



# The First Case of Left Ventricular Assist Device Implantation (Artificial Heart) in Ningxia

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## Abstract

On October 01<sup>st</sup>, 2022, our hospital successfully implanted a left ventricular assist device (artificial heart) in a patient with dilated cardiomyopathy. The patient recovered well after the operation and was discharged successfully on the 9<sup>th</sup> day after the operation. After discharge, the patient received lifelong anticoagulant treatment with aspirin and warfarin, reviewed the blood coagulation function regularly, adjusted the amount of warfarin according to the blood coagulation situation, so that the INR was always maintained between 2.0 and 3.0, and came to our hospital's outpatient clinic for review regularly. The operation of the left ventricular assist device (artificial heart) was evaluated, and the medication was adjusted according to the condition.

**Keywords:** Left ventricular assist device; Artificial heart Dilated cardiomyopathy

## Case Information

### Medical history

The patient, a 50-year-old male, was admitted due to intermittent chest tightness and shortness of breath for 1 year, which worsened for 3 days. Patient and family members reported that the patient had no obvious cause of chest tightness, shortness of breath, nocturnal wakefulness, and nocturnal sitting breathing for about 30 sec before 1 year. It can relieve itself, accompanied by sweating profusely, no nausea or vomiting, no abdominal pain or diarrhea. One year ago, the patient sought medical attention at the local hospital, Mengzhong Hospital, and was diagnosed with "heart failure". After medication treatment, the symptoms improved (details are unknown). Three days ago (2020-09-19 09:00), the patient experienced chest tightness and shortness of breath during the process of getting up from the stool and going to the bathroom, accompanied by dizziness, nausea, and blackness, as well as sweating profusely. They also woke up at night and sat upright breathing at night, lasting for about 30 sec. They had no headache, vomiting, or abdominal pain or diarrhea. They sought medical attention at the local hospital, Mengzhong Hospital, and their electrocardiogram showed atrial fibrillation. Thoracic CT+cranial CT findings: 1. No obvious abnormalities were found on plain CT scan of the brain. 2. Multiple cord shadows in both lungs. 3. Enlargement of the heart shadow, significant pericardial effusion in the left ventricle, and consideration of cardiac insufficiency. 4. Small amount of fluid accumulation around the liver and spleen. Chest color Doppler ultrasound examination showed that bilateral lung ultrasound findings were consistent with interstitial lung syndrome, with a small amount of fluid accumulation in the left chest. Routine echocardiographic findings: The whole heart is enlarged, focusing on the left heart, the ventricular wall motion is generally reduced, mitral regurgitation (a small amount), tricuspid valve regurgitation (a small amount), aortic valve calcification and regurgitation (a small amount), the aortic sinus and ascending aorta are widened, the main pulmonary artery is widened, the left ventricular false tendon is reduced, and the left heart function is reduced [1]. No obvious relief is found after treatment of cardiac strengthening, diuresis, and heart load reduction. So today, we went to the emergency department of our hospital. Routine echocardiography in emergency department of our hospital: EF 15%, lv 84 mm, left ventricular wall motion generally significantly reduced, whole heart enlargement, widened mitral valve in aortic sinus, pulmonary artery, tricuspid valve regurgitation (mild), aortic valve regurgitation (moderate), left ventricular diastolic function significantly reduced, left ventricular systolic function significantly reduced. The cardiology department admitted the patient with acute exacerbation of chronic heart failure. During the course of the disease, the patient is clear and mentally competent, with poor diet and sleep, normal bowel

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movements, and no significant changes in weight recently. He has a history of hypertension for 20 years, the highest blood pressure is 170/110 mmHg, and he regularly takes Shakubatra Valsartan Tablets 50 mg twice a day at ordinary times. After admission to the cardiology department, considering the patient's obvious symptoms of heart failure, combined with the patient's physical signs and past medical history, the diagnosis of acute exacerbation of chronic heart failure was clear, and Atorvastatin calcium tablets were actively given to regulate lipid and stabilize plaque, improve vascular endothelial function, Metoprolol succinate sustained-release tablets to control ventricular rate, sakubatri-valsartan to inhibit RAAS system, delay ventricular remodeling, improve prognosis, Furosemide tablets, Spironolactone tablets to diuresis, Dapagliflozin is used to diuresis and improve heart failure, Sodium nitroprusside is pumped into the dilated tube to reduce the pre and post cardiac load, low-dose dopamine+dobutamine is pumped into the heart to strengthen the heart, expand the renal artery, coordinate diuresis, and actively "Furosemide injection" is pumped into the diuresis to reduce the body fluid load and pre cardiac load. The patient's symptoms are better than before. After the consultation, our department will consider: Dilated cardiomyopathy, heart valve disease: Aortic valve insufficiency (severe), cardiac function IV (NYHA), acute heart failure, arrhythmia: Paroxysmal atrial fibrillation, paroxysmal atrial flutter, hypertension 3 (extremely high-risk), fatty liver, simple renal cyst (left kidney), Hyperuricemia. So, he transferred to our department for further diagnosis and treatment [2].

### Symptoms and signs

Body temperature: 36.5°C, pulse: 65 beats/min, respiration: 14 beats/min, blood pressure: 94/68 mmHg, no cyanosis in the lip, filling of the jugular vein, abnormal cardiac apex pulsation, located 3.0 cm outside the midline of the left fifth intercostal clavicle, without abnormal protrusions or depressions [3]. The apical pulse touched abnormally, the heart boundary expanded to both sides, the heart rate was 98 times/min, the strength of the first heart sound was different, the heart rhythm was absolutely irregular, the pulse rate was less than the heart rate, no premature beat was heard, and grade 3/6 diastolic murmur could be heard in the auscultation area of the aortic valve. The breathing sounds in both lungs are clear, and no dry or wet rales are heard. The abdomen is soft, with no tenderness or rebound pain throughout the entire abdomen. The radial artery is symmetrical and normal on both sides, with no abnormalities in peripheral vascular signs, and no edema in both lower limbs.

### Related imaging and laboratory results

Measurement index of floating catheter in General Hospital of Ningxia Medical University: Pulmonary Artery Pressure (PAP): 46/20 (19) mmHg, Pulmonary Artery Wedge Pressure (PAWP): 32/20 (24) mmHg, Central Venous Pressure (CVP): 9 mmH<sub>2</sub>O, Right Atrial Pressure (RAP): 16 mmHg. Conventional echocardiography (2022-09-30) shows: LVED: 85 mm; EF: 22.09%, whole heart enlargement (mainly left heart), generally significant reduction of left ventricular wall centripetal motion, aortic valve insufficiency (severe), mitral and Tricuspid valve regurgitation (mild), pulmonary hypertension (mild), significantly decreased left ventricular systolic function, and decreased right ventricular systolic function. Thoracic aorta+abdominal aorta+iliac artery+Femoral artery iterative reconstruction (2022-09-29): 1. Manifestation of thoracic aorta, abdominal aorta, celiac trunk, left kidney Atherosclerosis. 2. Left atrial appendage thrombosis. 3. Left renal cyst. Routine ECG examination (2022-09-28): 1. Atrial fibrillation; 2. ST-T abnormality (if there are

chest pain, chest tightness, shortness of breath and other symptoms, further examination is recommended.) 3. Poor r wave progression in lead V1-V4. Coronary angiography shows normal coronary artery. N-terminal brain natriuretic peptide (2022-09-30): NT proBNP 3269.20 pg/ml.

### Surgical methods

Considering that the patient is dilated cardiomyopathy, suffering from recurrent heart failure and aortic valve disease, the diagnosis is clear, and it is an indication for heart transplantation and left ventricular assist device (Artificial heart), aortic valve replacement should be performed at the same time, and surgery should be performed as soon as possible. Due to the current short donor, it was decided to perform "implantation of left ventricular assist device (Artificial heart) +Aortic valve replacement", and relevant examinations have been improved, no obvious surgical contraindication was found, so "left ventricular assist device (Artificial heart) implantation + Aortic valve replacement" was performed in our hospital on October 01<sup>st</sup>, 2022 [4-8]. The specific surgical method was as follows: The patient was in a supine position, and the shoulder and back were elevated after successful tracheal intubation under general anesthesia. Routine disinfection and towel laying in the operation field. The median sternal incision was 25 cm long to 10 cm below the xiphoid process, the skin was cut in turn, the Subcutaneous tissue was cut, the sternal saw was used to cut the sternum, bone wax was used to stop bleeding, and spread it out. A bag about the size of fist was set up in the posterior sheath of the left rectus abdominis muscle, free thymus, T-shaped open-heart bag was cut, extracardiac exploration showed that the whole heart was enlarged, myocardial contractility was weak, and the whole body was heparinized at 3 mg/kg. The extracorporeal circulation pipeline was established routinely, and the temperature of single nasopharynx was reduced to 32°C, Ascending aorta was blocked, superior Inferior vena cava was blocked, RA was cut, PFO was about 3 mm, aortic root was cut obliquely, HTK solution was injected through left and right coronary openings and CS openings, cardiac arrest, ice debris was embedded in pericardium, AV valve leaflets were weak, severe insufficiency was found [9]. The diseased Aortic valve leaflet was removed, the AV valve ring and LV chamber were repeatedly washed with normal saline, the double headed needle with gasket was intermittently sutured, a 25 # MOSIC biological Aortic valve was implanted, the AO incision was closed, the PFO was closed with a single needle, the right atrium was closed, and the left atrial appendage was closed with an extracardiac suture. The diameter of the left cardiac auxiliary outflow passage was about 3 cm, and the artificial conduit was continuously anastomosed with the anterior wall of the ascending aorta with 5-0 proline suture; raise the apex of the heart, take 12 double needle sutures with a gasket at the depression of the apex, with a diameter of about 3 cm, cut open the apex, and explore the trabecular meshwork of the apical muscle without thrombus formation. Insert an artificial heart into the vascular channel, adjust the length of each pipeline, take a ventricular assist pump, connect each pipeline, and fully exhaust. There is no gas found in the solid body of the TEE syndrome, and establish a tunnel below the right rib arch, penetrating from the middle line of the clavicle and the three transverse fingers below the rib arch, connect the artificial heart cable from the tunnel to connect the external host, exhaust the left and right heart, open the ascending aorta, gradually see the extracorporeal circulation flow to 1 L/min, start the artificial heart, debug the artificial heart to work well, TEE confirms that the valve has no reflux, adjust the position of the artificial pipe, fully parallel and then stop

the machine, gradually withdraw the extracorporeal circulation pipe, protamine neutralize heparin. Thoroughly hemostasis was achieved in the surgical field, with one drainage tube placed in the pericardium and one drainage tube placed behind the sternum. After checking the accuracy of the gauze instruments, the sternum was fixed with steel wire suture and rib plate, and the chest was closed layer by layer to the skin. The surgery went smoothly.

### Postoperative treatment status

On the day after operation, the patient was sent to the intensive care unit for enhanced monitoring. The rotational speed of the left ventricular assist device (Artificial heart) was adjusted to 1850 RPM. The operation of the machine was monitored through the monitor of the left ventricular assist device (Artificial heart), and corresponding adjustments were made in due time. Vascular active drugs such as dopamine, epinephrine, Norepinephrine, and Nitroglycerin were properly used to assist the circulation. The patient's circulation was stable on October 02<sup>nd</sup>, 2022. Properly reduce the pumping dose of vasoactive drugs such as dopamine and epinephrine, pull out the Tracheal intubation at 12:00 p.m. on the same day, still give symptomatic support treatment such as active infection prevention, diuresis, potassium supplementation, continue to use vasoactive drugs such as dopamine, norepinephrine, and suprarenal gland to assist circulation, and Treprostinil reduces pulmonary artery pressure and reduces right ventricular load, from today, we will take Aspirin + Warfarin for anticoagulant treatment, regularly review the whole set of blood coagulation, closely monitor the blood coagulation, and take chest radiography (DR). 1) Interstitial changes in both lungs on the same day. 2) Postoperative changes in sternum and heart; heart shadow enlargement. 3) Consider a small amount of pleural effusion on the left side. 4) Changes after Tracheal intubation. 5) After superior vena cava catheterization, the apex was located at the level of the upper edge of the fifth posterior rib. On October 02<sup>nd</sup>, 2022, routine electrocardiogram examination (12 leads) [General]. 1) Sinus tachycardia. 2) Complete left bundle branch block. 3) I degree atrioventricular block. Blood gas analysis: PCO<sub>2</sub> 32.7 mmHg, PO<sub>2</sub> 61.6 mmHg, Lac 1.70 mmol/L, TEA<sub>bc</sub> 15.3 g/dL, RI 103, Calcitonin: PCT 32.000 ng/ml, critical value, ten items of liver function: ALB 44.3 g/L, AST 179.7 U/L, ALT 32.7 U/L, ST/LT 5.5, four items of kidney function: GLU 12.08 mmol/L, eGFR 52.79 ml/(min × 1.73 m<sup>2</sup>), UREA 12.78 mmol/L, CREA 134.1 umol/L, N-terminal brain natriuretic peptide: NT proBNP 5632.30 pg/ml, four coagulation items: INR 1.12, APTT 30.4 seconds, routine blood test (Complete blood count + five classifications + nucleated red blood cells): NEUT% 88.6%, WBC 10.70 × 10<sup>9</sup>/L. Continuing to closely observe the patient's vital signs and postoperative recovery, relevant vasoactive drugs were basically discontinued on October 06<sup>th</sup>, 2022. The longitudinal drainage tube was examined, and the drainage fluid was less than 50 ml. It was completely removed on the same day. At the same time, the bedside cardiac color Doppler ultrasound + left ventricular function measurement showed that: After the aortic valve position biological valve replacement, there was no obvious abnormality, the left ventricular wall movement was generally reduced, the whole heart was enlarged, the left ventricular diastolic function was reduced, and the left ventricular systolic function was significantly reduced. EF: 35.27%. Coagulation four items: INR 2.87. Maintain INR between 2.0 and 3.0.

### Results

The patient recovered well after operation, without chest

tightness, shortness of breath and other uncomfortable symptoms, with stable vital signs, stable circulation, no abnormality in physical examination, good healing of chest incision, good operation of left ventricular assist device (Artificial heart), no infection at the cable stoma position, and was discharged successfully on the 9<sup>th</sup> day after operation (October 10<sup>th</sup>, 2022). It is recommended that patients should use aspirin and Warfarin for anticoagulant treatment for life after discharge, review the coagulation function regularly, and adjust the dosage of Warfarin according to the coagulation condition, so that the INR is always maintained between 2.0 and 3.0. Within one month, Hydrochlorothiazide, Spironolactone and Potassium chloride sustained-release tablets still need to be used for short-term diuresis and potassium supplementation. They should regularly come to our hospital for outpatient reexamination, evaluate the operation of left ventricular assist device (Artificial heart), and adjust medication according to the condition.

## Discussion

### What is an artificial heart?

The artificial heart we often refer to is not a total Artificial heart, but an implantable Left Ventricular Assist Device (LVAD), which is mainly composed of blood pump, artificial blood vessel, cable, and energy supply system. It is mainly used to build a heart auxiliary channel for the blood in the body. It can partially or completely replace the left ventricular function of its own heart; the patient's blood can flow from the left ventricle to the blood pump through the inlet vessel of the artificial heart. The centrifugal force generated by the rotation of the impeller in the blood pump pushes the blood out and sends it to the ascending aorta through the outlet vessel of the artificial heart, thus assisting the patient's blood circulation.

### Indications of artificial heart

In brief, it is mainly used to provide mechanical support for the blood circulation of patients with advanced refractory left heart failure, that is, transitional treatment and long-term treatment before heart transplantation or to restore heart function [10,11]. For example, chronic Heart Failure (HF) is the most standard indication for LVAD in patients with end-stage heart failure waiting for heart transplantation. Patients with severe low cardiac output syndrome or heart failure after cardiac surgery can use LVAD for cardiac assistance, which can reduce the burden on the heart and promote the gradual recovery of myocardial function. In patients with acute myocardial infarction complicated with cardiogenic shock, coronary artery disease is serious or myocardial damage is irreversible. At least 40% of the left ventricular myocardium is damaged. Coronary artery bypass surgery cannot be performed and hemodynamics is extremely unstable. LVAD can temporarily stabilize hemodynamics, promote the improvement of myocardial function, and win time or long-term support for further use of other treatments. The patients with myocarditis and cardiomyopathy have serious hemodynamic disorder due to serious myocardial dysfunction. LVAD can be temporarily used for circulatory support to stabilize hemodynamics, gain time for the recovery of myocardial function and avoid multiple organ failure. Patients with ventricular arrhythmias are not the traditional standard for LVAD. If ventricular arrhythmias still persist and seriously affect hemodynamics, ventricular assist devices can be considered. Because the right heart function is often poor, it is appropriate to use biventricular assist devices. For some high-risk cardiac surgeries, the risk of surgery is extremely high, and there may be surgical failure or inability to detach from the extracorporeal circulation machine. In

this case, LVAD can be used as a routine backup rescue method [12].

### Selection of artificial heart

According to the mode of action, the cardiac assist devices currently in use around the world can be divided into volumetric blood pumps, turbine vane driven blood pumps and other types of blood pumps. According to the placement location, power type, and application time limit, it can be roughly divided into pulsatile blood flow or continuous advection, auxiliary devices built-in or external, pneumatic, electric, and magnetic levitation (currently auxiliary devices are mostly used for magnetic levitation and hydraulic levitation technology), and short-term or long-term auxiliary devices [13,14]. According to the assisted ventricles, they are divided into left ventricular assist devices, right ventricular assist devices, and biventricular assist devices, among which left ventricular assist devices are the most widely used [15].

At present, in China, most cardiac assist devices are left ventricular assist devices, and the third generation of magnetic levitation left ventricular assist device artificial heart has been used [16,17]. EVAHEART Yongrenxin is the only artificial heart approved for DT - Destination Therapy in China. Renxin has rich experience in long-term assistance in the world. The longest time of assistance overseas has been 10.5 years, and the longest time of assistance in China has been 4 years.

### Adjustment of revolutions of artificial heart

The pump speed is expressed in revolutions per minute, which determines the pump flow rate. It should be adjusted based on the follow-up results of patients after discharge and the analysis results of machine data at regular intervals to select the appropriate revolutions for patients.

### Selection of anticoagulation strength

After implantation of left ventricular assist device, it is necessary to use aspirin and Warfarin as a routine dual antibody treatment to control INR between 2.0 and 3.0. If there is no significant bleeding 1 day after LVAD implantation, ordinary heparin treatment should be started and the activated partial thromboplastin time should be gradually extended. Aspirin should be administered within 24 h to 72 h after surgery to achieve the Internationally Standardized Ratio (INR) of the patient to the target value required by the device. It is recommended to use unfractionated heparin as a transitional treatment for patients before taking Warfarin. After the International Standardized Ratio (INR) of patients reaches the target value, the dosage of aspirin and Warfarin can be maintained, but the blood coagulation situation still needs to be regularly detected and adjusted accordingly according to the blood coagulation situation [18,19].

### Maintenance of cable position of artificial heart

Patients need to be guided to effectively clean and care for the area where the cable penetrates the skin. The connection between the cable and the controller, the integrity of the cable, whether it is damaged, twisted or not twisted, whether it is fixed to the controller and body, and whether the dressing is clean, intact, and undamaged. The patient should ensure that the cable is not externally damaged, fixed to the abdominal wall, and avoid twisting or pulling the transmission wire. Disinfect and replace dressings at the point where cables pass through the skin with iodophor daily. A retainer can be used to ensure that the cable is always connected to the abdominal wall. Strict attention should be paid to hand hygiene to prevent bags containing batteries and controllers from falling or pulling, and to

prevent cables from being pulled out to prevent infection. At the same time, patients should be encouraged to develop a good habit of taking photos of the cable outlet for retention, in order to monitor and detect the occurrence of infection in a timely manner, so as to take corresponding measures in a timely manner.

### Long term complications of artificial heart

The possible long-term complications include: complications related to the blood pump and its affiliated structures, such as incomplete blood pump function, controller failure, etc.; the patient's own heart related complications, such as arrhythmia and valve regurgitation; complications related to the contact surface between the blood pump and the patient, such as infection, cerebrovascular accident, thrombus inside the pump, etc. [20]. If the above situation occurs during long-term use, it is necessary to seek medical attention in a timely manner, improve relevant examinations, and develop the next diagnostic plan.

### Whether heart transplantation is still needed in the long term

The patient's choice of Left Ventricular Assist Device implantation (LVAD), or Artificial heart, means a long-term lifestyle change [21]. Unlike heart transplantation, where LVAD is installed, the patient needs to take anticoagulant drugs for a long time and carry the device that supplies power to LVAD when traveling. After recovery for a period of time, the patient can live a normal life without affecting the quality of life, and perform heart transplantation, long-term anti-rejection drugs need to be taken after surgery, which will damage the autoimmune system to varying degrees and affect a certain quality of life. At present, EVAHEART Yongren Heart, which is widely used in China, can provide long-term assistance. If patients can accept a new lifestyle, heart transplantation may not be carried out in the long term.

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