 2.03 days. Nine patients were successfully withdrawn from the ECM; 1 patient experienced 3 ECPRs, was switched to a ventricular assist device, and died of severe multiple organ dysfunction syndrome; 2 patient had a right foot drop. Except for the patient who died, none of the patients suffered from any central nervous system complications.

4. Discussion

4.1 CPR, ECMO, and ECPR

ECMO is an advanced form of mechanical circulatory support. It uses a centrifugal pump and a biomimetic membrane lung system, which can provide sufficient oxygenated blood flow to the organs, along with short-term respiratory and circulatory support. It has been clinically used to support various patients with severe respiratory failure and circulatory failure.[21, 22] Traditional CPR can provide partial perfusion blood flow to vital organs through manual compression and mechanical compression equipment for CA patients; however, this physical compression method only supports minimal blood flow.[23] In recent years, the application of ECMO combined with CPR to treat refractory CA has attracted attention as a new model of circulatory support, called ECPR.[24]For patients who meet the indications, a cannula is quickly inserted through the skin or through the peripheral blood vessel to initiate ECMO support. ECPR can promptly restore the organs' adequate perfusion blood flow and reduce ischemic damage.[25] ECPR also is one of the critical technical categories in the American Heart Association Guidelines for Cardiopulmonary Resuscitation.[26] Compared to traditional CPR, ECPR is believed to improve patients' overall survival rate, and present a better neurological outcome.[25, 27]

ECPR represents a change to the traditional approach to CA treatment.[28] However, it should be noted that ECPR is a highly invasive surgery that requires sufficient resources, professional team members, and a well-scheduled hospital system to implement a rapid and effective treatment intervention. Invasive operation risks and ECMO-related complications are issues that must be considered in the treatment decision-making process. Issues may arise, especially in obstetrics, such as simultaneous bleeding and the existence of a density-indicating controller (DIC).[4] Before ECPR is initiated, a comprehensive assessment should be undertaken and responsible decisions made.

4.2 The advantages of ECMO

Short-term mechanical circulation assists devices, such as the IABP, Impella, left ventricular assist devices, and VA-ECMO, have become essential support methods for various refractory cardiogenic shocks.[29, 30] Different mechanical assist devices are used at different periods and in response to different indications.[31] In obstetrics, the application of ECMO is gradually beginning to receive attention.[32] In recent years, ECMO has been successfully used to treat pregnant women with peripartum cardiomyopathy (PPCM), PE, and amniotic fluid embolism.[12, 16, 18]

Among them, the ECPR technology, which is dominated by VA- ECMO, gives full play to the unique advantages of ECMO in the treatment of refractory CA in obstetrics. First, ECMO is easy for professionals to implant at the bedside, and is less affected by the surrounding environment. Second, due to advancements in biomaterial technology, VA-ECMO can be retained for several days or several weeks. Thus, ECMO is a superior "bridge" that assists patients to achieve treatment outcomes, including recovery, heart-lung transplants, and long-term mechanical assistance, and it can also be withdrawn in the event of ineffectiveness.[9] Third, ECMO is an easy to obtain resource. Due to medical engineering advancements, the VA-ECMO is now quite compact and can be moved easily, and thus it is propitious at rescuing CA or shock patients.[33] Thus, ECMO appears to be a highly feasible way to save lives when CPR is ineffective.

The case study reported in this article illustrates the advantages of ECMO. After being notified, our team transported the ECMO equipment and consumables in an ambulance to provide remote support, and implemented ECMO successfully at the local hospital ICU's bedside. In case 5,[16] an Australian tertiary obstetric hospital treatment team also took advantage of ECMO. After the team encountered a pregnant woman with refractory CA, the nearby extracorporeal life support (ECLS) team promptly requested support. Initially, the nearby adult (ECLS) centers were unable to provide ECPR, a ECLS team of pediatric hospital alerted and installed children's ECMO tubes and membrane lungs for the patient. When the nearby adult ECLS team arrived, it was replaced to an adult ECMO circuit to enable full-flow operation. The team made a remarkable decision and successfully saved the patient's life. This was also possible due to the high flexibility of ECMO, which can provide practical circulation support in a short time.

4.3 Harlequin syndrome and the conversion of ECMO models

Commonly used ECMO modes include the veno-venous (VV)-ECMO, VA-ECMO, and veno-arteriovenous (VAV)-ECMO. The choice of ECMO mode is related to each patient's specific condition.[34, 35]However, various ECMO intubation methods have limitations.[36] Changes to ECMO mode should be based on a patient's condition during the diversion period. Such operations include brief support interruptions, air intake, and bleeding. Changes to ECMO mode must be performed by experienced and professional medical personnel, as it is a complex and high-risk procedure.

Harlequin syndrome (or North–South syndrome) is a common complication of peripheral femoral VA-ECMO with severe pulmonary failure. It means the patient is at a dual circulation with poor oxygenation of the upper body and excellent oxygenation of the lower body[37]. The Harlequin syndrome is obvious in the early stage of cardiac function recovery, because the blood of poor oxygenation from pulmonary was drained out while the ECMO blood flow reinfusing into the femoral artery made differential hypoxia. This syndrome needs to be actively managed to maintain sufficient oxygen supply to the brain and heart. Treatment strategies include switching to VAV perfusion mode, changing the axillary artery cannulation, multiple intubations, or changing to dual pump mode.[38, 39]

In cases 4 and 9, both patients developed severe acute respiratory distress syndrome (ARDS) after ECPR, and developed Harlequin syndrome. The patients in the 2 cases were converted from VA to VAV mode . After the patients' heart functions recovered, the treatment mode was switched to VV model for lung therapy. No cardio-cerebral hypoxia or intubation complications were reported in the 2 cases. At present, there is no unified guidelines for the selection of an ECMO support mode. The correct ECMO support mode must be selected according to the disease and situation.[35] The safety and effectiveness of multiple ECMO conversion treatments in different modes requires further investigation.

4.4 ECMO complications: ICH

An ICH is a severe complication of the ECMO process and is often life threatening. ICH may be caused by a number of factors, including ECPR, sepsis, and renal failure.[40] The duration of ECMO and heparin anticoagulation can also cause ICH.[41] When ICH occurs, the recommended treatment measures are as follows: stop anticoagulation, infuse coagulation products, treat dehydration, treat hyperventilation, and engage in surgical intervention(s). Severe ICH requires the withdrawal of ECMO support to limit the expansion of hematoma and protect nervous system function.[42, 43] In the present case study, the CT scan of the patient's head 1 day after weaning showed massive ICH. Due to the local hospital's limited treatment technology, a surgery to decompress the skull was performed; however, the patient's condition continued to deteriorate. In these circumstances, the follow-up treatment of the patient was exceptionally challenging. Technological issues, family members' financial burdens, ethical aspects, and uncertainty about the patient's condition had to be addressed. The patient underwent craniotomy and blood clot removal. The patient ultimately recovered after a long and comprehensive treatment period. During ECMO, ICH is a catastrophic event associated with high mortality and poor prognosis.[44] The surgical treatment of craniotomy after ICH also has a variety of unpredictable risks. Medical staff should consider the risks of surgery and subsequent blood risks after an operation.[42] If administered to high-risk patients, routine neurological examinations, strict anticoagulation monitoring and management, timely head imaging examinations, and "awake" ECMO are required during the ECMO support period. ECMO treatment should be withdrawn as early as possible.

4.5 Drop foot during ECMO

Administering ECMO through peripheral blood vessels is the preferred method, as it is convenient, quick, and only moderately traumatic. VA-ECMO often uses a femoral arteriovenous catheter bypass. However, the incidence of vascular complications in peripheral ECMO is not uncommon.[45] It has been reported that the rate of peripheral vascular complications is 20–40%; this rate is closely related to the size of the cannula.[46, 47] Direct cannulation in blood vessels commonly causes lower limb ischemia, which may develop due to acute compartment syndrome or limb neuropathy due to drop foot.[48]

Of the 9 identified cases, only 1 patient presented with the symptoms of right drop foot; however, the cause and prognosis of the patient's drop foot was not stated. Aydin[49] reported a similar situation: After installing VA-ECMO through the right femoral artery and vein, the patient developed acute compartment syndrome of the right lower limb, and concurrent drop foot syndrome. The patient's nerve function test results showed right lower limb weak muscle strength and sensory disturbance. After 2 months of treatment, the patient still displayed physical sequelae. Limb ischemia has a negative effect on the clinical outcomes of ECMO treatment, including survival rates.[50] Once the symptoms of limb ischemia appear, a DPC should be inserted to reduce complications associated with ischemia. However, there is still a lack of strong evidence of its benefits.[51] DPC can also be placed synchronously when installing ECMO to enable the lower limbs to get extra blood perfusion. The initial DPC placement method is believed to reduce the incidence of limb ischemia.[52]

Theoretically, the use of side-graft cannulation for ECMO should provide adequate blood flow to the limbs. Cannulation techniques were applied in case 4 [15] and case 5;[16]however, this may still result in hypoperfusion syndrome and lead to limb ischemia.[53, 54] Papadopoulos et al. described a controlled technique whereby hyper perfusion of a limb could be avoided by adjusting the angle of the side grafting to change the priority perfusion direction of ECMO blood flow by shrinking the blood vessel distal to the graft.[55] Comprehensive measures must be undertaken to monitor the perfusion of the limbs, and timely intervention is equally essential. If the acute compartment syndrome is complicated, fasciotomy is also a remedy.[52, 56, 57]

Fortunately, in the present case study, the patient did not present with symptoms of lower limb ischemia or extravagant perfusion, because we placed the DPC, and selected the appropriate size of artery cannulation (17Fr, Medtronic) based on her weight (41 kg).

4.6 Long-term ECPR

The administration of ECPR in the rescue treatment of various types of CA has rapidly increased in frequency over the past few years. However, according to the registration data of the Extracorporeal Life Support Organization, the overall survival rate of adult ECPR is only about 30%.[58] The duration of advanced cardiovascular life support before the start of ECPR is closely related to the survival rate. As the period of CPR increases, the survival rate reduces. The recommended starting time for ECPR is within 60 minutes of CPR, as the overall survival rate is less than 10% if the CPR period exceeds 60 minutes.[59] A CPR period of over 60 minutes is considered the "ECLS limit," after which acceptable clinical outcomes will not be achieved.[9]

Currently, very little relevant data about ECPR periods are available. In the present case study, the pregnant woman underwent CPR for a period of 5 hours before ECPR. In relation to the other identified cases, 3 patients underwent CPR for a period of over 60 minutes and survived to discharge. In other fields, it has been[58]reported that a child underwent long-term ECPR of 4.5 hours successfully without any neurological complications. In another instance,[59] a 50-year-old woman who suffered from CA caused by hypothermia was discharged from hospital with excellent neurological function and an ECPR time of 95 minutes. Thus, the final clinical outcomes associated with long-term ECPR remain uncertain.

High-quality CPR is the cornerstone of ECPR. A lack of blood flow for a period of 5 minutes is the most crucial prerequisite of brain resuscitation. Additionally, it is necessary to ensure sufficient personnel are available to continuously perform high-quality chest compressions or implement mechanical compression device–assisted recovery.[60] The administration of ECPR requires numerous resources and has high treatment risks.[63] In the present case study, even after a long period of ECPR, the patient survived and was discharged. When treating young patients with curative potential, ECPR should be considered even if the CPR period is "over" the aforementioned 60-minute period.

5. Viewpoint

Many potential high-risk factors may cause CA in pregnant women, such as PPCM, a hypercoagulable state, PE, amniotic fluid embolism, and hemorrhaging due to significant physiology changes. Identifying high-risk pregnant women, making emergency plans, and having ECMO on stand-by is necessary, as ECMO provides quick support in the event of an emergency cardiovascular event, ensures a short period of low blood flow, and improves clinical prognoses.

6. Conclusion

In the event of refractory CA in pregnant women, ECPR can be lifesaving if combined with high-quality CPR. ECPR can provide patients with efficient cardiopulmonary support and should be considered. Additionally, even if patients have been subject to a long period of CPR, treatment is still recommended to increase patients' chances of survival.

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Conflicts of Interest

The authors have no potential conflicts of interest to declare.

Authors' contributions

F. L analyzed and interpreted data, drafting the manuscript.

Y. C conceived important content and approved the manuscript.

T. F data collection and management.

Qp. X study design and developed the concept.

L. D revised the manuscript critically for important intellectual content and prepared the manuscript for publication.

Mh. X initial revision of the manuscript.

Yk. H , Hj. P , Hj. H data statistics.

All authors read and approved the final manuscript.

Informed Consent

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Abbreviations : ECPR: extracorporeal cardiopulmonary resuscitation; ECMO: extracorporeal membrane oxygenation; ICH: intracranial hemorrhage. [a]Craniotomy and decompression.

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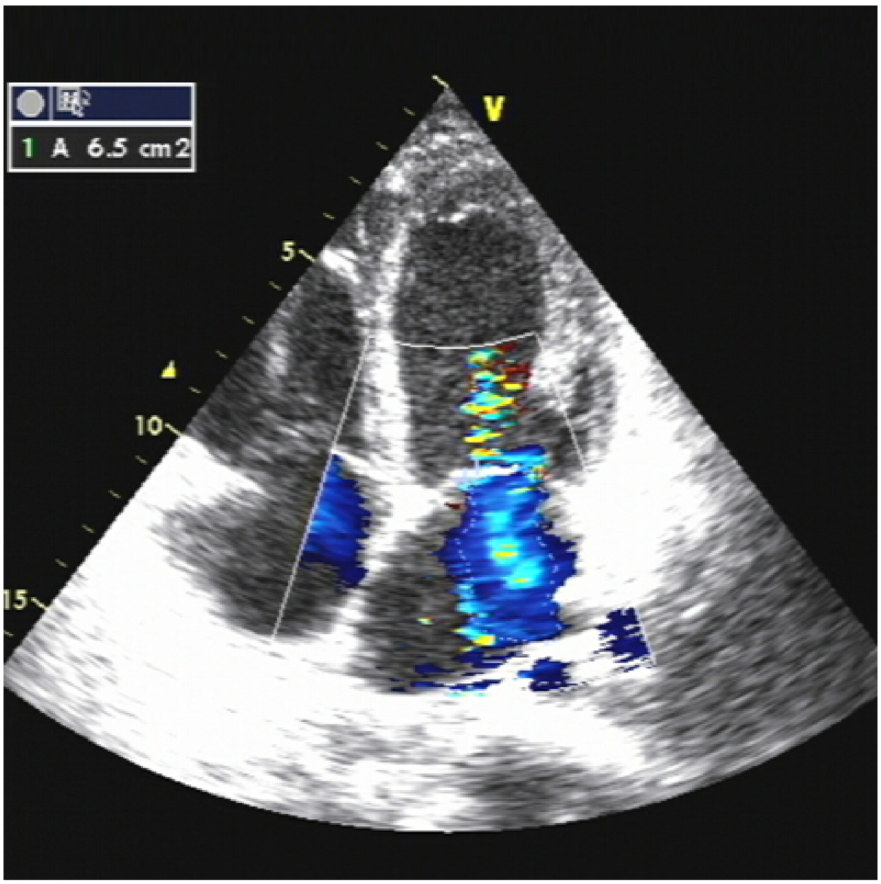

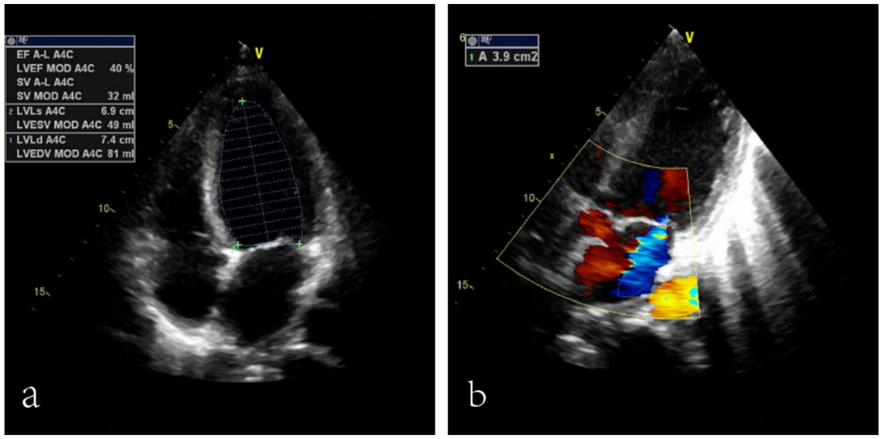
EF A-L A4C
LVEF MOD A4C 40 %
SV A-L A4C
SV MOD A4C 32 ml
LVLs A4C 6.9 cm
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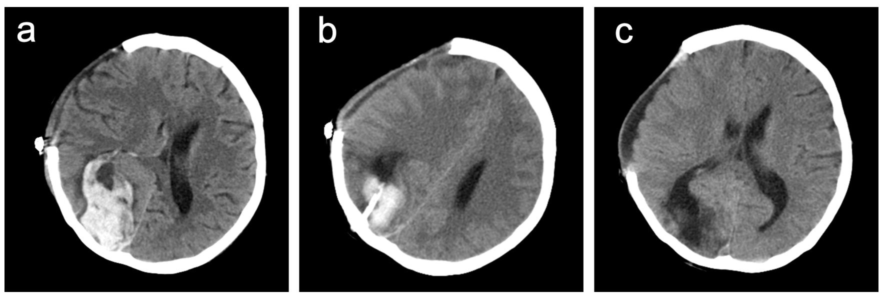
LVEDV MOD A4C 81 ml
a
A 3.9 cm2
b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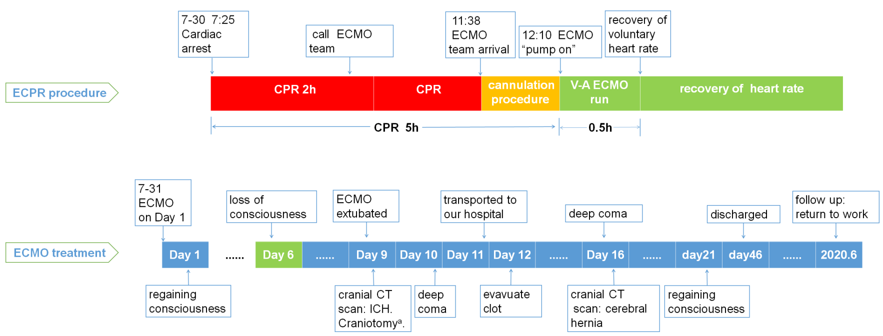
ECPR procedure
7-30 7:25 Cardiac arrest
call ECMO team
11:38 ECMO team arrival
12:10 ECMO "pump on"
recovery of voluntary heart rate
CPR 2h
CPR
cannulation procedure
V-A ECMO run
recovery of heart rate
CPR 5h
0.5h
ECMO treatment
7-31 ECMO on Day 1
loss of consciousness
ECMO extubated
transported to our hospital
deep coma
discharged
follow up: return to work
Day 1
Day 6
Day 9
Day 10
Day 11
Day 12
Day 16
day21
day46
2020.6
regaining consciousness
cranial CT scan: ICH. Craniotomy[a].
deep coma
evavuate clot
cranial CT scan: cerebral hernia
regaining consciousness