SCIENTIFIC RESEARCH GROUP:

Barannik Serhiy
Doctor of Medical Sciences, Professor of the Department
general surgery, surgery No3, orthopedics and traumatology of FPE
Dnipro State Medical University, Ukraine

Korpusenko Igor
Doctor of Medical Sciences, Professor,
Head of the Department of general surgery, surgery No3,
orthopedics and traumatology of FPE
Dnipro State Medical University, Ukraine

Trofimov Mykola
Doctor of Medical Sciences, Professor of the Department
general surgery, surgery No3, orthopedics and traumatology, FPE
Dnipro State Medical University, Ukraine

Chukhriyenko Alla
Doctor of Philosophy, Assistant
Department of general surgery, surgery No3, orthopedics and traumatology, FPE
Dnipro State Medical University, Ukraine

Shevtsov Vadim
Surgeon
KNP "Dnipro Clinical Emergency Hospital", Ukraine

PATHOPHYSIOLOGICAL CHANGES AND COMPENSATORY REACTIONS IN THE BODY OF THE VICTIM DUE TO MASSIVE BLEEDING AND BLOOD LOSS

A person's life depends on the functions of his organs and systems, and they can function normally only with good blood circulation in the body as a whole. Hemodynamics is ensured by the work of the cardiovascular system and the volume of circulating blood. It is with this that the importance of the problem of bleeding and blood loss is determined by the frequency and prevalence of this pathology in all strata of the population; bleeding almost always accompanies such emergency situations as traffic accidents and accidents, and also complicates various diseases and is always present during surgical interventions. Untimely provision of assistance in case of bleeding threatens with life-threatening complications - a decrease in the volume of circulating blood, the development of hemodynamic disorders and hemorrhagic shock, and as a result, the death of the victim; a doctor of any specialty should be able to provide first aid to a bleeding patient.

Blood is not just a transport medium that connects various organs and tissues into a single organism. In addition to transporting gases and bioactive substances, quanta of information and control, it performs many compensatory functions, immune protection and others. Like all organs and systems of the body, blood is genetically specific, its cellular and biochemical composition constantly reproduces itself. Blood is the same "native" and irreplaceable foreign tissue system of the body as all its other systems and organs. It, like other vital organs and systems, performs many functions. Under the conditions of its damage, a decrease in its volume cannot be an isolated

damage to any one of the functions of the blood. That is, artificial restoration of the gas transport function of the blood is better than nothing, but it is still not a complete compensation of all blood functions.

Like other body systems, the blood has its own self-compensation mechanisms, as well as compensatory mechanisms that are inherent in other systems. Damage or reduction of blood volume, which is not compensated by its own mechanisms, leads to a change in the function of the cardiovascular system, metabolism, etc., aimed at compensating for blood loss. The body's primary reactions to acute blood loss depend on the rate at which blood volume decreases, on the volume of blood loss, and on the previous state of the body.

Compensatory reactions, which begin in the conditions of autoregulation, are aimed at the rapid restoration of blood volume and quality. Compensatory mechanisms are activated in all functional systems of the body, starting with the blood system itself. The volume of reserves of compensatory capabilities of each organism in response to blood loss is influenced by individual characteristics, which depend not only on the previous functional state of systems and organs, but also on constitutional ones and which must be taken into account during the provision of assistance.

Blood loss of a high degree leads to significant violations of the functions of organs and systems, as well as violations in the body's immune system, causes significant changes in the state of cytokines. Proinflammatory and anti-inflammatory cytokines play the most active role. Today, it is determined that most diseases are associated with disorders of the immune system. Gastrointestinal bleeding, which is a consequence of damage to the blood tissue and reflects its severity, is not an exception. As a result, in response, an inflammatory reaction is formed on the part of the damaged tissue. At the same time, at all stages of the formation of the body's specific immune response, the dominant role belongs to cytokines. An increase in the level of cytokines is an important component of the body's adequate response during inflammation. At the same time, excessive expression of these mediators causes changes in physiological processes in the body. The study of these changes can help in predicting the severity of the homeostasis disturbance, the development of complications and the progression of the disease, and possible changes in treatment tactics.

Bleeding is not just any pathological condition, it is a complication of a certain group of diseases and injuries. Bleeding is one of the most dramatic situations in medicine, and therefore occupies a special place in surgery, in the life of the surgeon himself. This value of bleeding is determined by its following features:

* Bleeding is a complication of many, even minor, diseases and injuries, as well as a consequence of the surgeon's actions.

* Continuous bleeding is an immediate threat to the patient's life.

* During bleeding, the speed of decision-making and assistance becomes extremely important.

* A surgeon's ability to cope with bleeding is an indicator of his professionalism.

Compensatory reactions, which begin in the conditions of autoregulation, have the purpose of immediately restoring the volume and therefore the amount of blood. Compensatory mechanisms are activated in all functional systems of the body, starting with the blood system itself.

Blood system. In conditions where the amount of hemoglobin has decreased, the shape of the oxyhemoglobin dissociation curve changes, due to which the efficiency of O2 transfer to tissues increases. It is known that sufficient tissue oxygen extraction is maintained even at a hematocrit of 15%. At the same time, the mechanisms of erythropoiesis are activated, and new, including immature erythrocytes and other blood cells enter the bloodstream. The coagulation system responds by hypercoagulation to stop the bleeding more quickly, and if this compensatory hypercoagulation is not stopped, it can (and usually does) lead to the development of disseminated

intravascular coagulation syndrome, which makes the bleeding worse. The possibility of its development must always be taken into account when developing tactics for managing patients with blood loss.

Restoration of blood volume is an immediate reaction of the body, which is carried out through hormonal and nervous regulation. Under the conditions of long-term bleeding (hemorrhagic shock), the blood as an organ is damaged: its transport function is impaired, the coagulation system, anticoagulation system, and fibrinolysis system suffer (coagulopathy occurs), the function of the reticuloendothelial system, immune protection, buffer, etc. is impaired.

Circulatory system. Sudden hypovolemia associated with blood loss leads to migration of extracellular fluid into the vascular bed. The physiological mechanism of this migration consists in spasm of arterioles, reduction of hydrostatic capillary pressure and transition of pericapillary fluid into the capillary. During the first 5 min. after blood loss, the amount of fluid corresponding to 10-15% of normal BCC can pass to the vessels. The secretion of antidiuretic hormone of the pituitary gland and aldosterone increases, which increase the reabsorption of water in the renal tubules, if glomerular filtration is not too significantly impaired. Thanks to this, the BCC does not decrease, or even increases. The reflex that provides this mechanism begins with the volume receptors of the heart and large vessels and closes through the hypothalamus in the pituitary gland and adrenal glands. A decrease in cardiac output leads to an increase in vascular resistance in some organs and tissues to direct the main blood flow to the brain and myocardium. This reflex response begins with afferent neurons that turn on the reflex from baroreceptors, which are stimulated by a decrease in mean arterial and pulse pressure. Reflexes from chemoreceptors are also involved in the reaction, which are stimulated by a decrease in local blood flow and changes in PaO2 and PACO2. First of all, vessels-capacities react - veins, which contain up to 2/3 of BCC, due to which the emptying of the vein is one of the most important signs that require active intervention in case of blood loss.

A decrease in blood pressure can be an adaptive reaction of the body aimed at stopping bleeding. Premature use of vasopressors against the background of unstopped bleeding to reach the norm of 120/70 mm Hg. Art. - this is a frequent, unfortunately, consequence of being instructed in medical thinking (?). If cardiac output continues to decrease, arteriolar spasm occurs, which should centralize blood flow. However, arteriolospasm leads to a decrease in the volume velocity of blood flow in the capillaries, where as a result of a change in blood rheology, cell aggregation with sludge phenomena occurs. This ends with the sequestration of blood in the affected capillaries, which further reduces BCC, disrupts venous inflow, and increases hypovolemia. Stimulation of sympathetic-adrenal activity during hypovolemia not only increases peripheral vascular resistance, but also accelerates the heart rate, increases the force of heart contractions, and increases the need for oxygen due to an increase in basic metabolism.

When evaluating the physiological effects of hypovolemia, it should be borne in mind that a 10% decrease in BCC is not manifested by anything other than some tachycardia and vasoconstriction. A loss of 15% of BCC leads to moderate rheological disorders, which are compensated by the influx of tissue fluid into the vascular bed during the next 2-3 hours. Hypovolemia when the BCC is reduced by 20% reduces cardiac output and creates a defective rheological circle.

Respiratory system. There are changes in gas exchange, which are of a different nature. Initially, adaptive hyperventilation, aimed at increasing venous inflow by the suction action of the chest, leads to respiratory alkalosis. At the same time, hemoglobin saturation with oxygen and oxygen content in arterial blood increase slightly.

Due to the fact that with hypovolemia, the blood flow in most organs is reduced, and their need for oxygen is unchanged or even increased (stimulation of the sympathetic system), the venous blood flowing from such organs contains little oxygen and the arteriovenous difference in the hypoxic organ is increased. Thus, a decrease in the oxygen content in the mixed venous blood

with hypovolemia indicates that the patient suffers from hypoxia, even if the oxygen content in the arterial blood is satisfactory.

But the normal content of oxygen in mixed venous blood with blood loss does not mean that there is no hypoxia. It's just that with extreme degrees of hypovolemia, the capillaries of many tissues are completely shut off from the microcirculation, and the most severe hypoxia of these tissues does not have an imprint in the numbers of the total oxygen content in the mixed venous blood. It should be emphasized that in most cases of blood loss, including massive blood loss (more than 30% BCC), tissue oxygen starvation occurs not only due to hemic hypoxia, but also due to circulatory hypoxia. That is, **the first and main task is not to add hemoglobin, but to normalize microcirculation.**

Blood loss, like any hypovolemia, always damages the lungs, because the pulmonary capillary filter is clogged with aggressive mediators and metabolites that come from tissue structures of microcirculation. Together with them, aggregates come from the tissues that clog the pulmonary capillary filter, and this combined impact of the physiological consequences of hypovolemia on the lungs leads to a syndrome of acute lung damage, the essence of which consists in interstitial edema, a pronounced alveolar shunt, a violation of alveolocapillary diffusion, a decrease in lung distensibility, which increases the oxygen price of breathing, etc. All bleeding is acute or chronic. With acute bleeding, blood flow is observed for a short period of time, and with chronic bleeding, it occurs gradually, in small portions. Sometimes there is slight, sometimes periodic bleeding for several days. Chronic bleeding can be observed with gastric and duodenal ulcers, malignant tumors, hemorrhoids, uterine fibroids, etc.

Assessment of the severity of blood loss is extremely important, because it determines the nature of blood circulation disorders in the patient's body and, ultimately, the danger of bleeding to the patient's life. Death from bleeding occurs as a result of circulatory disorders (acute cardiovascular failure), and also, much less often, due to the loss of functional properties of blood (transportation of oxygen, carbon dioxide, nutrients and metabolic products). Two factors are of decisive importance for the development of bleeding: volume and speed of blood loss. A simultaneous loss of up to 40% of circulating blood volume (CCB) is considered incompatible with life. At the same time, there are situations when, against the background of chronic or periodic bleeding, patients lose a much larger volume of blood, red blood levels are significantly reduced, but the patient gets out of bed, walks, and sometimes works. The general condition of the patient is also of some importance - the background against which bleeding occurs: the presence of shock (traumatic), previous anemia, exhaustion, insufficiency of the cardiovascular system, as well as the patient's gender and age.

Determining the degree of severity of blood loss is extremely important for solving the issue of treatment tactics, and also determines the nature of transfusion therapy. The relationship between blood circulation and breathing in hypovolemia is always complex. Hyperventilation as an adaptive reaction to hypovolemia, aimed at increasing venous inflow, is accompanied by a different effect of inhalation (as well as exhalation) on the large and small circle of blood circulation. Thus, during inspiration, the filling of the right ventricle, pulmonary vessels, and therefore the right ventricular stroke volume increase, while the same indicators decrease for the left ventricle. Due to the fact that there are several contractions of the heart for each breath, the pressure in the aorta and pulmonary artery changes in the opposite direction during inhalation. Baroreceptors and lung stretch receptors cause the heart rate to increase or decrease with each breath.

Such physiological relationships do not have clinical manifestations in healthy conditions, but with blood loss, pericarditis, increased elastic or inelastic resistance of the lungs, hemodynamic differences with each inhalation or exhalation become quite clear, and pulsus paradoxus, if sought, is always determined.

Other systems. Blood loss is accompanied by damage to organ blood flow, due to which the function of the kidneys and liver is first of all impaired. Insufficiency of the central nervous system occurs last, because the centralization of blood flow during hypovolemia allows maintaining adequate blood supply to the brain for a long time.

Metabolism. A reduction in tissue blood flow leads to a disruption of metabolism, which becomes anaerobic due to a lack of oxygen. In addition, there is an accumulation of lactic acid, anaerobic glycolysis gives 15 times less energy than aerobic. Metabolic acidosis occurs, which has a harmful effect primarily on the circulatory system itself. It depresses the myocardium, reduces its reactivity to sympathetic stimulation and contributes to the growth of hypovolemia, which in turn worsens disorders in the microcirculation system. Acidosis shifts the oxyhemoglobin dissociation curve down and to the right, resulting in less oxygen being supplied to the pulmonary capillary blood than at normal pH. Similarly, in the tissues, the transfer of oxygen by blood is facilitated. If the pulmonary effect prevails, acidosis leads to severe arterial and venous hypoxemia, and if it is tissue, venous hypoxemia may be less pronounced, although arterial remains at the previous level.

Acidosis increases membrane permeability, fluid transudation from the vascular bed increases, as a result of which BCC decreases even more. For the same reason, the level of electrolytes changes and hemodynamics suffers due to additional violations of myocardial contractility.

Hemorrhagic shock. In the late stages of massive blood loss, hemorrhagic shock occurs, which in its essence is multiple organ failure (POF), the trigger of which was blood loss. The components of PON in hemorrhagic shock can be systematized as follows.

First, there is hypovolemia with a violation of the rheological properties of blood and its sequestration in capillary systems. Due to sequestration of blood in hemorrhagic shock, the ascending BCC of 5 L after blood loss of 1 L will not be equal to 4 L, but only 3-3.5 L, because some blood volume is sequestered in the capillary systems.

Secondly, generalized metabolic disorders develop - redox processes are disturbed, metabolic acidosis occurs, the electrolyte composition of tissues, oncotic pressure, etc., change.

Thirdly, organ ischemia leads to organ disorders - renal, hepatic, pulmonary (we emphasize, pulmonary and not just respiratory failure!), dysfunction of the myocardium, intestines, etc.

Fourthly, infectious diseases and purulent-septic lesions are aggravated or arise again, and finally, fifthly, coagulopathy of the type of disseminated intravascular coagulation syndrome occurs.

Therefore, ***hemorrhagic shock is a multi-organ failure that occurs as a result of uncompensated or untimely compensated massive blood loss.***

In case of severe acute blood loss, treatment begins with jet infusion of blood into 1-2 veins and after the systolic pressure rises to 80 mm Hg. switch to drip administration. Cardiac drugs, vitamins C, B6, Vikasol, calcium gluconate, glucocorticoids, prednisolone and others are used.

Thus, when providing medical care for bleeding, the surgeon must solve three main tasks:

* in the near future, at least temporarily stop the bleeding, that is, interrupt the patient's blood loss and thus eliminate the threat to his life;

* achieve a reliable stop of bleeding with minimal losses for the function of various organs and systems of the body;

* to restore the disorders in the body that arose as a result of blood loss.

Bleeding also contains other threats, for example, with injuries of large veins, air embolism is possible. With bleeding into the pericardial cavity, cardiac tamponade occurs, with hemorrhage into the brain, paralysis and paresis occur, and with localization in vital centers, death. The cause of death from bleeding is paralysis of the vascular or respiratory centers. Blood loss of about 4-4.5%, relative to body weight, is considered fatal. Therefore, knowledge of the clinic and diagnosis of external and internal bleeding, the ability to establish their nature, provide timely first medical

and medical aid, and the ability to stop bleeding are necessary in the training of doctors of any specialty. Bleeding is a direct threat to the patient's life, and the patient's fate depends on the correct actions of the doctor.

References:

1. Barannyk S., Chukhrienko A., Chabanenko G. Gastro-intestinal bleeding and compensatory capabilities of the human organism. *The IX International Science Conference « Innovative technologies in science and education», March 04 – 06, 2021, Jerusalem, Israel. 320 p.* P. 114-116.
2. Трофимов Н.В., Крышень В.П., Баранник С.И., Чухриенко А.В., Чабаненко Г.Н., Гайтеров А.Н. Клинико-статистические аспекты течения желудочно-кишечных кровотечений у больных с патологией сердечно-сосудистой системы. *Медичні перспективи.* 2019. Том XXIV, №1. С. 35-39.
3. Trofimov M.V., Barannik S.I., Krychen V.P., Muntyan S.O., Lyaschenko P.V., Gaponov I.V., Chukhrienko A.V. Optimization of treatment of patients with acute bleeding syndrome in the lumen of the digestive duct. *Шпитальна хірургія. Журнал шмені Л.Я. Ковальчука. 2020. №4(92).* С. 52-57.
4. Trofimov M.V., Kryshen V.P., Kudryavtseva V.Y., Chukhriienko A.V., Lyashenko P.V., Gaponov I.V. Clinical teatures of gastrointestinal ulcerative bleeding in elderly patients complicated by cardio-vascular pathology. *Wiadomosci Lekarskie. Vjlume LXXIV, ISSUE 2, February 2021.* P. 202-206.
5. Трофимов Н.В., Чухриенко А.В., Баранник С.И., Кудрявцева В.Е. Особенности динамики показателей иммунной системы организма у пожилых пациентов с язвенными желудочно-кишечными кровотечениями, отягощенных патологией сердечно-сосудистой системы. *Azerbaycan tibb jurnal 2021, N4.* P. 109-115.
6. Barannyk S., Trofimov M., Ekhalov V., Chukhrienko A., Chabanenko G. Clinical significance of pathophysiological changes in the body of the victim as a result of bleeding and blood loss. *The XXV International Scientific and Practical Conference «Innovative trends of science and practice, tasks and ways to solve them», June 28 – July 01, 2022, Athens, Greece. 594 p.* P. 253-260.