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Phenomenon of Demikhov. Heart transplantation in experiment and clinical cases in the USSR and abroad (1968–1972). The Second in the USSR heart transplantation in a Clinic (Solovyev G.M., June 10, 1971)

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Abstract

The article presents materials of Soviet and foreign medical literature of 1968–1972 devoted to heart transplantation in experiment and clinical practice. It is shown that in the USSR after unsuccessful heart transplantation performed by A.A. Vishnevsky on November 4, 1968, experimental studies on isolated heart preservation in order to preserve its viability were conducted; models of orthotopic and heterotopic heart transplantation on large and small animals were created; morphological,

physiological, biochemical and immunological changes in the transplanted heart were studied. The second heart transplantation in this country was performed by G.M. Solovyev on June 10, 1971, but it was also unsuccessful. It's remarkable that the 20-year experience of V.P. Demikhov in experimental heart transplantation was used only partially: a number of surgeons applied the cardiopulmonary complex isolated according to V.P. Demikhov's technique for biological heart preservation in experimental animals. At the same time after the successful heart transplantation performed by C. Barnard on December 3, 1967, the world boom of clinical transplantation began. In 1969, 101 such operations were performed. For example, D. Cooley performed them on 21 patients and on another one performed two surgeries. There were cases when patients operated on in 1968 lived for 800-900 days or more after surgery. The best results were shown by R. Lower, M. DeBakey and N. Shumway. However, the vast majority of heart transplants resulted in lethal outcomes in the immediate or long-term postoperative period. This led to the fact that the euphoria of successful transplants gradually began to diminish: in 1969 only 47 operations were performed, and in 1970-1971 only 17 surgeries per year.

Keywords: history of medicine, heart transplantation in the USSR, heart transplantation abroad, 1968–1972 years, second heart transplantation in the USSR, Solovyev G.M., 1971

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AH - artificial heart
BP - blood pressure
CAD - circulatory assist device
CC - cross circulation
CPB - cardiopulmonary bypass
DHT - deep hypothermia
ECG - electrocardiography
HLM - heart-lung machine

Introduction

From December 3, 1967 to January 1, 1972, surgeons from 20 countries of the world performed 184 human-to-human heart transplants, and by the beginning of 1972, 9 patients had survived for more than 3 years [1]. However, experimental studies in these years did not lose their relevance, since hearts transplanted into animals were valuable models for studying many little-known issues of this problem.

Experimental research in the field of heart transplantation carried out in the USSR in 1968–1971

After the first unsuccessful operation of transplanting a human heart to a human undertaken in December 1968, A.A. Vishnevsky with a group of surgeons from the A.V. Vishnevsky Institute of Surgery and the Military Medical Academy named after CM. Kirov [2], the clinical heart transplants in the USSR ceased, but intensive studies began on the possibilities of making this operation in an experiment on small (mice, rats, rabbits) and large (dogs, pigs) animals. Methods for preserving the explanted heart outside the body, the technique of its orthotopic transplantation, and the creation of models of a heterotopically transplanted heart for studying the morphological, physiological, biochemical, immunological, and other important aspects of heart transplantation were worked out.

We analyzed the Proceedings of the V and VI All-Union Conferences on Organ and Tissue Transplantation held in Gorky (now Nizhny Novgorod) in 1970 and in Riga, the capital of the Latvian SSR (now the Republic of Latvia), in 1972. We found in the Proceedings about 70 works from 20 institutions of the Soviet Union where the experiments experimented with heart transplants were conducted in 1968-1972. What did Soviet surgeons do during these years?

At the A.V. Vishnevsky Institute of Surgery of the USSR Academy of Medical Sciences, doctors A.A. Vishnevsky, V.F. Portnoy (Fig. 1) and G.K. Vandyaev created an original model of an extracorporeal preservation of the heart with its continuous perfusion with oxygenated blood (Fig. 2), which was used to study the ways to preserve the organ viability for the purpose of its subsequent transplantation.

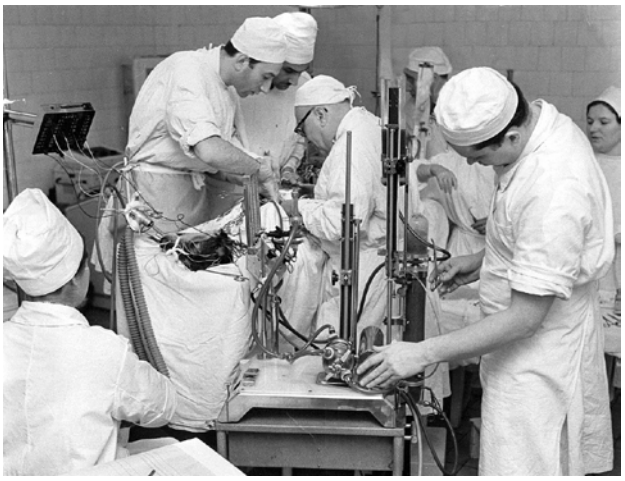


Fig. 1. In the operating laboratory for experimental surgery, A.V. Vishnevsky Institute of Surgery, USSR Academy of Medical Sciences. The surgery is performed by (from left to right) V.F. Portnoy, A.D. Arapov, and A.A. Vishnevsky. 1970s

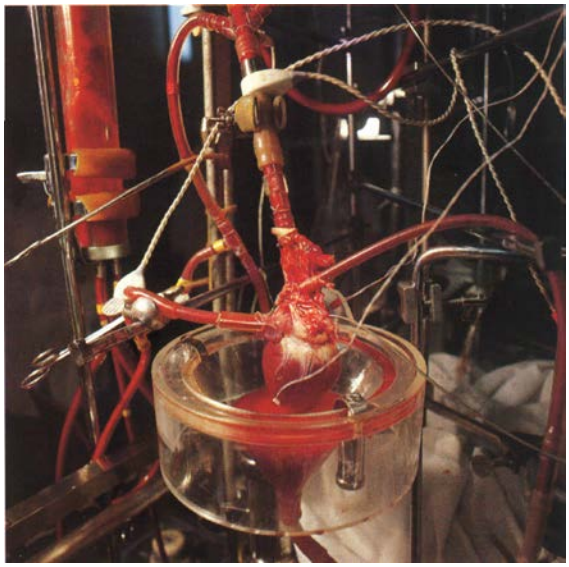


Fig. 2. Model of extracorporeal preservation of the heart with its continuous perfusion with oxygenated blood. Authors: A.A. Vishnevsky, V.F. Portnoy, G.K. Vandyaev. 1970s

Transplantation of such a heart after a 2-hour perfusion showed good preservation of energy-rich compounds in the myocardium [3]. For long-term preservation of the isolated heart, the polarizing hypothermic perfusion [4] and extracorporeal connection of the isolated heart to another organism in a heterotopic position were used [5]. After heart transplantation, the recipient hemodynamics was monitored [6]. Together with the Gorky Medical Institute, they studied the possibility of short-term preservation of an isolated heart under conditions of normothermic anoxia, anoxic cardiopulmonary bypass (CPB), and cardioplegia with an oxygenated novocaine solution without potassium and with a low sodium content [4, 7].

The rejection reaction and ways to overcome it were studied by surgeons of the A.N. Bakulev Institute of Cardiovascular Surgery of the USSR Academy of Medical Sciences under the guidance of V.I. Burakovsky, G.E. Falkovsky, and M.A. Frolova. After heterotopic heart transplantation on the iliac vessels, the morphological,

hematological and physiological studies were performed. It was found that the first signs of rejection in dogs without immunosuppressive[1] therapy appeared on the 2nd–3rd day, and the crisis occurred on the 4th–5th day [8, 9]. With the administration of immunosuppressants (prednisolone, imuran, antilymphocyte globulin), vague signs of rejection (for example, altered ratio of activities of lymphocyte mitochondrial enzymes) were recorded on days 15–27 [10, 11]. To preserve the function of the isolated heart for 5–6 hours, autoperfusion was performed using an isolated cardiopulmonary preparation with closed pulmonary coronary blood circulation according to the V.P. Demikhov's method [12]. This method of biological heart preservation was also used in the studies conducted jointly with the staff of the Institute of Organ and Tissue Transplantation of the USSR Academy of Medical Sciences [13].

The original experiments were made by the staff of the Faculty Surgery Department at the 2nd Moscow State Medical Institute named after N.I. Pirogov under V.S. Saveliev's guidance, using hyperbaric oxygenation, hypothermia, coronary perfusion with solutions of various compositions and cell metabolism inhibitors (neuroleptics) for the heart preservation, and then transplanting the heart into an orthotopic position under CPB conditions according to N. Shumway [14, 15]. Intra- and immediate postoperative complications were also studied [16]. In total, the Department submitted 11 reports for presentation to two Conferences only on the problem of heart transplantation, in which, in addition to V.S. Saveliev, another 24 people took part. This combination of techniques and an impressive team of researchers suggest that V.S. Savelyev and his staff were preparing for a heart transplant in clinic.

[1]Hereinafter, the term *immunosuppressive* therapy and its derivatives (immunosuppression, immunosuppressants, etc.) are used. They were used in the 1960s and 1970s. Now the term is immunosuppression.

The functional usefulness of a cardiopulmonary preparation isolated according the method of V.P. Demikhov was studied under the guidance of N.I. Gerasimenko at the Central Research Institute of Tuberculosis of the Health Ministry of the USSR. It was shown that, such a preparation as a biological circulatory assist device under specially created conditions can maintain the viability of the heart-lung complex for up to 10 hours [17].

At the Volgograd Medical Institute under A.G. Konevsky guidance, 346 experiments were performed on transplanting the hearts of puppies into adult dogs in a heterotopic position. Satisfactory function of these hearts was observed from 5.7 to 8.2 days with a maximum period of up to 32 days. Immunosuppressive therapy was not used [18]. It is not clear from the text of the abstract, which method the authors used, but in general, the conditions of their experiments resembled those conducted by V.P. Demikhov, and their number (346) and the results (survival up to 32 days without immunosuppression) were impressive.

Ukrainian surgeons from F.G. Yanovsky Institute of Tuberculosis and Thoracic Surgery headed by N.M. Amosov performed auto- and homo-transplantations of hearts in dogs, taking for transplantation both the beating hearts of animals and hearts revived at 20–50 minutes after respiratory and cardiac arrest [19]. Meantime, after the onset of clinical death by bloodletting, donor dogs were placed in a pressure chamber at excessive atmospheric pressure for 30–40 minutes, and after the recipient was prepared and connected to the CPB pump (heart-lung machine), the donor heart was revived by perfusion and transplanted, obtaining a good pumping function. Surgeons planned to use this technique to restore the heartbeating after clinical death with the aim of subsequent heart transplantation in humans [20]. A group of surgeons from the Riga Medical Institute (Ya.V. Volkolakov et al.) performed heart

transplantation under conditions of deep hypothermia, considering this method to be the method of choice [21].

Various approaches to heart preservation and transplantation in experiment were developed and studied at the 1st Moscow Medical Institute named after I.M. Sechenov in cooperation with the Research Institute of Clinical and Experimental Surgery of the Health Ministry of the USSR (B.V. Petrovsky and others), the Gorky Medical Institute (B.A. Korolev and others), the Kemerovo Medical Institute (V.N. Smyslova and others), the Novosibirsk Research Institute of Circulation Pathology of the Health Ministry of the RSFSR (E.N. Meshalkin et al.), the Institute of Cardiology of the Health Ministry of the Armenian USSR (A.L. Mikaelyan et al.), the Institute of Clinical and Experimental Surgery of the Ministry of Health of the Kazakh SSR (A.A. Amanbaev et al.), the Institute of Problems of Cryogenic Biology and Medicine of the Academy of Sciences of the Ukrainian SSR (B.M. Datsenko and others), and the Institute of Experimental and Clinical Surgery of the Health Ministry of the Georgian SSR (V.S. Vasadze, S.M. Chilaya and others).

From the Organ Transplantation Laboratory of the N.V. Sklifosovsky Research Institute for Emergency Medicine, which was headed by V.P. Demikhov, there was only one presentation made by V.M. Goryainov that covered the electrophysiological study of a transplanted heart using electrocardiography (ECG) [22].

The analysis showed that the issues of experimental heart transplantation were mainly solved by those teams that had experience in cardiac surgery. To preserve the life of a transplanted heart between its excision and transplantation, many used the cardiopulmonary complex with pulmonary and coronary circulation up to V.P. Demikhov's technique, as well as his principle of transplanting an additional heart into

a heterotopic position to study morphofunctional, neurohumoral, immunological reactions, and rejection crises. Kyiv surgeons used methods for achieving clinical death and revitalization of dogs according to S.S. Bryukhonenko.

In general, one gets the impression that many major Soviet surgeons were preparing for clinical heart transplantation (N.M. Amosov, V.I. Burakovsky, A.A. Vishnevsky, Ya.V. Volkolakov, B.A. Korolev, E.N. Meshalkin, V.S. Saveliev). But the research they conducted never went beyond the experimental operating room in those or subsequent years[2]. In 1971, only a team of cardiac and neurosurgeons, anesthesiologists-resuscitators, perfusionists, immunologists, biologists, and physiologists under the guidance of G.M. Solovyov could perform clinical heart transplantation. To do this, his team also conducted a series of experimental studies, which details we would dwell on in more detail to show to which extent G.M. Solovyov and his staff were ready to perform this operation on a human in clinic.

Experimental studies in the field of heart transplantation conducted at the Institute of Organ and Tissue Transplantation of the USSR Academy of Medical Sciences in 1969–1971

In 1969, the Institute of Organ and Tissue Transplantation of the USSR Academy of Medical Sciences was established in Moscow on the basis of the City Clinical Hospital No. 52 located in the north-west of the capital in the Oktyabrskoye Pole area. It was headed by Professor G.M. Solovyov, one of the pioneers of cardiac surgery and clinical transplantology in the USSR, the Laureate of the USSR State Prize, Corresponding Member of the USSR Academy of Medical Sciences, (Fig. 3). Soon after the establishment of the Institute, its staff began to

[2]In 1983, an attempt to transplant a human heart was made by V.I. Burakovsky and G.E. Falkovsky.

perform orthotopic heart transplants in dogs and pigs under conditions of cross-circulation (CC) and CPB [23], deep hypothermia (DHT) [24], and created models of intra-abdominal heart transplantation in rats [25].

Fig. 3. Director of the Institute of Organ and Tissue Transplantation, USSR Academy of Medical Sciences, Laureate of the USSR State Prize, Corresponding Member of the USSR Academy of Medical Sciences, Professor G.M. Solovyev (1928–2004)

When conducting experiments on large animals, the investigators solved the issues of reducing the surgery duration, choosing the optimal suture for the atria in the biatrial technique of heart transplantation, possible using a mechanical suture of the main vessels, sealing the sutures with glue, as well as developing various options for the surgical technique of heart transplantation. In addition, methods of anesthesia, CC and CPB, patient management in the postoperative period, etc. were worked out. Rat models were created for morphological, physiological, biochemical and immunological studies.

In total, 30 experiments on dogs weighing 7–20 kg and 5 experiments on pigs weighing 28–30 kg were performed to work out the technique of the operation under the conditions of CC and CPB. In experiments, in addition to G.M. Solovyov, 9 more employees of the

Institute took part. Of the total 35 operated animals, the graft functioned from several minutes to 7 hours in 12 dogs, up to 3 hours in 5 pigs. In 11 animals, the donor heart contractions began, but the heart was unable to provide blood circulation. In 7 experiments, the heartbeat could not be restored. The main causes of death were: long duration and inadequacy of CC and CPB, marked disturbances in recipient's homeostasis, prolonged ischemia of the donor heart. Meanwhile, the outcome of surgery was often predetermined due to inadequate hemodynamics of the recipient. Nevertheless, the experiments made it possible to work out a number of surgical techniques, develop tactics for transferring blood circulation from CC and CPB to the transplanted heart, and develop methods for its pharmacological therapy [23].

Experiments on heart transplantation under DHT conditions were performed under the guidance of G.S. Lipovetsky on 25 puppies weighing 4–6 kg. The cardiac activity recovered in 12 experiments and lasted from 45 minutes to 8 hours. Rapid recovery of donor heart contractility was observed in those animals that underwent "intratransplant myocardial protection"[3] with cold. The causes of the transplanted heart inability to maintain blood circulation in 13 recipients were the following: air embolism, calcium chloride overdose, bleeding from the sutures, and an increase in myocardial temperature during transplantation [24]. We emphasize that all experiments were conducted without taking into account the immunological status of donors and recipients.

M.A. Danilov and V.G. Deev presented a review of the literature on heterotopic heart transplantation in rats using a suture technique to connect vessels. The authors listed the advantages of these experiments: the possibility of using immunologically pure animal lines, a relatively

[3]Authors' term

low-cost of experiments, the simplicity of keeping rats, and the possibility of neglecting the asepsis rules [25]. This technique was used by V.G. Deeva and a group of authors who conducted 23 experiments on outbred animals (Group 1), 24 experiments on rats of the same line (Group 2), and 18 experiments with heart transplantation from rats of one line to animals of another (Group 3). In 12 animals from the 1st group, the activity of the transplanted heart was restored, after which it functioned from 5 to 24 days (mean 15 days). In 11 rats from the 2nd group, the heart functioned from 7 to 46 days (mean 24 days). In the 3rd group, 11 animals survived with the graft functioning from 4 to 11 days (mean 7 days) [26]. Note that besides the Institute of Organ and Tissue Transplantation of the USSR Academy of Medical Sciences, this technique developed in the USA in 1962–1964 was used in the USSR, in the A.N. Bakulev Institute of Cardiovascular Surgery (Director Professor V.I. Burakovsky) of the ISSR Academy of Medical Sciences, and the Institute of Cardiology of the Health Ministry of the Armenian SSR (Director Professor A.L. Mikaelyan), whose works were referred to by the authors.

Commenting on the above facts, we note that in the USSR, the first experimental CC on dogs was used by V.P. Demikhov, however, rather to overcome the biological incompatibility of the donor's heart and the host's body than to ensure the perfusion of the recipient during transplantation. He did not perform operations under the conditions of CC and CPB, using his own technique of switching vessels during transplantation so that the heart continued to contract during transplantation. To connect the main vessels during heart transplantation in dogs V.P. Demikhov was the first to use V.F. Gudov-designed vascular stapling device, believing that the speed and quality of the suture played a decisive role in a successful heart transplant.

In total, by 1960, V.P. Demikhov performed 250 heterotopic heart transplants in dogs with a survival time of up to 32 days (maximum 141 days), 67 orthotopic transplantations of the "heart-lungs" complex with a survival rate of up to 6 days, and (in 1951–1955) 22 orthotopic transplantations of an isolated hearts with a survival time of up to several hours. We emphasize that V.P. Demikhov stopped making heart transplants in the orthotopic position, in his words, because of "insufficiently perfect methods of heart replacement surgery". Recall that his technique consisted of heart transplantation by suturing the vena cava, suturing the pulmonary vein collector into the left atrial appendage, and connecting the aorta and pulmonary artery [27]. He did not use the biatrial technique; he did not have HLM, either.

But here is the question. Could his experience accumulated over 20 years of work in experimental heart and lung transplantation be useful to surgeons at the Institute of Organ and Tissue Transplantation of the USSR Academy of Medical Sciences in 1969-1971? Undoubtedly, yes. But they chose to go their own way. Not a single reference to the works of V.P. Demikhov in their works, data from which are given above, no. Although, as follows from the materials of conferences on organ transplants, they used the cardiopulmonary preparation V.P. Demikhov worked out for the preservation of the isolated heart.

Clinical heart transplant performed at the Institute of Organ and Tissue Transplantation of the USSR Academy of Medical Sciences in June, 1971

The failed attempts at clinical heart transplants, which in 1968 were undertaken by A.A. Vishnevsky [2] and N.M. Amosov [2 8], are well known, but a similar operation, which in June 1971 was performed by G.M. Solovyov, is little known to the general reader. Meanwhile, it

became the second completed transplantation in the country, but, like the patient of A.A. Vishnevsky, G.M. Solovyov's patient died in the immediate postoperative period. As N.M. Amosov recalled, he was ready for the transplant, but did not do it.

It's hard to tell how good G.M. Solovyov's team, which included Yu.K. Gruzdev, Yu.M. Zaretskaya, A.N. Ivanov, S.Ya. Kisis, S.P. Naumov, G.G. Radzivil, A.Z. Troshin, V.A. Chernov and, apparently, other employees, was ready for this intervention, having performed 60 orthotopic heart transplants in dogs and pigs and 65 heterotopic heart transplants in rats, because these experiments worked out mainly technical rather than resuscitation or immunological aspects of operations. Meantime, half of the operated animals died during the intervention. However, in G.M. Solovyov's opinion, he did have the conditions to perform such an operation in clinic: he himself and his assistants mastered the technique of reconstructive open heart surgery and operations on the main vessels, had experience in immunosuppressive therapy for kidney transplantation. Therefore, faced with a situation in which heart transplantation, in their opinion, was the only way to save the patient's life, they decided to perform it [1].

Patient M., 26 years old, on November 2, 1970, was taken to the Intensive Care Unit of a Moscow hospital in an extremely severe condition with pulmonary edema, cardio- and hepatomegaly, cyanosis and anasarca. After being brought out from the terminal state, M. received intensive therapy in the Internal Medicine Department of this hospital, which helped to achieve compensation, though incomplete, for blood circulation only with strict bed rest. On March 9, 1971, at the urgent request of M., and considering usefulness of the conservative therapy, the patient was transferred to the Department of Surgery and Heart Transplantation of the Institute of Organ and Tissue

Transplantation of the USSR Academy of Medical Sciences. After examination, M. was diagnosed with rheumatic three-valve heart disease, insufficiency of the aortic and tricuspid valves, combined mitral valve disease with predominat insufficiency, circulatory insufficiency of stage IV (according to A.N. Bakulev classificaion). In the Institute, the intensive treatment to M. was continued, but due to the increase in circulatory decompensation, the decision was made to prepare the patient for surgery for a three-valve defect (Fig. 4). Given the acute cardiomegaly, in the presence of acute intraoperative heart failure and appropriate conditions (in particular, the presence of a donor), the patient was also considered as a candidate for heart transplantation. M. himself, exhausted by illness, repeatedly asked for a heart operation and insisted on transplantation, if necessary. All necessary immunological studies were performed in advance.

Fig. 4. Model of cardiac valve replacement surgery: mitral − with MKCh-29 prosthesis, aortic − with AKCh-6 prosthesis, tricuspid − with MKCh-40 prosthesis. Pretreated pig heart. Authors A.V. Didelev, V.P. Miroshnichenko, V.S. Shmelyev (I.M. Sechenov First Moscow State Medical University). Preservation in M.V. Gordeeva's triple solution. 2012. Anatomical Museum, A.N. Bakoulev National Medical Research Center for Cardiovascular Surgery

On June 10, 1971, patient P., aged 34, was delivered to the City Hospital No. 67 in Moscow with a severe combined craniocerebral injury in deep coma. During the operation, after the removal of a massive subdural hematoma and cerebral detritus, massive crushing of the brain tissue was found. A Council of neurosurgeons and critical care physicians of the hospital, doctors of the organ procurement team of the Institute of Organ and Tissue Transplantation recognized the patient's injury as incompatible with life and, under the protection of resuscitative measures; P. was transferred to City Clinical Hospital No. 52. When P.'s tissue typing was performed, they were found to be compatible with M.'s tissues in strong antigens.

A thorough neurological examination of P. confirmed his brain death. Despite intensive life support, the victim's condition worsened. At this time, M. who was planned to have three valves replaced was taken to the adjacent operating room. HLM was connected after cannulation of the left femoral artery and vena cava. After opening the pericardium, an acute cardiomegaly was detected due to an increase in the size of all heart chambers and significant myocardial hypertrophy. The diagnosis of rheumatic heart disease was rejected. The detected changes were regarded as idiopathic myocarditis of unknown etiology with relative valvular insufficiency. During the revision of the heart, it stopped, which required a 5-minute direct cardiac massage.

In this situation, in order to save patient M.'s life, the decision was taken to transplant him with P.'s heart, which had ceased beating shortly before this decision was made and resumed beating at direct cardiac massage and CPB. Brain death was confirmed by a visiting forensic physician, after which a group of surgeons excised P.'s heart under the myocardium with cold at +4°C with cutting off the hollow and pulmonary

veins. Another group of surgeons removed the heart from the recipient, saving part of the atria walls and the interatrial septum.

Transplantation of the heart into the chest of the patient M. was performed by G.M. Solovyov up to the Lower-Shumway technique, consecutively connecting the interatrial septum with a twisting suture and the walls of the right and left atria with a two-row suture, and then the aorta and pulmonary artery. The transplanted heart ischemia time was 90 minutes. The heartbeat was restored by defibrillation, CPB pumping was discontinued. Blood pressure (BP) was 90/60 mm Hg, heart rate was 144 per minute.

After 15 minutes, the transplanted heart stopped. Direct cardiac massage and auxiliary CPB restored his work. BP stabilized, HLM was turned off, the wound was sutured in layers with drainage of the pericardial and right pleural cavities. The total perfusion time was 3 hours (Fig. 5).

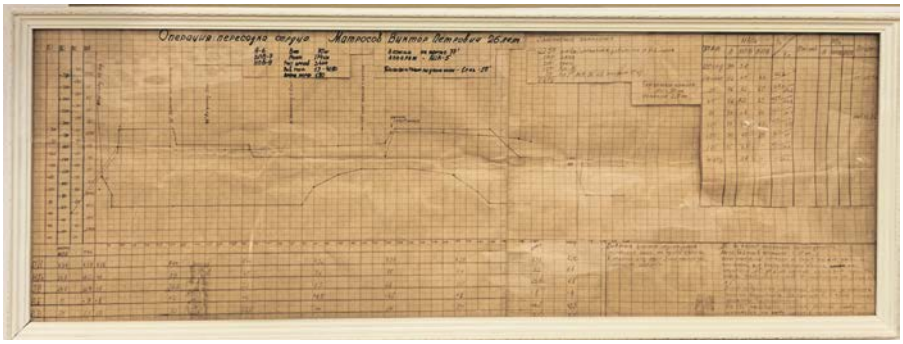


Fig. 5. Perfusion map of patient M., 26 years old. Author: S.P. Naumov. Museum of Cardiovascular Surgery, A.N. Bakoulev National Medical Research Center for Cardiovascular Surgery. Donation by S.P. Naumov. 2003

For 1 hour 15 minutes of monitoring the patient, 1300 ml of blood was released through the drains. During rethoracotomy, the blood was found to come from the left atrium and aorta in the region of the sutures.

Additional sutures were placed on the atrium, and the aortic wall was strengthened with an autopericardium. The chest wall was sutured up to the drains. The bleeding stopped. The blood loss was compensated with a direct blood transfusion, the blood being taken from several employees of the Institute.

After 3 hours, the patient woke up, began spontaneously breathing. BP was 110/70, heart rate was 120 per minute. Considering the respiratory failure, mechanical ventilation was continued, while a gradual increase in inspiratory resistance was noted. Progressive pulmonary insufficiency led to a rhythm disturbance and cardiac arrest. Cardiac Life Support measures turned out ineffective, and 7 hours later M. died of acute cardiopulmonary failure.

At pathologist anatomical examination, it turned out that M. had suffered from chronic idiopathic Abramov-Fiedler myocarditis[4], which led to hypertrophy of the heart with dilatation of its cavities and relative insufficiency of the aortic, mitral and tricuspid valves in combination with brown induration of the lungs with sclerosis of the interalveolar septa, perivascular and peribronchial tissue, the walls of blood vessels and pleura. A forensic autopsy of the donor P. revealed brain damage incompatible with life, with extensive damage to the bones of the vault and base of the skull [1].

After that, clinical heart transplants in the USSR ceased.

Clinical heart transplantation according to world literature of 1968–1971

"Recent advances in the field of heart transplantation are associated with persistent attempts to implement the accumulated experimental

[4]Abramov-Fiedler myocarditis is a rare type of myocarditis characterized by the presence of multinucleated giant cells in the myocardium and the rapid development of fatal heart failure.

experience in clinical practice," said Yu.N. Molkov and T.A. Sidorin [29]. Mentioning further the founders of experimental heart transplantation A. Carrel and his assistant C. Guthrie who in 1902–1905 developed a technique for transplanting a donor heart to the vessels of the neck, the authors listed the experimenters who used the technique of A. Carrel. In their opinion, these were F.S. Mann et al. (1933), N.P. Sinitsyn (1948), B.V. Ognev (1947), and V.P. Demikhov (1960). We have no objections to the first three names. However, having indicated in the list of sources the monograph of V.P. Demikhov [27], the authors showed incompetence, because in this book there was not a single experiment similar to the experiments of A. Carrel or F. S. Mann.

Elsewhere, speaking of the fact that by the early 1970s. "technical aspects of heart transplantation have been studied sufficiently and cannot serve as an obstacle to [its] transplantation in humans", the authors referred to Soviet and foreign sources from 1968–1972, again without citing a single article by V.P. Demikhov of an earlier time (1947-1963) and without even mentioning that, unlike his colleagues, he transplanted *a beating heart*.

Of course, there is no direct relationship here, but the oblivion of 20 years of experimental work by V.P. Demikhov, on whose experience foreign surgeons learned (it was not for nothing that they translated the V.P. Demikhov's book into English, German and Spanish), partly led to the fact that by 1972 only 2 clinical heart transplants had been performed in the USSR: by A.A. Vishnevsky and G.M. Solovyov. What was being done in the world heart transplantation at that time?

As of January 1, 1972, 184 heart transplants had been performed in 181 recipients in 59 cardiosurgical clinics of the world, of which 29 were alive by that time. At the same time, of 29 patients, 24 lived for more than 3 months, 18 for more than a year, 14 for more than 2 years, 9 for more

than 3 years, and 6 people lived for 38–40 months [29]. The year 1968 became the most “fruitful”. During that year, 101 heart transplants were performed in the world (54 in the USA, 14 in Canada, 10 in France, 2 in South Africa, and 21 in 16 other countries[5]). The largest number of transplants (22) was performed by D. Cooley (Fig. 6). However, according to Yu.N. Molkov and T.A. Sidorin, D. Cooley did not attach due importance to immunology, believing that he could find the best technical options for successful transplantation. Therefore, the authors concluded, the surgeons were disappointed. It was only N. Shumway (Fig. 7) who, having retained enthusiasm, carefully performed typing of donors and recipients and meticulously administered postoperative immunosuppressive therapy. By January 1972, it was N. Shumway who performed the greatest number of heart transplants in the world: 36, and had the largest number of survivors: 16 patients [29]. Was it really so?

Fig. 6. Professor D. Cooley (1920-2016). Texas Heart Institute, Texas Children's Hospital and St. Luke's Episcopal Hospital, Baylor College of Medicine, Houston, Texas, USA

[5] In 1968, surgeons from Australia, Argentina, Brazil, Great Britain, Venezuela, Germany, Israel, India, Spain, Poland, the USSR, Turkey, Czechoslovakia, Chile, Switzerland, and Japan performed 1-2 heart transplants each.

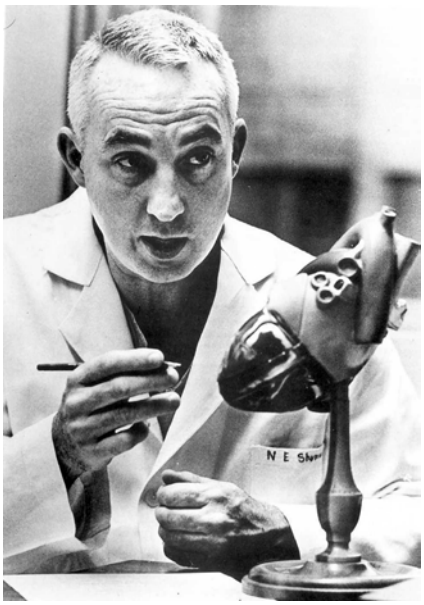


Fig. 7. Professor N.E. Shumway (1923–2006). Stanford University Medical Center, Palo Alto, California, USA

To begin with, we note that all patients operated on by surgeons at the dawn of clinical heart transplantation were admitted to clinics in a very severe condition with end-stage heart failure caused by cardiomyopathies of various, including ischemic, origin, endocardial fibroelastosis, and extreme coronary heart disease (Fig. 8 A-C) or with multi-valve defects. That is why D. Cooley attached great importance to both the improvement of transplantation technique (Fig. 9 A–H) and immunological control.

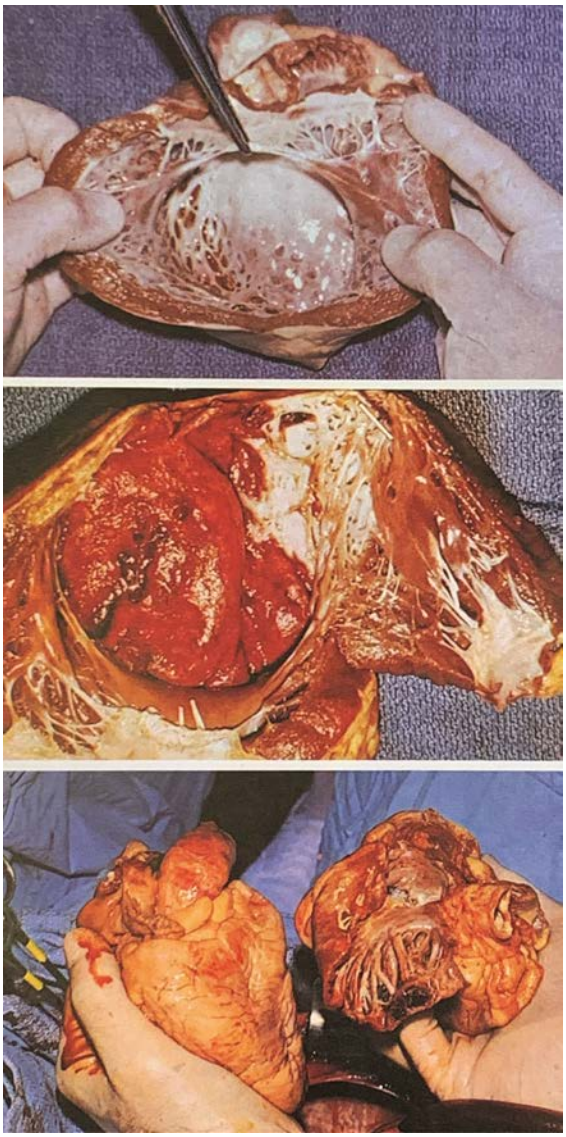
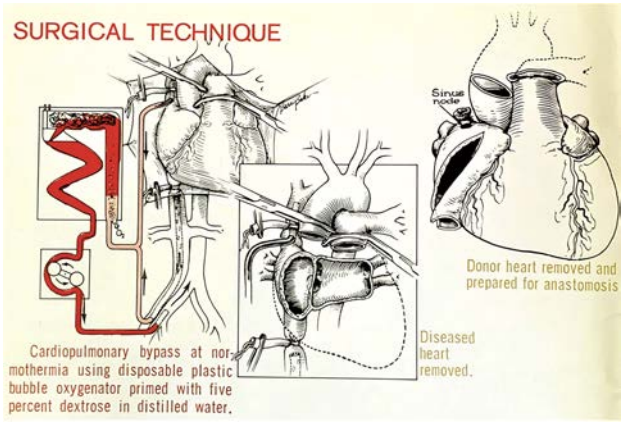
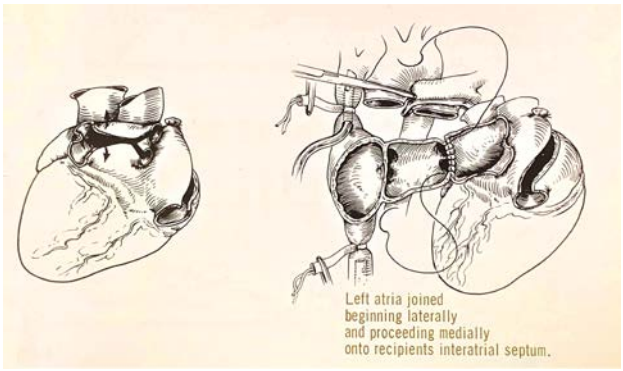


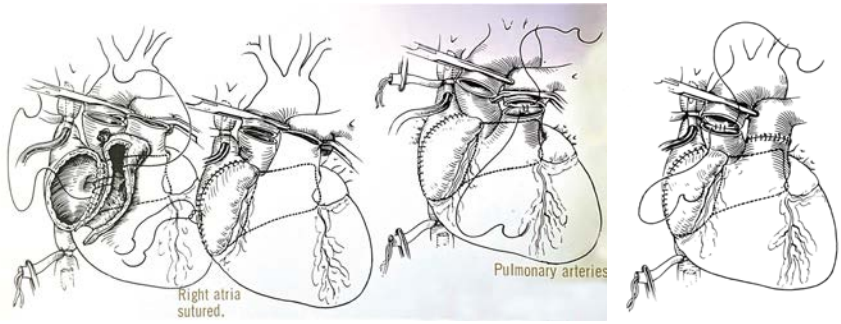
Fig. 8. Excised hearts of recipients (from top to bottom): A − heart of a 5-year-old girl with endocardial fibroelastosis and myocardiopathy; B − heart of a 48-year-old man with end-stage coronary insufficiency; C, left − healthy donor heart ready for transplantation, C, right − excised heart of a 49-year-old woman with acute coronary insufficiency [30]



A B C



D E



F G H

Fig. 9. D. Cooley's heart transplant technique: A − scheme of normothermic cardiopulmonary bypass using a bubble oxygenator; B − scheme of recipient heart excision; C − donor heart with dissected right atrium; D − donor heart with dissected left atrium; E − suture of the left atrium to the interatrial septum; F − suture of the right atrium; G − suture of the pulmonary artery; H − aortic suture [31]

It was D. Cooley, who operated on 4 patients in the period from March to August 1968 and performed the first *successful heart transplant*

in the United States on May 21, 1968, developed an immunosuppressive therapy scheme that he borrowed from the liver transplant pioneer T. Starzl and that included azathioprine, prednisolone, and the antilymphocyte globulin, which use made it possible to reduce the doses of the first two drugs and prevent side effects from their use. In addition, D. Cooley proposed the first algorithm for monitoring an acute graft rejection: ECG, erythrocyte sedimentation rate, blood levels of lactate dehydrogenase and leukocytosis, increased body temperature, decreased exercise tolerance and cardiac output, signs of cardiac weakness, etc. [32].

The experience of 12 transplantations allowed D. Cooley to expand indications for transplantation. These, in particular, included heart lesions in amyloidosis and systemic vasculitis, cardiomyopathy due to myocardial dystrophy, and congenital heart defects not subjected to radical correction. The list of contraindications was also expanded. These included: diabetes that could be exacerbated by immunosuppressive therapy, pulmonary hypertension, cancer, infection, and an old age (as a relative contraindication). In addition to transplanting human hearts, D. Cooley performed an unsuccessful heart transplant from ram to a human and a heart-lung complex transplant in a 2-month-old girl with atrioventricular communication and pulmonary hypertension from a donor with anencephaly [33].

After 18 transplantations of D. Cooley summed up the first results: 15 of 17 patients died, 12 of whom had coronary insufficiency as the cause of death. Three patients died from progression of rheumatism, cardiomyopathy, and endocardial fibroelastosis. However, D. Cooley came to an optimistic conclusion: since some of his patients lived for 5 months or more, they could have potentially lived longer. The main problem, in his opinion, was the histo-incompatibility of the donor's heart and the recipient's body [34]. Recall that of the patients operated on by

him in 1968, 2 lived for more than 3 months (126 and 146 days), and one patient, operated on March 5, 1968, lived for 202 days; later, on November 20, he was retransplanted with another heart with which lived for another 3 days [35].

The Table shows patients who had lived for more than 3 months by March 1, 1971, listing the surgeons who operated on them.

Table. Survival of patients after orthotopic heart transplantation by March 1, 1971 [35]

A patient	Date of surgery	Number of days lived up to March 1, 1971	Surgeon
Blaiberg	01/02/1968	593	C. Barnard, South Africa (1)
Thomas	03/05/1968	204*	D. Cooley, USA (1)
Boulogne	05/12/1968	523	Ch. Dubost, France
Fierro	05/21/1968	146	D. Cooley, USA (2)
De Bord	02/07/1968	149	D. Cooley, USA (3)
Everman	07/20/1968	266	D. Cooley, USA (4)
Jurgens	07/23/1968	170	D. Cooley, USA (5)
Russell	**08/24/1968**	**919****	**R. Lower, USA**
McKee	08/31/1968	624	N. Shumway, USA (1)
Carroll	**08/31/1968**	**912**	**M. DeBakey, USA (1)**
Anolik	09/01/1968	443	H. Banson, USA
Orlandi	09/02/1968	409	J. Zerbini, Brazil
lawson	04/09/1968	476	D.B. Effler, USA
Smith	08/09/1968	621	C. Barnard, South Africa (2)
Ashche	10/09/1968	132	N. Shumway, USA (2)
Vlako	**09/19/1968**	**894**	**M. DeBakey, US (2)**
Barnum	09/20/1968	446	D. Kahn, USA (1)
Sanchez	**01/10/1968**	**881**	**L. Kaplan, Chile**
Ongaro	09/10/1968	204	D. Wilson , Canada
Harrison	10/18/1968	177	M. DeBakey, USA (3)
Anick	**10/21/1968**	**861**	**D. Lepley, USA**
Decker	25/10/1968	126	D. Cooley, USA (6)
Sheaffer	**26/10/1968**	**856**	**N. Shumway, USA (3)**
Parkinson	**03/11/1968**	**848**	**L. MacLean, Canada**
Johnston	**11/17/1968**	**834**	**S. Baker, Canada**
Karraker	11/22/1968	281	N. Shumway, USA (4)
Vitria	**11/27/1968**	**824**	**E.Henry, France**
Kaminski	**01/12/1968**	**820**	**D. Kahn, USA (2)**
Marion	12/22/1968	225	F. Fontan, France
Gilien	08/02/1969	751	N. Shumway, USA (5)
Pounds	04/14/1969	686	N. Shumway, USA (6)

Fisher	04/17/1969	683	C. Barnard, South Africa (3)
Trout	22/05/1 9 69	648	N. Shumway , USA (7)
Paul	08/13/1969	565	B. Roe, USA
Johnson	03/09/1969	544	N. Shumway, USA (8)
Bartholomew	09/29/1969	518	T. Starzl, USA
Van Buren	04/01/1970	421	N. Shumway, USA (9)
Marshall	01/16/1970	409	N. Shumway, USA (10)
Madigan	04/28/1970	307	C. Baker, USA
Townswick	04/07/1970	240	N. Shumway , USA (11)

* 202 days after surgery, D. Cooley transplanted a heart to this patient for the 2nd time, but the patient died on the 3rd day.

** Bold indicates patients who survived more than 800 days after surgery.

It is easy to note that survivors for longest time were those operated on by R. Lower (919 days), M. DeBakey (912 and 894 days) and L. Kaplan (881 days). The greatest number of "long-live" survivors were operated on by N. Shumway (11 patients), followed by D. Cooley (6 patients), C. Barnard and M. DeBakey (3 patients each), and D. Kahn (2 patients). Moreover, the survival results among D. Cooley patients look modest compared to the performance of other surgeons. According to contemporaries, if in the middle of 1968 D. Cooley was in a state of euphoria from his successes and predicted that heart transplants would become a daily operation in the 1970s, later on, the fight to save the live to E. Thomas who lived with a transplanted heart for 202 days and died on the 3rd day after its replacement, significantly reduced the enthusiasm of the surgeon, who became famous so overnight. After April 1969 D. Cooley made a couple more surgeries, but both recipients died soon after. “I joined the transplant program with great hope,” said cardiologist J.Nora, a member of his team. “Our first transplants seemed so encouraging that we thought we had somehow overcome this fundamental biological rule: the body rejects foreign tissue in order to protect itself from it. But we have not overcome this rule. Once J. Nora came to D. Cooley in desperation, begging him to stop. The surgeon then prepared for a new transplant. “At least wait until we find a better match,”

J. Nora told him. "That's the wrong candidate." “But I promised his family,” D. Cooley shrugged. Of course, he was worried about his failures, but, as V.P. Demikhov once did, not paying attention to them, walked forward. It seemed to him that just about, and he would grab God by the beard [35]. N. Shumway also tried to replace a stopped transplanted heart with another one, but his patient lived only a few hours.

An analysis of the number of heart transplants by years and months showed that since 1968 the number of these operations in clinic had considerably decreased. So, in 1968, 101 heart transplants were performed, in 1969 there were 47 of them, and in 1970 and 1971 only 17 operations each. Some eminent cardiac surgeons (J. Kirklin, D. McGoon) did not make them at all in principle.

The greatest number of transplants, 118 of 184 (64%), were made by Americans. It is no coincidence that of 29 recipients who were alive by the beginning of 1972, 22 (76%) had been operated on in the USA. The second place belonged to the Canadians (17 transplants and 4 survivors); the third were C. Barnard with his team (10 transplants and 2 survivors) and the French (10 operations and 1 survivor). In other countries, 29 heart transplants were performed, but none of the patients survived until 1972 [29].

Besides N. Shum way and D. Cooley, a great experience with heart transplants was gained by M. DeBakey (Fig. 10), more careful than the first two surgeons. In 1969, he published the results of 10 transplantations performed from September 1968 to January 1969: 9 patients suffered from ischemic cardiomyopathy and one 16-year-old adolescent had a complete form of congenital heart disease known as atrioventricular canal with end-stage heart failure, ascites, and cachexia. Two patients survived, including a teenager with AVC. Postoperative follow-up showed that the

survivors had a satisfactory quality of life and tolerate physical activity well. When studying the causes of death of 8 patients, it turned out that their donor hearts were not suitable for transplantation due to severe coronary angiosclerosis [36]. Since this publication, coronary angiography of the donor heart has become mandatory.

We emphasize, at that time the moral and ethical issues of heart transplantation in most countries, except for the USSR, were resolved by law and did not impede the development of the issue. It was hampered by insufficiently developed rules of the patient selection, the transplantation technique and tactics of postoperative management, intra- and postoperative complications, toxic immunosuppressants and, as a result, poor outcomes.

Fig. 10. Professor M.E. DeBakey (1908–2008). Baylor College of Medicine, Houston, Texas, USA

The first experiments on the creation and implantation of an artificial heart (AH) in animals in 1957 in Cleveland were carried out by a group of surgeons led by W. Kolff and T. Akutsu. After the replacement of the native heart with a mechanical one, the animals lived up to 1.5

hours. But these experiments did not go beyond the experimental laboratory.

The failures of heart transplantation in clinic became the impetus for continuing research in this area. In 1968, M. DeBakey took up the creation of a biventricular AH. His device consisted of two pneumatically driven Dacron pumps, was externally controlled and was supposed to be a bridge to donor heart transplantation. M. DeBakey implanted it in 7 calves, but all died from organ hypoperfusion. It turned out that the pressure created by the mechanical heart to maintain blood pressure did not provide adequate perfusion of the calf [37]. M. DeBakey began to improve the design of the AH, hoping to be the first to implant it in a human, but it so happened that D. Cooley got ahead of him and on April 4, 1969, performed the first implantation of D. Liotta-designed AH (Fig. 11) to a 47-year-old patient with acute heart failure.

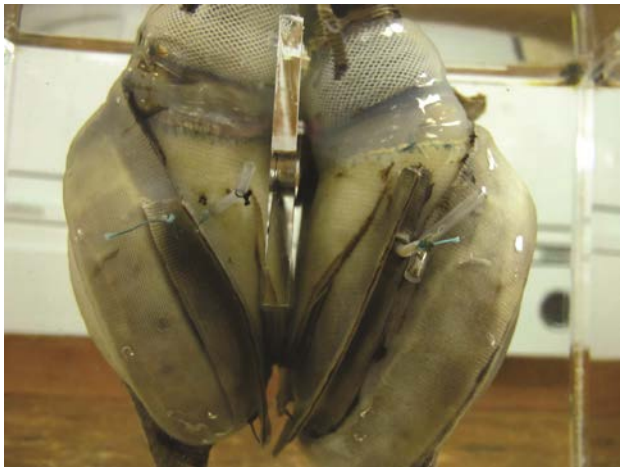


Fig. 11. The world's first artificial heart made of dacron, polyurethane and silastic designed by D. Liotta − D. Cooley. 1969. Available at: https://www.theatlantic.com/technology/archive/2010/10/the-worlds-first-artificial-heart/63949/

There is a mythologem that it was this fact that caused a quarrel between two great surgeons of the twentieth century, who reconciled shortly before the death of M. DeBakey in 2008 (Fig. 12). However, their

achievements led to the fact that Houston (Texas, USA), where they (M. DeBakey and D. Cooley) worked, became the world capital for the treatment of diseases of the heart and blood vessels.

Fig. 12. Dr. DeBakey accepting honorary membership in the Denton A. Cooley Cardiovascular Surgery Society. D. Cooley − left, M. DeBakey − right. 2007. Available at: https://bulletin.facs.org/2017/04/memoriam-denton-cooley-md-facs-fierce-competitor/cooley-debakey/

But a real "long-live" survivor among donor heart recipients was E. Vitria, a traveling salesman from Marseille, who was operated on by E. Henry on November 27, 1968. The patient, who at the time of surgery was 48 years old, lived after it for 18 years, 5 months and 13 days, and died on May 11, 1987. After the surgery, he continued enjoying life, drove a car, swam in the sea, smoked cigarettes, drank wine and loved women. In 1982, E. Vitria, was awarded the highest award of France, the Order of the Legion of Honor (Fig. 13), for glorifying French surgery throughout the world.

Fig. 13. Mayor of Marseille G. Deferre presents E. Vitria, who has lived with a donor heart for 10 years, on the day of the anniversary of his operation, the Legion of Honor. Marseille, November 27, 1978. Available at: https://www.gettyimages.ae/detail/news-photo/emmanuel-vitria-b%C3%A9n%C3%A9ficiare-dune-transplantation-cardiaque-news-photo/1301013897

Unfortunately, the dog Grishka, who lived longest in the world of dogs with a transplanted heart for 141 days in 1962, was remembered only in the 1980s, and not by Soviet, but by European surgeons who awarded V.P. Demikhov with a special diploma of the pioneer of experimental heart transplantation in Munich in 1989.

Conclusion

Thus, in the Soviet Union, after an unsuccessful operation of transplanting a human heart to a human, which was performed on November 4, 1968, by A.A. Vishnevsky, the Director of the A.V. Vishnevsky Institute of Surgery of the USSR Academy of Medical Sciences, surgeons from many clinics in the country began experimental studies on the problem: methods were developed for an isolated heart preservation to maintain its viability; models of orthotopic and

heterotopic heart transplantation were created on large and small animals; morphological, physiological, biochemical and immunological changes in a transplanted heart were studied.

The second in the USSR operation of clinical heart transplantation on June 10, 1971 was performed by G.M. Solovyov, but soon after the intervention, the recipient died. It should be noted that before performing the operation in the clinic, the surgeons of the Institute made several series of experiments, during which they worked out the technical and medical aspects of the operation.

At the same time, the previous 20-year experience of experimental heart transplantation by V.D. Demikhov he had gained 1946–1967 was used only partially: a number of surgeons used V.P. Demikhov-designed cardiopulmonary complex for biological conservation of the heart in experimental animals.

Abroad, the situation was different. After a successful heart transplant performed on December 3, 1967, by C. Barnard, a worldwide boom in clinical transplantation began. In 1968, 101 such operations were performed. Most were performed in the USA. For example D. Cooley performed them on 21 patients and performed two operations on 1 more patient. There were cases where the patients operated on in 1968 lived for 800–900 or more days. R. Lower, M. DeBakey, and N. Shumway had the best results with a more number of successful operations performed by N. Shumway.

However, the vast majority of operations ended in deaths in the immediate or late postoperative periods. This led to the fact that the euphoria from successful transplants began to decrease: 47 operations were performed in 1969, and 34 operations in 1970-1971 (i.e. 17 per year).

It's time to sum up and reflect on what has been done.

References

1. Solovyev GM, Kisis SYa, Radzivil GG, Gruzdev YuK, Chernov VA, Naumov SP, et al. Nash pervyy opyt peresadki serdtsa v klinike. In: Solovyev GM. (ed.) *Transplantatsiya serdtsa i konservatsiya organov v eksperimente i klinike:* nauchnye trudy Instituta transplantatsii organov i tkaney AMN SSSR. Moscow; 1972. p. 43–49. (In Russ.).

2. Vishnevskiy AA, Kolesnikov IS, Portnoy VF, Arapov AD, Ballyuzek FV, Kaydash AN, et al. Peresadka serdtsa cheloveku. (Predvaritel'noe soobshchenie o pervoy operatsii, osushchestvlennoy voennymi vrachami 4/XI 1968 g. v Voenno-meditsinskoy akademii im. S.M. Kirova) *The Military Medical Journal.* 1968;12:8–15. (In Russ.).

3. Cherkashchenko LN, Pronina TV. Issledovanie kontsentratsii fosfornykh soedineniy v miokarde pri ekstrakorporal'nom sokhranenii i gomotransplantatsii serdtsa sobak. In: Solovyev GM. (ed.) *Transplantatsiya organov i tkaney:* Materialy V Vsesoyuznoy nauchnoy konferentsii po peresadke organov i tkaney. Gor'kiy; 1970. p. 249–250. (In Russ.).

4. Portnoy VF, Pochinko VV, Cherkashchenko LN, Shargorodskaya AYa. Polyarizuyushchaya gipotermicheskaya koronarnaya perfuziya kak metod kratkovremennogo sokhraneniya serdtsa i vvedeniya v dlitel'nuyu konservatsiyu. In: Solovyev GM. (ed.) *Transplantatsiya organov i tkaney:* Materialy VI Vsesoyuznoy nauchnoy konferentsii po peresadke organov i tkaney. Riga; 1972. p. 402–404. (In Russ.).

5. Dvortsin GF. Kardio- i gemodinamika izolirovannogo serdtsa v usloviyakh ekstrakorporal'nogo podklyucheniya v geterotopicheskuyu pozitsiyu. In: Solovyev GM. (ed.) *Transplanta-tsiya organov i tkaney:* Materialy VI Vsesoyuznoy nauchnoy konferentsii po peresadke organov i tkaney. Riga; 1972. p. 251–252. (In Russ.).

6. Portnoy VF, Dvortsin GF, Grishkevich VM. Ekspress-otsenka sostoyaniya gemodinamiki posle ortotopicheskoy peresadki serdtsa s

pomoshch'yu elektromagnitnogo raskhodomera i vychislitel'nykh ustroystv. In: Solovyev GM. (ed.) *Transplantatsiya organov i tkaney:* Materialy VI Vsesoyuznoy nauchnoy konferentsii po peresadke organov i tkaney. Riga; 1972. p. 240. (In Russ.).

7. Matyushin IF, Portnoy VF, Pochinko VV, Samartseva TF, Travina NM. Issledovanie vosstanovitel'nogo perioda posle anoksii miokarda i kratkovremennoy konservatsii serdtsa. In: Solovyev GM. (ed.) *Transplantatsiya organov i tkaney:* Materialy VI Vsesoyuznoy nauchnoy konferentsii po peresadke organov i tkaney. Riga; 1972. p. 422–424. (In Russ.).

8. Burakovskiy VI, Falkovskiy GE, Frolova MA. Osobennosti ostrogo ottorzheniya allotransplantanta serdtsa. In: Solovyev GM. (ed.) *Transplantatsiya organov i tkaney:* Materialy V Vsesoyuznoy nauchnoy konferentsii po peresadke organov i tkaney. Gorkiy; 1970. p. 271–272. (In Russ.).

9. Kazakov EN, Galankina IE Geterotopicheskaya transplantatsiya serdtsa. Klinicheskaya i morfologicheskaya kharakteristika reaktsii ostrogo ottorzheniya. In: Solovyev GM. (ed.) *Transplantatsiya organov i tkaney:* Materialy V Vsesoyuznoy nauchnoy konferentsii po peresadke organov i tkaney. Gorkiy; 1970. p. 252–253. (In Russ.).

10. Kazakov EN. Kliniko-laboratornaya kharakteristika krizov ottorzheniya geterotopicheski transplantirovannogo serdtsa. In: Solovyev GM. (ed.) *Transplantatsiya organov i tkaney:* Materialy VI Vsesoyuznoy nauchnoy konferentsii po peresadke organov i tkaney. Riga; 1972. p. 242–243. (In Russ.).

11. Frolova MA, Gudkova RG, Bolshukhina LA, Falkovskiy GE. Fermentativnaya aktivnost' limfotsitov krovi kak vozmozhnyy pokazatel' razvitiya reaktsii ottorzheniya pri allotransplantatsii serdtsa. In: Solovyev GM. (ed.) *Transplantatsiya organov i tkaney:* Materialy VI Vsesoyuznoy nauchnoy konferentsii po peresadke organov i tkaney. Riga; 1972. p. 198. (In Russ.).

12. Gadzhiev AA, Yarlykova EI, Ilin VN, Matveev YuG. Autoperfuziya serdtsa v usloviyakh izolirovannogo serdechno-legochnogo preparata. In: Solovyev GM. (ed.) *Transplantatsiya organov i tkaney:* Materialy VI Vsesoyuznoy nauchnoy konferentsii po peresadke organov i tkaney. Riga; 1972. p. 424–425. (In Russ.).

13. Makarov AA, Alekseev LM, Danilov MA, Didenko VI, Kabkova IK, Krutik IG, et al. Izuchenie vozmozhnosti ispol'zovaniya serdechno-legochnogo preparata dlya biologicheskoy konservatsii serdtsa. In: Solovyev GM. (ed.) *Transplantatsiya organov i tkaney:* Materialy V Vsesoyuznoy nauchnoy konferentsii po peresadke organov i tkaney. Gorkiy; 1970. p. 434–435. (In Russ.).

14. Savelyev VS. Sovremennye printsipy konservatsii serdtsa. In: Solovyev GM. (ed.) *Transplantatsiya organov i tkaney:* Materialy V Vsesoyuznoy nauchnoy konferentsii po peresadke organov i tkaney. Gorkiy; 1970. p. 430. (In Russ.).

15. Kukhareva NS, Kostenko IG, Makarov AN, Smirnov SV. Sravnitel'naya otsenka razlichnykh metodov konservatsii, po dannym EKG peresazhennogo serdtsa. In: Solovyev GM. (ed.) *Transplantatsiya organov i tkaney:* Materialy V Vsesoyuznoy nauchnoy konferentsii po peresadke organov i tkaney. Gorkiy; 1970. p. 433–434. (In Russ.).

16. Stupin IV, Smirnov SV. Operatsionnye i blizhayshie oslozhneniya vo vremya operatsii peresadki serdtsa v eksperimente. In: Solovyev GM. (ed.) *Transplantatsiya organov i tkaney:* Materialy V Vsesoyuznoy nauchnoy konferentsii po peresadke organov i tkaney. Gorkiy; 1970. p. 259–260. (In Russ.).

17. Gerasimenko NI, Averbakh MM. Funktsional'naya polnotsennost' zhiznedeyatel'nosti izolirovannogo serdechno-legochnogo preparata. In: Solovyev GM. (ed.) *Transplantatsiya organov i tkaney:*

Materialy VI Vsesoyuznoy nauchnoy konferentsii po peresadke organov i tkaney. Riga; 1972. p. 434–435. (In Russ.).

18. Konevskiy AG, Gavrikov KV, Dvoretskaya MN, Petrenko LA. Peresadka serdtsa. Vliyanie polovykh osobennoy i nekotorykh fiziologicheskiy sostoyaniy na posttransplantatsionnyy period. In: Solovyev GM. (ed.) *Transplantatsiya organov i tkaney:* Materialy VI Vsesoyuznoy nauchnoy konferentsii po peresadke organov i tkaney. Riga; 1972. p. 248–249. (In Russ.).

19. Atamanyuk MYu, Knyshev GV, Lissova OI, Tsyganiy AA, Yusin VYa, Vovchenko OI. K metodike peresadki serdtsa (predvaritel'noe soobshchenie). In: Solovyev GM. (ed.) *Transplantatsiya organov i tkaney:* Materialy V Vsesoyuznoy nauchnoy konferentsii po peresadke organov i tkaney. Gorkiy; 1970. p. 246–247. (In Russ.).

20. Amosov NM, Beregorovskiy BA, Gorbach AA, Lissova OI, Lobkova MD, Mishchenko VI, et al. Gomotransplantatsiya serdtsa posle dlitel'noy ostanovki. In: Solovyev GM. (ed.) *Transplantatsiya organov i tkaney:* Materialy V Vsesoyuznoy nauchnoy konferentsii po peresadke organov i tkaney. Gorkiy; 1970. p. 247. (In Russ.).

21. Volkolakov YaV, Putninsh OE, Latsis GV, Latsis AT, Breytsis YuG, Ledus VE. Primenenie metoda glubokoy gipotremii pri transplantatsii serdtsa v eksperimente. In: Solovyev GM. (ed.) *Transplantatsiya organov i tkaney:* Materialy VI Vsesoyuznoy nauchnoy konferen-tsii po peresadke organov i tkaney. Riga; 1972. p. 236–237. (In Russ.).

22. Goryaynov VM. Elektrokardiograficheskoe issledovanie peresazhennogo serdtsa. In: Solovyev GM. (ed.) *Transplantatsiya organov i tkaney:* Materialy V Vsesoyuznoy nauchnoy konferentsii po peresadke organov i tkaney. Gorkiy; 1970. p. 251–252. (In Russ.).

23. Solovyev GM, Lipovetskiy GS, Zimin NK, Chistyakov VN, Gruzdev YuK, Kormer AYa, et al. Ortotopicheskaya transplantatsiya serdtsa u sobak i

sviney v usloviyakh perekrestnogo i iskusstvennogo krovoobrashcheniya. In: Solovyev GM. (ed.) *Transplantatsiya serdtsa i konservatsiya organov v ekspe-rimente i klinike:* Nauchnye trudy Instituta transplantatsii organov i tkaney AMN SSSR. Moscow; 1972. p. 9–17. (In Russ.).

24. Lipovetskiy GS, Chistyakov VN, Zimin NK, Kormer AYa, Vavilov VA. Ortotopicheskaya transplantatsiya serdtsa na shchenkakh v usloviyakh glubokoy gipotermii. In: Solovyev GM. (ed.) *Transplantatsiya serdtsa i konservatsiya organov v eksperimente i klinike:* Nauchnye trudy Instituta transplantatsii organov i tkaney AMN SSSR. Moscow; 1972. p. 18–26. (In Russ.).

25. Danilov MA. Tekhnika geterotopicheskoy peresadki serdtsa na krysakh. In: Solovyev GM. (ed.) *Transplantatsiya serdtsa i konservatsiya organov v eksperi-mente i klinike:* Nauchnye trudy Instituta transplantatsii organov i tkaney AMN SSSR. Moscow; 1972. p. 27–34. (In Russ.).

26. Deev VG, Danilov MA, Vasilenko VT, Guldyaev VV. Intraabdominal'naya peresadka serdtsa u krys. In: Solovyev GM. (ed.) *Transplantatsiya serdtsa i konservatsiya organov v eksperimente i klinike:* Nauchnye trudy Instituta transplantatsii organov i tkaney AMN SSSR. Moscow; 1972. p. 35–42. (In Russ.).

27. Demikhov VP. *Peresadka zhiznenno-vazhnykh organov v eksperimente.* Moscow: Medgiz Publ.; 1960. (In Russ.).

28. Amosov NM. *Golosa vremen.* Moscow: Vagrius Publ.; 1999.

29. Molkov YuN, Sidorina TA. Nekotorye dannye po statistike vyzhivaemosti patsientov s peresazhennym serdtsem. In: Solovyev GM. (ed.) *Transplantatsiya serdtsa i konservatsiya organov v eksperimente i klinike:* Nauchnye trudy Instituta transplantatsii organov i tkaney AMN SSSR. Moscow; 1972. p. 50–55. (In Russ.).

30. Cooley DA. Human heart transplantation: past, present, future. *Abbotttempo.* 1971;9(3):2–5.

31. Leachman R, Leathermav L, Rochelle DG, Nora JJ, Butler WT, Rossen RD, et al. *Transplantation of Human Heart. Houston:* Medical Communication; 1969.

32. Cooley D, Bloodwell R. Transplantation of the human heart. Report of four cases. *JAMA.* 1968;205(7):479–486. PMID: 4876454

33. Cooley DA, Hallman GL, Bloodwell RD, Nora JJ, Leachman RD. Human heart transplantation. Experience with twelve cases. *Am J Cardiol.* 1968;22(6):804–810. PMID: 4880225 https://doi.org/10.1016/0002-9149(68)90175-6

34. Cooley DA, Bloodwell RD, Hallman GL, Leachman RD, Nora JJ, Rochelle DG, et al. Human cardiac transplantation. *Circulation.* 1969;39(5 Suppl 1.):I3–I12. PMID: 4893439 https://doi.org/10.1161/01.cir.39.5s1.i-3

35. Thompson Th. Hearts: of surgeons and transplants, miracles and disasters along the cardiac frontier. New York: The McCall Publ. Co; 1971.

36. De Bakey ME, Diethrich EB, Glick G, Noon GP, Butler WT, Rossen RD, et al. Human cardiac transplantation: clinical experience. *J Thorac Cardiovasc Surg.* 1969;58(3):303–317. PMID: 4897631

37. DeBakey ME, Hall CW, Hellums JD, O'Bannon W, Bourland H, Feldman L, et al. Orthotopic cardiac prosthesis: preliminary experiments in animals with biventricular artificial heart. *Cardiovasc Res Cent Bull.* 1969;7(4):127–142. PMID: 4895797

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