

## E.N. Meshalkin (1916–1997) and his priority in the construction of the world’s first clinically successful cavopulmonary anastomosis

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Received 17 July 2017. Accepted 13 August 2017.

The idea of a cavopulmonary anastomosis originated simultaneously with US surgeons (A. Blalock), Italy (C. Carlon), the USSR (A. Bakulev) and Hungary (F. Robiczek). The first experimental cavopulmonary shunt in several modifications was carried out by C. Carlon in the late 1949 – early 1950s. The first two unsuccessful operations in clinic were performed by the American surgeon H. Shumacker before November 1954. Priority of the world’s first series of clinically successful operations belongs to E.N. Meshalkin (from April 3 to October 1956). In a sense, his success was due to experimental research done over a period from autumn 1955 to spring 1956 by N.K. Galankin, T.M. Darbinian, and D.A. Donetsky. However, up until August 1956 N.K. Galankin and his colleagues objectively were not ready to introduce cavopulmonary anastomosis in clinical practice. The first successful cavopulmonary shunt in the USA was carried out by W. Glenn on February 25, 1958. The author’s experience, his authority, and publication in a prestigious journal led to the fact that cavopulmonary anastomosis in literature is usually called Glenn procedure. We believe, however, that it would be more correct to call it the Bakulev–Meshalkin operation or Russian anastomosis.

**Keywords:** cavopulmonary anastomosis; E.N. Meshalkin; the world’s first clinically successful cavopulmonary anastomosis

**How to cite:** Bockeria L.A., Podzolkov V.P., Glyantsev S.P., Kokshenev I.V., E.N. Meshalkin (1916–1997) and his priority in the creation of the world’s first successful cavo-pulmonary anastomosis in clinic. *Patologiya krovoobrashcheniya i kardiokirurgiya = Circulation Pathology and Cardiac Surgery*. 2017;21(3S):80-90. (In Russ.). <http://dx.doi.org/10.21688/1681-3472-2017-3S-80-90>

### Introduction

One of the techniques used for surgical treatment of Fallot tetralogy in the fifties of the last century was to increase pulmonary blood flow by constructing anastomosis between the superior vena cava and the pulmonary artery. This technique was named “cavopulmonary anastomosis [1].”

The evolution of the idea and the development of this technique are described in both domestic and foreign literature [2, 3]. However, if foreign surgeons’ priorities (for instance, C. Carlon, W. Glenn and others) are set forth in reasonable detail, then the research carried out

in Russia is not always accurate, even if brought back by the researchers’ memory [4]. On adding more precise data to those already obtained before, the authors put down the main stages of cavopulmonary anastomosis evolution from its onset to the beginning of the XXI century [5, 6]. However, a lot of materials collected did not allow them to shed light on one of the priorities of Soviet surgery—a series of the world’s first cavopulmonary anastomosis operations performed by E.N. Meshalkin in spring 1956 in Moscow.

Our paper is designed to fill this gap in domestic and world’s medical historiography.





**Fig. 1.** Professor Nikolai K. Galankin (1914–1977)

### Italy – USA – Hungary: how it all began

The idea of connecting the superior vena cava and the pulmonary artery originated simultaneously with several surgeons in different countries independently of each other, but the aim of its implementation was different [2–5].

In 1949, A. Blalock and his colleagues were the first to develop an experimental model of anastomosis between the pulmonary artery and the superior vena cava or the innominate vein to unload pulmonary circulation in patients with transposition of the great arteries and tried to introduce it in clinical practice, unfortunately to no avail. At the same time, a group of surgeons under the leadership of F. Gerbode conducted experiments on animals aimed at exploring the possibility of repairing the defects of blood drain from the superior vena cava by applying left-atrial-pulmonary anastomosis [2], while S. Rodbard and D. Wagner developed a right-atrial-pulmonary anastomosis to correct pulmonary trunk atresia [4].

C.A. Carlon et al. were the first to announce a new method of filling up the pulmonary vessels on March 27, 1950 [4]. The authors presented a few models: 1) “end-to-end” anastomosis between a proximal end of the superior vena cava and a distal end of the right pulmonary artery;

2) “end-to-end” anastomosis between the azygos vein and the right pulmonary artery; 3) “end-to-side” anastomosis between the azygos vein and the right pulmonary artery followed by securing the superior vena cava ostia; 4) “end-to-side” anastomosis between the azygos vein and the right pulmonary artery followed by ligating the ostia of the superior vena cava and the right pulmonary artery [7]. All techniques were tested on dogs, with the only survivors being the dogs that received the second model of cavopulmonary anastomosis. Therefore, C. Carlon did not dare to use the technique in clinic up until 1964 when he announced his first clinical outcomes [3].

In 1954, W. Glenn and J. Patino reported about cavopulmonary anastomosis modeling in 9 dogs, which was performed by using C. Carlon’s azygo-pulmonary shunt [8].<sup>1</sup> In 1955, W. Glenn’s group operated 50 more dogs, 6 of which lived postoperatively for a considerable time. By June 1957, the group performed 75 observations, in the majority of which superior vena cava and pulmonary artery were anastomosed with the azygos vein. Like C. Carlon, W. Glenn was not prepared to do surgery in clinic at that time [4].

The same year, F. Robiczek et al. started their experimental studies on the technique by modeling a direct cavopulmonary anastomosis between the superior vena cava and the right pulmonary artery according to C. Carlon’s first model “end-to-end.” Later, the authors operated 15 dogs and in 1956 described their experience by suggesting using anastomosis to repair congenital heart diseases with lowered pulmonary blood flow. Since the modest Hungarian surgeons were not aware of other publications, they called the operation as “our proposal [10].”

H.B. Shumacker was the first to construct a clinical cavopulmonary anastomosis. In the early 1950s, he observed two children with pulmonary hypertension caused by a common arterial trunk in one of them and transposition of the great arteries in the other. Both children received an “end-to-end” shunt between the superior vena cava and the right pulmonary artery. However, both patients died after 8 and 15 hours respectively, therefore, H.B. Shumacker did not publish his observation; but when debating on pulmonary blood

<sup>1</sup> In 1999 I.E. Konstantinov and V.V. Aleksi-Meskishvili suggested that this technique should be called Carlon’s procedure [4].



**Fig. 2.** Ph.D. student T.M. Darbinian (1929–2009) and Professor A.A. Vishnevsky (1906–1975) [Cardiovascular Surgery Museum at A.N. Bakulev National Medical Research Center of Cardiovascular Surgery]

flow problems in 1954, he mentioned this case without giving the precise date of surgery, thus demonstrating that a human's heart can function with its right heart partly bypassed at least during a few hours [9].

### **N.K. Galankin, T.M. Darbinian and D.A. Donetsky were the first surgeons in the USSR who formed an experimental cavopulmonary shunt**

There exist some data that in the USSR the idea of filling the pulmonary bed with blood by making use of the superior vena cava was born in A.V. Vishnevsky Institute of Surgery at the beginning of 1955. One of its authors, N.K. Galankin, described this event as follows:<sup>2</sup>

*“In January 1955, A.V. Vishnevsky operated a girl for tetralogy of Fallot. He put a Blalock–Taussig’s shunt with the subclavian artery elongated by using a graft.<sup>3</sup> During the surgery,*

<sup>2</sup> This description differs from that (according to T.M. Darbinian) quoted in the paper [4].

<sup>3</sup> Vishnevsky – Donetsky procedure

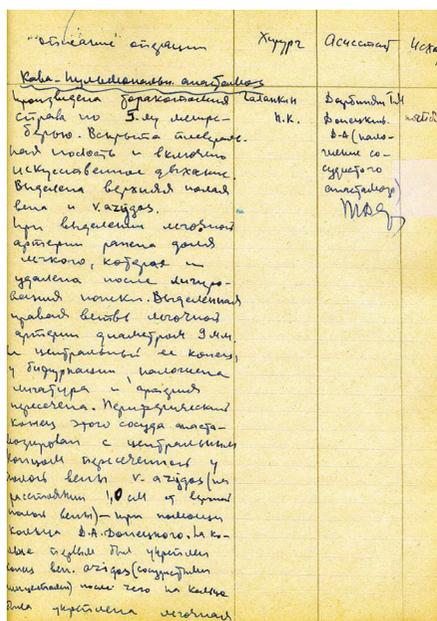
*an additional left superior vena cava of the same diameter as the left pulmonary artery was exposed in the patient. ... The vessels were so close to each other that “they themselves were begging to be connected.” I told A.A. [Vishnevsky] about that. ... “How?” promptly responded he. “Bypassing the right ventricle, straight into the lungs? A very bright idea, but you can’t do it without experiment! [2]”*

What had happened to that idea later on became clear when we looked through the 1955 surgical protocols of the Experimental Department at the A.V. Vishnevsky Institute of Surgery, which were stored in the Cardiovascular Surgery Museum of A.N. Bakulev Scientific Center for Cardiovascular Surgery. It was found out that the first cavopulmonary anastomosis in a 24-kg dog was performed by N.K. Galankin (Fig. 1) and T.M. Darbinian (Fig. 2), the intern of his Department, during 2 hours on August 26, 1955 (Fig. 3).

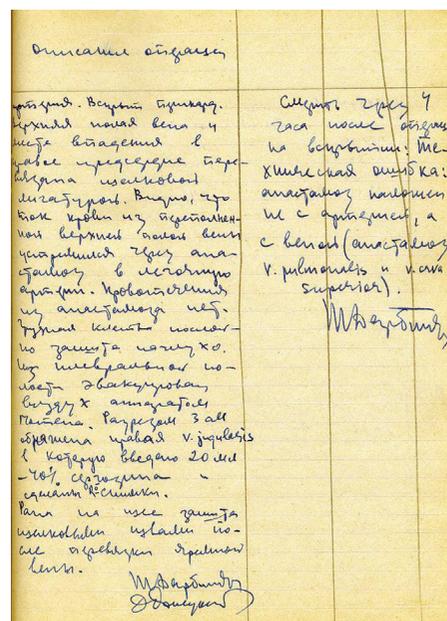
The operation had three features: 1) cavopulmonary anastomosis was applied similarly to an azygopulmonary model; 2) the shunt was constructed by means of a steel ring with spikes<sup>4</sup>; 3) the autopsy of the dog, which died 4 hours after surgery, revealed a technical mistake: anastomosis was formed not with the pulmonary artery but the pulmonary vein (Fig. 4). Subsequent operations lasted 3.5–4 hours, however, the first 5 dogs died. Survived was only the 6th dog operated by T.M. Darbinian on October 26. After 10 days the dog underwent vasography which revealed anastomosis patency.

T.M. Darbinian wrote about the causes of the first animals' death and why the 6th dog survived. *“When I started analyzing our failures, I noticed that this [6th] dog had been already operated on the left lung. Therefore, this lung was fixed by adhesions to the thoracic wall and was in a flattened state. Dogs have a very thin membrane between the pleural cavities, and following surgery on the right side, pneumothorax tends to easily develop on the left. In the first 5 dogs, we drained the right pleural cavity only, with the left lung partially deflated. Therefore, because of increased vascular resistance in the left lung against the background of its collapse the blood flow*

<sup>4</sup> This ring was designed by D.A. Donetsky, the then young employee of the Institute of Surgery of USSR Academy of Medical Sciences. Its application would reduce the time of superior vena cava clamping by 5–6 min. The above fact enables to conclude that the given technology of vascular suturing was in use from the onset of experiments.



**Fig. 3.** The starting page of the experimental-cavopulmonary-anastomosis protocol (first operation). Surgeons: N.K. Galankin, T.M. Darbinian, D.A. Donetsky. A.V. Vishnevsky Institute of Surgery, Moscow, August 1955. [Cardiovascular Surgery Museum at A.N. Bakulev National Medical Research Center of Cardiovascular Surgery]



**Fig. 4.** The final page of the experimental-cavopulmonary-anastomosis protocol (first operation) with autographs of T.M. Darbinian and D.A. Donetsky and description of intervention outcomes. A.V. Vishnevsky Institute of Surgery, Moscow, August 1955. [Cardiovascular Surgery Museum of A.N. Bakulev National Medical Research Center of Cardiovascular Surgery]

through the anastomosis was hindered [4].” However, the 7th and the 8th dog died again, this time of bleeding.<sup>5</sup>

On operating 8 animals and summing up the results of the technique development, at the end of 1955 N.K. Galankin and T.M. Darbinian sent a paper named “Experimental cavopulmonary anastomosis (a preliminary report)” to the “Eksperimentalnaya khirurgiya” journal. In their paper, the authors suggested that the operation could be used to increase pulmonary blood flow in patients with congenital heart disease and pulmonary hypotension. Despite the fact that the journal’s editor-in-chief was their leader, A.A. Vishnevsky, the editorial board decided to return the paper to the authors for revision, and not because, as was suggested by I.E. Konstantinov and V.V. Aleksi-Meskhishvili, the editorial board secretary

<sup>5</sup> Five of eight animals were operated by N.K. Galankin, the remainder—by T.M. Darbinian. D.A. Donetsky took part in 7 operations. In one case anastomosis was not constructed because the dog named Tarzan died of atrial fibrillation on the operating table.

E.N. Meshalkin “held it back” for 4 months (according to T.M. Darbinian) [2]. We believe that the editorial board members: M.G. Grigoriyev, I.S. Zhorov, V.V. Kovanov, E.N. Meshalkin, S.P. Protopopov, P.I. Stradyn and A.N. Syzganov understood very well that it was the mortality of experimental animals equal to 86% (7 out of 8) that prevented publishing the lethal outcomes without their detailed analysis.

That was how N.K. Galankin explained the reasons for returning the paper to the authors: “In January [a month later] 1956 our paper was returned ‘for revision’ under the pretext that it lacked the explanation of why 6 out of 7 animals had died.<sup>6</sup> At that time the experiment was passed into the hands of T.M. Darbinian. Additional 15 experiments were done, the paper was revised and sent to the ‘Eksperimentalnaya khirurgiya’ journal again, that time under the name

<sup>6</sup> He might have forgotten to include Tarzan who died intraoperatively.



**Fig. 5.** Professor Evgeny N. Meshalkin (1916–1997) [1]

*‘Anastomosis between the superior vena cava and the right pulmonary artery’ [4].”*

Indeed, according to the available surgical protocols, starting from December 15, 1955, all experiments on constructing cavopulmonary anastomosis were performed by T.M. Darbinian and young surgeons. During subsequent 1.5 months he operated on 10 more dogs, 6 six of them died, the outcome of two dogs is uncertain and only two dogs survived. It follows from the protocol entry dated as of December 24, 1955 that *“right-sided thoracotomy in the second intercostal space followed by third rib resection is the best approach to form CPA,”* while the entry as of January 26, 1956, consists of just a few lines: *“A typical cavopulmonary anastomosis surgery with recording of hemodynamic indicators. 10 mm Donetsk’s ring with 4 spikes.”* This allows us to conclude that a surgical approach and technique were then well-proven and standardized. The mortality, however, was high: only 3 survivors out of 14 dogs.

Nevertheless, in January 1956 N.K. Galankin reported on the results of his experiments at the Institute’s Scientific Board meeting and asked for a permit to operate a clinical patient by using, as he called it, *“cavopulmonary anastomosis.”* Undoubtedly, his request was denied.

The experimental modeling of cavopulmonary anastomosis was going on. Finally, on February 15, 1956,

the anastomosed dog lived for 18 days and died during angiocardiology. All junctions were first constructed by D.A. Donetsk’s rings of various diameter and, sometimes, as T.M. Darvinian noticed in the surgical protocol as of February 24, 1956, *“it was impossible to form anastomosis without the ring due to a large distance between the vessels...”* It should be also noted that beginning from March 1, 1956, the operation was renamed *“cavo-arterio-pulmonary anastomosis.”* On April 5 the operated dog not only survived but in a week’s time underwent repeated thoracotomy for exudative pleuritis and on May 11 the recovered *“patient,”* as the protocol says, though with a 5-kg loss in weight, was taken to the lab to measure its arterial and venous pressure.

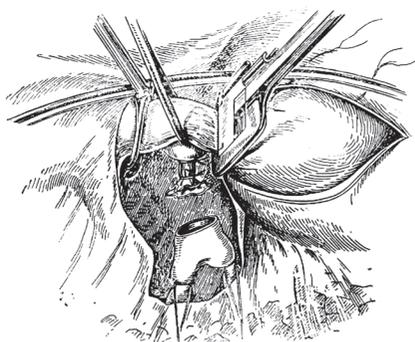
Obviously, N.K. Galankin was very eager to try to apply cavopulmonary anastomosis to some very sick patient, all the more so as he was well aware of H. Shumacker’s first two unsuccessful operations. But, to be unbiased, it is worth noting that the risk of this intervention in his case was unjustifiably high. Thus, it was only in February 1956 that N.K. Galankin started performing Potts procedure experimentally. For comparison, during the entire 1954 E.N. Meshalkin already performed 20 Blalock and Potts’ procedures in patients with tetralogy of Fallot, and over a period from January 18 to February 24, 1955, as we found out in the surgical protocols of Departmental Surgery Clinic at N.I. Pirogov 1<sup>st</sup> Russian Medical University, he constructed (16!) aorto-pulmonary anastomoses while operating practically in a day. Therefore, what happened on early April 1956 was quite predictable.

### **E.N. Meshalkin is a pioneer in clinical cavopulmonary anastomosis**

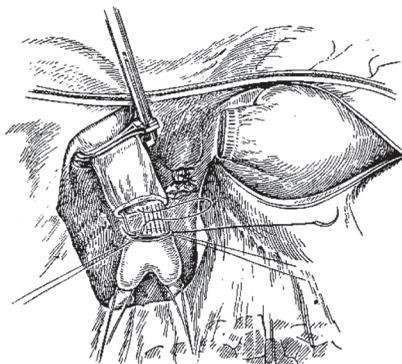
On April 3, 1956,<sup>7</sup> Deputy Director<sup>8</sup> of Thoracic Surgery Institute of USSR Academy of Medical Sciences, Professor E.N. Meshalkin (Fig. 5) performed, as it turned out, the world’s first successful cavopulmonary anastomosis in a 16-year-old patient G. suffering from *“bulbus right-dividedness”* (that was the name of tetralogy of Fallot at that time) in the operation room of Moscow 1st Gradsky Hospital. In this disease, as is clearly seen on the preoperative angiocardiology (E.N. Meshalkin), venous blood flowing heavily from the right ventricle into the pulmonary trunk because of its stenosis was bypassed

<sup>7</sup> March 3 is the date given in the article, which is not correct.

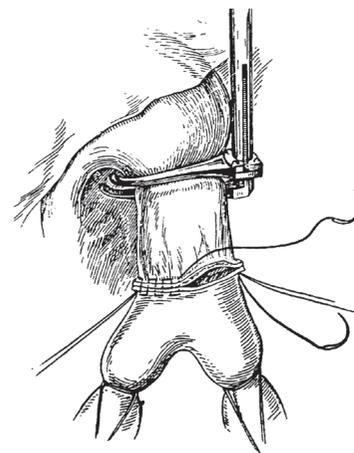
<sup>8</sup> E.N. Meshalkin took up this position on March 31.



**Fig. 6.** The pulmonary artery is transected. Its bifurcation and the stump ligated by two sutures are visible. The superior vena cava is clamped at its junction with the right atrium by a lung stapler and will be sutured by means of a mechanical (staple) stitch [13]



**Fig. 7.** A technique of suturing posterior walls of the superior vena cava and the pulmonary artery by means of a continuous U-shaped inverting suture “end-to-end” as used by E.N. Meshalkin. In the center there a ligated stump of the pulmonary artery, at the upper right a sutured stump of the superior vena cava [13]



**Fig. 8.** A technique of suturing anterior walls of the superior vena cava and the pulmonary artery by means of a continuous U-shaped inverting suture as used by E.N. Meshalkin. The superior vena cava is secured by Blalock's clamp [13]

through an opening in the ventricular septum and delivered into the aorta. Probing the heart cavities (V.S. Savelyev) revealed low saturation of arterial blood with oxygen (74%), and the right position of the aorta precluded the use of Potts procedure.

In addition, because of pronounced stenosis E.N. Meshalkin refused from infundibulectomy, a technique he had a good command of.<sup>9</sup> The surgeons had to perform a surgery, which nobody in the world had ever done before, and out of 13 operated dogs, according to E.N. Meshalkin, only two had survived.

This reasoning enables us to raise doubts as to whether, as some sources indicate, E.N. Meshalkin performed the operation without any preparation, only relying on experimental results of N.K. Galankin and T.M. Darbinian [4, 5]. It is not true.

<sup>9</sup> The Soviet Union's first infundibulectomy under hypothermia for congenital pulmonary artery stenosis and “possible insignificant ventricular septal defect” was performed by E.N. Meshalkin on November 11, 1955. He demonstrated the patient on January 27, 1956, at the 1625th Meeting of Moscow Surgery Society [11].

The decision to construct cavopulmonary anastomosis in clinic was preceded by long training on corpses and dummies, as a result of which the anastomosis construction time and, accordingly, superior vena cava cross-clamping time were reduced to 15 min. This issue was crucial for E.N. Meshalkin, as he believed that in contrast to dogs, due to increased pressure in the superior vena cava, patients might experience subarachnoid bleeding. Time proved he was right. Anyway, the intraoperative construction of cavopulmonary anastomosis took 25 min. At 3 days the patient had no cyanosis of the upper part of the body, at 9 days the patient left his bed and he was discharged in June 1956. When demonstrating the patient to his colleagues a year after the intervention, E.N. Meshalkin evaluated his state as “excellent,” as the youth could “walk fast, run and do manual work” and added that the surgery had been the first in the world [12].

It should be noted that at the meeting of Moscow Surgery Society, where the patient was demonstrated, there was a dispute on the priority of the procedure. A.A. Vishnevsky suggested it could be called as “N.K. Galankin's operation,” while E.N. Meshalkin objected that, on the one hand, T.M. Darbinian's



**Fig. 9.** A.N. Bakulev (on the right) and E.N. Meshalkin: teacher and disciple [Cardiovascular Surgery Museum of A.N. Bakulev National Medical Research Center of Cardiovascular Surgery]

experiments matched what he had observed in humans, while on the other hand, hemodynamics of a healthy dog differs from that of a patient and since the operating conditions in a clinic taking into account tremendous mortality are unpredictable, “then the time will show who is right [12].”

In the article published in the “Eksperimentalnaya khirurgiya” journal, No. 6, November–December 1956, E.N. Meshalkin described a series of 24 cavopulmonary anastomoses performed by him in clinic over a period from April 3 to October 1956.

Twenty-three patients had tetralogy of Fallot and one with dextrocardia suffered from right ventricular atresia. Prior to performing cavopulmonary anastomosis in two patients, subclavian pulmonary anastomosis was formed to temporarily improve the state. “E.N. Meshalkin’s procedure” had essential technical features: mobilization of the right pulmonary artery up to bifurcation by transecting it distally and intrapericardial exposure of superior vena cava up to its junction with the right atrium. In 21 patients the ostium of the superior vena cava was clamped by a lung stapler, while in 3 patients it was ligated and dissected (Fig. 6).

All patients received an “end-to-end” cavopulmonary shunt. Average cross-clamping time was 17 min. The shunt was constructed by means of a continuous U-shaped inverting suture (Figs 7, 8). Four patients died (16.7%). Twenty survivors showed good results. It should be

круга кровообращения в легкое, минуя правое сердце.  
 Еще в 1951 г. А. Н. Бакулев предлагал нам при невозможности выполнить операцию анастомоза между аортой и легочной артерией или их ветвями накладывать анастомоз между верхней полой веной и легочной артерией, что, однако, нами было выполнено только в 1956 г.  
 Повидимому, первыми попытками анастомозировать вены большого

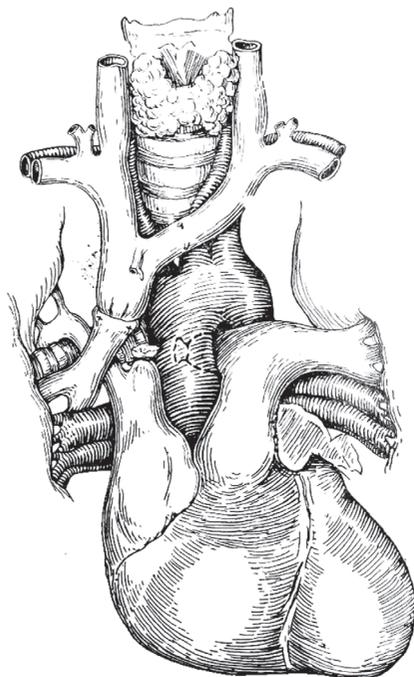
**Fig. 10.** A quotation from E.N. Meshalkin’s book on A.N. Bakulev’s priority

noted that contrary to N.K. Galankin – T.M. Darbinian and A.A. Vishnevsky – D.A. Donetsky who used rings with spikes, E.N. Meshalkin placed a special vascular suture developed by A.A. Bakulev and himself [13].

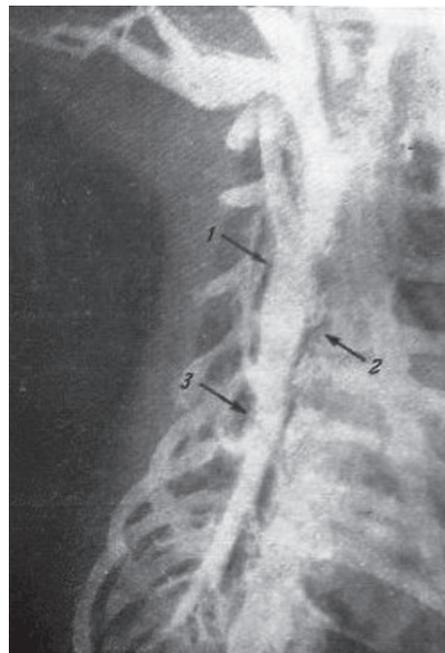
In this paper, E.N. Meshalkin said that in 1951 A.N. Bakulev (Fig. 9) suggested using cavopulmonary anastomosis in patients with cyanotic congenital heart disease in case there was no chance to apply aortopulmonary one. However, E.N. Meshalkin implemented this idea in 1956 only (Fig. 10). Thus, he definitely pointed out that the origins of his operation should be looked for not at A.V. Vishnevsky Institute of Surgery but at Departmental Surgery Clinic of 2nd Moscow Medical University and that the idea of the procedure belonged not to N.K. Galankin (according to N.K. Galankin) [2] or A.A. Vishnevsky (according to T.M. Darbinian) [4] but to A.N. Bakulev. At the same time, E.N. Meshalkin did not deny that he used his colleagues’ experimental data when operating in clinic.

It was also for the first time that he advanced an idea of the advantage of cavopulmonary anastomosis over other interventions for patients with cyanotic congenital heart disease. The advantage was that a venous shunt, while considerably improving a patient’s state, does not hinder further definitive repair of pulmonary artery stenosis and ventricular septal defect closure and that it was possible to form cavopulmonary anastomosis, with the superior vena cava partly cross-clamped, and to use a temporary bypass graft between the azygos vein and the right atrium to decrease pressure in the superior vena cava [13].

While looking through the surgical protocols of Departmental Surgery Clinic of N.I. Pirogov 1st Moscow Medical University, it was found out that after the operation as of April 3, E.N. Meshalkin constructed cavopulmonary anastomoses on April 27 and May 3 and that during these interventions he was assisted by Ch.Ts. Dragoychev. The latter may have helped E.N. Meshalkin in the first operation but we failed to find its protocol.



**Fig. 11.** A schematic diagram of experimental cavopulmonary anastomosis performed by N.K. Galankin and T.M. Darbinian. A view after right cavopulmonary shunt placement [14]



**Fig. 12.** Contrast angiography at 10 days after experimental cavopulmonary anastomosis surgery performed by N.K. Galankin and T.M. Darbinian. The arrows indicate superior vena cava (1), shunt (2), and pulmonary artery (3) [14]

### Implementation of cavopulmonary anastomosis in clinical practice after E.N. Meshalkin

At the time when E.N. Meshalkin was implementing cavopulmonary anastomosis in clinic, the Institute of Surgery of USSR Academy of Medical Sciences continued experimenting. So, in the surgical protocol as of May 18, 1956, there is T.M. Darbinian's entry: "The experiment has gone well," and the dog (Avrora by name) operated on May 31 lived with the functioning shunt up to July 6. By that time the total number of operations amounted to 34, but very few dogs survived.

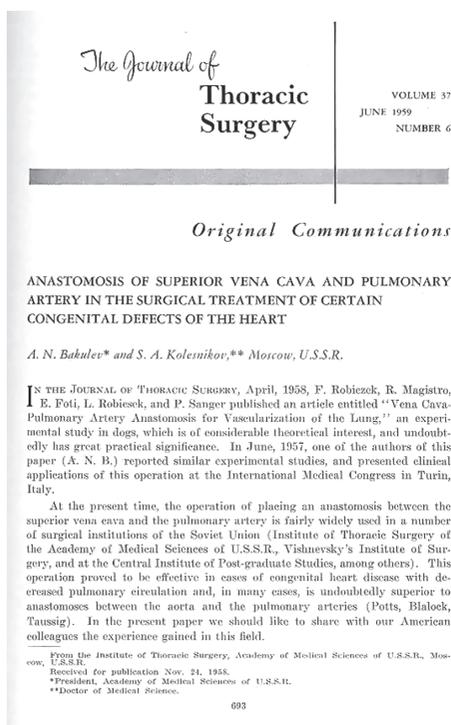
On June 18, T.M. Darbinian commenced using a handmade "end-to-side" suture and the entries tended to include just one phrase: "Cavoarteriopulmonary anastomosis," but mortality remained high. The dogs kept dying either of bleeding, or respiratory failure or opioid overdose.

The same month, half a year earlier than E.N. Meshalkin's paper [13], the article by N.K. Galankin

and T.M. Darvinian was published. It contained the results of their experimental work at the beginning of 1956.<sup>10</sup> The article shows some differences in methodological approaches of the authors.

For example, they transected the superior vena cava not at the point of its discharge into the right atrium, as E.N. Meshalkin did, but distally to its junction with the azygos vein (9 observations) or between its ostium and the right atrium. On taking into account the editorial board recommendations, the authors analyzed and determined the causes of deaths of 11 out of 13 animals: vivisection, asphyxia, ventricular fibrillation, right atrium bleeding, cardiac tamponade, pneumonia, pulmonary apoplexy and superior vena cava thrombosis. But the authors' main result, according to them, was that they managed to prove the possibility of making blood flow from the superior vena cava into the pulmonary artery bypassing the right

<sup>10</sup> E.N. Meshalkin's clinical experience is not mentioned in the paper, therefore it could have been admitted by the editorial board before April 3.



**Fig. 13.** A.N. Bakulev and S.A. Kolesnikov's article published in the Journal of Thoracic Surgery [18]

ventricle, and that it wouldn't hinder blood drainage from the upper half of the body [14] (Figs. 11, 12).

By the end of summer, the Institute of Surgery of USSR Academy of Medical Sciences already performed 45 experimental cavopulmonary anastomoses. Two dogs only lived more than a month, two more—up to 15 days. Most animals died on the operation table, a few hours or days (rarely) postoperatively. Many deaths were caused by the surgeons' technical mistakes and poor follow-up [14].

At last in August, several dogs survived successively and the Institute's Director A.A. Vishnevsky allowed to perform surgery in clinic. On September 14, 1956, N.K. Galankin constructed his first cavopulmonary anastomosis in a patient. Unfortunately, the patient died 36 hours after intervention. The second attempt was made by N.K. Galankin only on January 3, 1957, and this time it was a success. By May 1957 he operated 6 more patients with excellent outcomes in all of them. On May 14, 1957, T.M. Darbinian defended his Ph.D. thesis

“Operative technique and hemodynamics assessment when performing experimental anastomosis between the superior vena cava and the right pulmonary artery.”

By comparison, by the end of December 1956 E.N. Meshalkin operated on more than 70 patients with tetralogy of Fallot, with Potts anastomosis used in 36 patients and cavopulmonary anastomosis formed in 31 patients. This gives more credence to the fact that E.N. Meshalkin's experience as a cardiac surgeon by that time was much higher than that of his colleagues from the Institute of Surgery of USSR Academy of Medical Sciences.

It was only on February 25, 1958, that W. Glenn performed his first successful anastomosis in a 7-year-old child with transposition of the great arteries. After two months the anastomosis was still patent [15]. On April 1958, P. Sanger and F. Robiczek's group published the results of longstanding experiments [16] and on January 9, 1959, the surgeons performed their first operation in clinic [17]. But the eponym “Glenn procedure” tightened up its grip on cavopulmonary anastomosis in foreign literature.

While trying to explain this fact, I.E. Konstantinov and V.V. Aleksii-Meskhishvili write: “William Glenn was not the first to advance the idea of CPS. He reported neither on his first experimental study, nor on his first successful operation in clinic. Nonetheless, the extensive research done under his guidance at Yale University, as well as a scholarly paper published in the prestigious medical journal persuaded the world to consider this operation suitable for use in patients. Because of this, as well as thanks to huge experimental and clinical work, W. Glenn's name turned to be associated with this procedure [4, 15].”

It is obvious that neither W. Glenn who constructed cavopulmonary anastomosis in 1958 nor P. Sanger and F. Robiczek who achieved their first success in 1959 knew nothing about Soviet surgeons' results and about the fact that they had been long and successfully using cavopulmonary anastomosis in clinic.

Also of no use was the article by A.N. Bakulev and S.A. Kolesnikov, which came out in the Journal of Thoracic Surgery in 1959, where the authors described both A.N. Bakulev's idea advanced in the early 1950s and E.N. Meshalkin's priority in performing cavopulmonary anastomosis in clinic, and the experience of Institute of Chest Surgery of USSR Academy of Medical Sciences in carrying out this operation with its outcomes [18] (Fig. 13).

Nevertheless, when speaking at the Annual Session of A.N. Bakulev Medical Research Center of Cardiovascular Surgery on May 15, 2000, F. Fontan from Bordeaux confirmed that in the 1960s in Europe (at least in France) cavopulmonary anastomosis was called “Bakulev’s procedure.”

As for the first application of cavopulmonary anastomosis in clinic, H.B. Shumacker, in his monograph, in the chapter dedicated to the history of surgical treatment of tricuspid valve stenosis and atresia, sketched in a few words about his participation in cavopulmonary anastomosis development saying that “*in all, he performed a few operations of anastomosis between the superior vena cava and the right pulmonary artery, but most patients [including the first two] died [3].*”

Interestingly, in terms of efficiency, A.N. Bakulev and S.A. Kolesnikov placed cavopulmonary anastomosis in congenital heart disease with insufficient pulmonary circulation above the Potts and Blalock–Taussig procedures. Attention is also drawn to the fact that their article seems to be based on the greatest (by that time) range of experience of 41 operations performed at the Institute of Chest Surgery of USSR Academy of Medical Sciences over a period from April 3, 1956, to November 24, 1958 (the time of submitting the article to the journal). However, as we mentioned above, it was in 1956 alone that E.N. Meshalkin carried out 31 operations. And since in January 1957 he transferred from the Institute to the Central Institute of Post-Graduate Studies, it turns out that after his departure there were just 10 cavopulmonary anastomoses constructed at the Institute. Notably, most anastomoses were performed by the article coauthor S.A. Kolesnikov, who, after E.N. Meshalkin had left, became the leading surgeon in both acquired and congenital heart diseases.

The analysis of postoperative mortality rate demonstrates the complexity of surgery techniques and patient management at that stage of cardiac surgery development. If E.N. Meshalkin, an advanced and highly skilled cardiac surgeon, performed 24 operations in 1956 with only 4 lethal outcomes [13], then the remaining 27 operations carried out by other less experienced surgeons ended up with 11 deaths, with 8 deaths out of 14 caused by “*surgical technique defects and wrong indications for operation [18].*”

## Conclusion

The idea of cavopulmonary anastomosis originated simultaneously with US surgeons (A. Blalock), Italy (C. Carlon), the USSR (A. Bakulev) and Hungary (F. Robiczek). Some of them wanted to use anastomosis to fill the pulmonary circulation with blood, while others vice versa to discharge it.

The first cavopulmonary anastomosis with several experimental modifications including a classic “superior vena cava end to right pulmonary artery end” variant was formed by C. Carlon at the end of 1949 – beginning of 1950. The first two unsuccessful operations in clinic were done by the American surgeon H.B. Shumacker before November 1954. The priority of the world’s first successful operations in clinic belongs to E.N. Meshalkin (April 3 – October 1956). To some extent, his success might have been determined by the experimental studies conducted by N.K. Galankin, T.M. Darbinian and D.A. Donetsky over a period from autumn 1955 to spring 1956. However, for objective reasons, up until August 1956 N.K. Galankin and colleagues were not ready to implement cavopulmonary anastomosis in clinical practice.

After 4 years of experimental work, W. Glenn performed the first successful cavopulmonary anastomosis in the USA on February 25, 1958. His experience, authority, and publication in a prestigious journal led to the fact that cavopulmonary anastomosis is traditionally called Glenn procedure in cardiac surgery literature. However, we believe that it would be more just to call it Bakulev–Meshalkin procedure or simply, Russian anastomosis.

## Funding

The study did not have sponsorship.

## Conflict of interest

Authors declare no conflict of interest.

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