Impact Factor: 9.9 ISSN-L: 2544-980X

# The Use of Higher Mathematics in Surgery

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**Abstract:** This article examines the practical application of higher mathematics in modern surgery using the example of a successful operation to correct a congenital heart defect in an infant. The author focuses on the role of mathematical modeling, numerical methods (in particular, the Navier-Stokes equations and the finite element method) and an interdisciplinary approach in medical practice. It is shown how the integration of knowledge from mathematics, physics, biology and engineering allows achieving highly accurate results in complex surgical interventions. The prospects for the development of symbiosis between science and medicine are considered separately.

**Key words:** higher mathematics; surgery; mathematical modeling; finite element method (FEM); Navier-Stokes equations; hemodynamics; interdisciplinary approach; bioengineering; medical 3D printing; neural interface.

Higher mathematics is associated by most people with lectures, formulas and complex equations. But few people think that this knowledge often becomes the basis for practical decisions on which human lives depend. The role of mathematics is especially significant in medicine, where it helps to predict, plan and implement surgical interventions with high accuracy. This article considers one of the striking examples - the case of saving a baby with a congenital heart defect, in which computer modeling and mathematical methods played a key role. In this article, I want to show and explain that such concepts as higher mathematics, as well as physics, which I have been deeply studying for more than 2 years, play an important role in other various disciplines and subjects. I want to convey the idea that mathematics is not just something that develops human logic, which is already very important, but also the main and, I am not afraid of this word, the MAIN tool in other, seemingly incompatible with it, disciplines. Higher mathematics and probability theory are a tool for physics, information technology, the same biology and chemistry, everything that surrounds us, all these gadgets, machines and mechanisms of various kinds, which are used not only in medicine, but also in other industries.

Now let’s look at one situation. Which will serve as an example of the use of higher mathematics in surgery. The story took place in India, An 11-month-old baby named Lavesh Navedkar was admitted to Fortis Hospital in Mumbai with a severe circulatory disorder. He was diagnosed with a rare congenital malformation called Double Outlet Right Ventricular (DORV), in which both the large arterial vessels branch off from the right ventricle of the heart. This disrupts normal blood flow, leading to inadequate oxygenation of the blood and putting the patient's life at risk.

Conventional surgical methods are associated with high risks, especially with individual anatomical features, such as in infants. Therefore, doctors decided to use modeling and 3D printing technologies, relying on precise mathematical calculations. The first stages were magnetic resonance imaging and subsequent digital image processing. Using specialized programs such as Mimics and 3D Slicer, a three-dimensional model of the heart was created, reflecting the real geometric parameters of the organ.

The next step was to use the mathematical analysis of hemodynamics, using the Navier-Stokes equations to describe the behavior of a viscous fluid—in this case, blood—inside the cavities of the heart:

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$$\frac{\partial u}{\partial t} + (u \cdot \nabla)u = \frac{-\nabla p}{p} + \nu \nabla^2 u + f,$$

where u is the flow velocity vector, p is the pressure, ρ is the blood density, ν is its kinematic viscosity, f are external forces. The finite element method (FEM) was used for the numerical solution, which allows analyzing complex shapes and motion conditions. This equation is the foundation of hydrodynamics and biomechanics, especially in the analysis of hemodynamics - the movement of blood in vessels and the heart

It was important to determine the optimal configuration of the shunt connecting the chambers of the heart. Let me explain right away **A shunt** is a device that allows electric current (or magnetic flux) to flow around a section of a circuit, usually a low-resistance resistor, coil, or conductor. For this purpose, mathematical optimization methods were used , the objective function described the total energy efficiency of the flow and the minimization of the load on the vessel walls. Additionally, Monte Carlo simulations were carried out — a group of numerical methods for studying random processes . The essence of the method is as follows: The process is described by a mathematical model using a random variable generator , the model is repeatedly calculated, and the obtained data are used to calculate probabilistic characteristics of the process under consideration , in which the blood circulation parameters were varied to assess the stability of the solution.

After mathematical calculations and model validation, a physical model of the heart was produced using a 3D printer that works with polymers of varying rigidity. The model allowed surgeons to visually and tactilely study the patient's anatomy, conduct a rehearsal of the upcoming intervention, and plan each stage of the operation.

The operation was successful. Thanks to preliminary calculations, it was possible to minimize the time the patient spent under anesthesia, accurately install the shunt, and restore normal blood flow. Within a week, the boy began to recover, and was soon discharged from the hospital.

This example clearly shows how mathematical methods, previously considered purely theoretical, find direct application in medicine. An integrated approach, including mathematical modeling, numerical methods and engineering technologies, is becoming a standard in surgical practice.

The importance of mathematical knowledge is especially evident in combination with other sciences. Biology provides information on physiological processes, such as the operation of ion channels in myocardial cells. These processes, described in molecular biology textbooks, can be included in models as variables or boundary conditions. Chemistry, in turn, helps to take into account the rheological properties of blood, which affect the calculations of shear stresses and turbulence.

The formula for estimating viscous stresses looks like this:

$$\tau = \mu \left(\frac{du}{dy}\right),$$

where τ is the stress, μ is the dynamic viscosity, and $\frac{du}{dy}$ is the velocity gradient. Such calculations are important for analyzing the risk of vascular damage or thrombus formation.

Physics also plays a significant role: Without understanding the fundamentals of continuum mechanics and hydrodynamics, it is impossible to correctly interpret the behavior of tissues and fluids in the body. Knowledge from courses in engineering mechanics and computational mathematics becomes analysis tools in medicine.

In many countries, such methods are becoming the norm. Hospitals in the United States, Japan, Germany, and elsewhere are creating departments where surgeons, mathematicians, and engineers work together. Doctors' training programs include courses in modeling and data processing. New approaches to training are being developed that use virtual simulations based on real mathematical models.

Thus, saving Lavesh is not just an isolated case. This is an example of how an interdisciplinary approach, including mathematics, biology, engineering and medicine, allows achieving high results. This is proof that the knowledge obtained at the university has practical significance and can change the fate of people. And in my opinion, it is worthwhile to focus more on the interaction of various disciplines, try to somehow find a connection between them and unite them and try to deduce something new and amazing with the help of a certain symbiosis of knowledge, after all, all these concepts are very closely related to each other. Examples of the combination of such concepts as higher mathematics, probability theory, biology, chemistry and physics are also presented in various new models. For example, in 2024, the Neuralink company, led by Elon Musk, performed a successful operation to implant a neurointerface in a paralyzed patient. This chip allowed him to control the computer solely with his thoughts. The development was the result of close interaction of higher mathematics, physics, engineering and biology . I believe that this practice of interaction of knowledge from different spheres will lead to even more amazing and surprising results.

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