Review article

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Vascular injury during lumbar discectomy: risk factors, diagnosis, methods of surgical correction, features of anaesthetic management and intensive care

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One of the priority tasks in neurosurgery is to reduce the frequency of postoperative complications and mortality. Lumbar discectomy is the most frequently performed intervention in spinal neurosurgery and it is a fairly safe procedure. One of the possible intraoperative surgical complications, that threatens the patient’s life is vascular injury.

The first clinical case of damage to the large vessels during discectomy was described in 1945. It is believed that the frequency of this complication is 1–5 cases per 10,000 surgical interventions, but the literature notes that these figures may be significantly underestimated. Some authors indicate that the frequency of this complication, despite the development of surgical techniques over the past 50 years, has not significantly decreased, so it is important for surgeons to be informed and alert about the possibility of such a problem. Among the factors that significantly increase the risk of vascular damage congenital, acquired and technical are determined.

Variability of clinical symptoms of damage to lagre vessels is due to different localization of injury, type (arterial, venous or combined) and scale of vascular disaster. For each level of surgical intervention, the "most typical" vessel damage is identified. Vascular injury during discectomy can occur according to three clinical and pathomorphological scenarios: manifestation of vessel rupture symptoms, arteriovenous fistula or a pseudoaneurysm formation. According to different authors, the frequency of these findings varies significantly. This review examines the symptoms of possible variants of vascular damage development during discectomy and describes the characteristics of surgical correction methods. Along with clarifying the location and variant of vascular damage, the critical thing is assessing the amount of blood loss and the rate of ongoing bleeding. In the case of suspected massive bleeding, the paramount importance is the involvement of additional medical personnel for the surgical haemostasis and providing sufficient blood for haemotransfusions.

In case of a vascular accident, the key requirement for adequate anaesthetic management is the maintenance of permissive arterial hypotension until the moment of surgical haemostasis. Targeted treatment of haemorrhagic shock in case of damage to large vessels consists of rapid haemostatic resuscitation including blood components and products in a balanced 1:1:1 ratio, such as plasma, red blood cells, fresh frozen plasma, platelets, and coagulation factors. In Ukraine, obtaining a sufficient amount of blood components and products (according to the protocol of massive haemotransfusion) in case of unpredicted blood loss is a difficult task, therefore, in the absence of certain components or blood products, whole blood can be used as an alternative. The number and severity of complications and outcomes primarily depend on the efficiency and timeliness of blood transfusions, along with the speed of surgical arrest of bleeding. This publication describes in detail the main points of management of patients with massive bleeding according to modern international standards and Ukraine regulatory documents.

Keywords: *vascular injury; lumbar discectomy; risk factors; massive bleeding; surgical correction; permissive arterial hypotension; massive transfusion protocol; whole blood; anaesthetic management; intensive care*

Introduction

Surgery is an integral part of the modern healthcare system. Inadequate surgical care causes a projected loss of economic productivity of $12.3 trillion annually. According to forecasts, by 2030, the problem of effective surgery in low-middle income countries, to which Ukraine belongs according to the World Bank classification, can reduce the growth of the gross domestic product by almost 2% [1, 2].

Annually, about 310 million major surgical procedures are performed worldwide, of which about 40-50 million are performed in the USA and 20 million in Europe [3-5]. Although intraoperative mortality is quite low, the average postoperative mortality is 1–4%. In addition, about 15% of operated patients experience serious postoperative complications, and 5–15% are re-hospitalized within the first 30 days after surgery [6]. In fact, postoperative mortality accounts for about 14% of all deaths in the world [4, 7].

Cardiac surgery, angiosurgery and neurosurgery are specialties characterized by an increased risk of intraoperative and postoperative complications due to the invasiveness and complexity of operations. Accordingly, the analysis and development of methods aimed at reducing the incidence and severity of these complications, against the background of progressively expanding indications for surgical correction of certain nosologies and increasing the number of surgical interventions, are urgent tasks [3].

In spinal neurosurgery, the most common type of surgical intervention is lumbar discectomy, which is characterized by a relatively low incidence of postoperative complications [8]. The absolute majority of postoperative mortality cases are not directly related to the surgeon's actions. It is known that any extensive surgical intervention, as well as its anaesthetic management, are associated with stress-induced activation of the sympathetic nervous system, haemodynamic disturbances, coagulopathy, immune dysfunction, metabolic imbalance, and hypothermia [4, 9]. It has been observed that about 8% of adult patients suffer from myocardial ischemia in the postoperative period, and 10% of them will die within 30 days [10, 11]. Surgical stress also leads to perioperative complications involving the brain, kidneys, lungs, liver, and intestines [12–15].

Lumbar discectomy, given the minor surgical trauma and relatively short duration of the intervention, is a safe procedure in most cases. Of the possible intraoperative surgical complications, the only one directly threatening the patient's life is damage to the great vessels, which is registered quite rarely [16, 17].

Great vessels injury

The first report on vascular injury during lumbar disc surgery was published in 1945 [18]. In 1958, a survey of spinal surgeons in the United States conducted by R.L. Desaussure, revealed 106 cases of vascular injury associated with lumbar discectomy [19]. Between 1945 and 1984, more than 200 cases of simple or multiple vascular injuries were described [20]. Over the past 50 years, the incidence of this complication has not significantly decreased [21].

The approximate incidence of vascular complications during lumbar disc surgery is 1–5 cases per 10,000 surgeries. However, according to some authors, the actual incidence is at least 10 times higher [17, 21, 22]. The main reasons for the difference in statistical data are that vascular injuries are often asymptomatic or diagnosed much later after discharge from the hospital. In addition, a large number of cases actually go unreported [23, 24].

Anatomically, the vessels of the abdominal cavity are located in close proximity to the anterior portions of the vertebral bodies. It is known that the bifurcation of the aorta and the formation of the inferior vena cava by connecting the right and left common iliac veins occur at the level of L4 or L5 vertebral body. According to the literature, in 94% of cases, the aortic bifurcation is located between the L3-L4 and L4-L5 discs, in 4% - above the L3-L4 intervertebral disc, in 2% - below the L4-L5 intervertebral disc. In 50% of patients, the common iliac veins connect at the level of the L4-L5 intervertebral disc, in 28% - below this level, in 22% - above this level [25]. At the level of the L4-L5 intervertebral disc, the vessels are separated from the disc space only by the anterior longitudinal ligament [26]. A study by Calyani Ganesan et al. demonstrate that at the level of L4–L5 the common iliac arteries are located <5 mm from the anterior border of the disc space in 66% of cases in women and in 49% of men, at the level of L5–S1 in 23 and 19%, respectively ***(Table. 1)*** [27].

Table 1. The average distance between the anterior border of the intervertebral disc and the common iliac arteries depending on the side, level of the intervertebral disc, and gender [27]

Side	Average distance, mm	SD	For men, mm	For women, mm
Level L4-L5				
Right	6,6	4,7	7,6	5,6
Left	3,3	2,4	4,1	2,6
Level L5-S1				
Right	7,5	5,2	7,2	7,9
Left	9,7	4,2	9,6	9,8

Note: SD – standard deviation.

This article contains some figures that are displayed in color online but in black and white in the print edition.

The ratio of great arteries and veins located at the level of L3-L5 vertebrae is characterized by significant variability, which was studied in the work of A. Svein et al. [25]. The authors identified several types ***(Fig. 1)***:

- at the **L3-L4** level, in 96% of cases, the aorta and inferior vena cava lay next to each other without overlapping (type I), in 4% - the right common iliac artery partially overlapped the inferior vena cava (type II);
- **L4-L5** level is characterized by a greater number of options for the ratio of great vessels. Types I and II, specific to the L3-L4 level, occurred with a frequency of 2 and 14%, respectively. In 6% of cases, both common iliac arteries partially overlapped the common iliac veins (type III), in 40% - the right inferior iliac artery overlapped only the inferior vena cava (type IV), in 24% - the right common iliac artery completely overlapped the inferior vena cava, and the left common iliac artery – partially overlapped (type V), in 14% - both common iliac arteries completely overlapped the inferior vena cava (type VI);
- it was difficult to differentiate arteries and veins at the **L5-S1** level. However, it was noted that in 78% of cases, at least one iliac vessel was located at a distance of <3 mm from the disc border, in 96% - common iliac vessels were located on the anterolateral sides of the L5-S1 disc, in 4% of cases they were located - in front of the disc. In 44% of patients, the intestine was identified closely connected to the anterior surface of the disc.

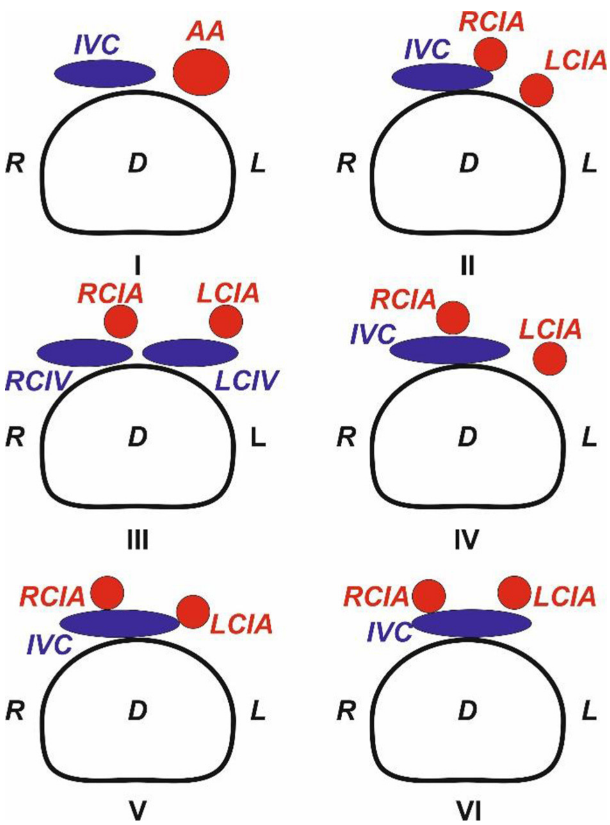

Fig. 1. Anatomical types of ratio of great vessels at the level of L3-L4 and L4-L5 intervertebral discs [25]: R and L – right and left sides, respectively; D – intervertebral disc; IVC - inferior vena cava; AA – abdominal aorta; RCIA and LCIA – right and left common iliac arteries; RCIV and LCIV - right and left common iliac veins

Considering the above anatomical features, as well as the fact that L4–L5 and L5–S1 are the most common surgical levels for lumbar degenerative disease, 75% of abdominal vascular injuries are observed secondary to L4–L5 discectomy [22].

It is noted that vascular damage is not necessarily related to the surgical technique during disc removal [17]. A number of factors have been identified that increase the risk of such an injury [17,20,23,25,28,29,30–34]:

1. Congenital:

- vertebral anomalies;

- variations in the sagittal diameter of the disc;

- variations and different configuration of the abdominal aorta and venous collectors and their branches.

2. Acquired:

- previous tears and other defects of the fibrous ring or anterior longitudinal ligament;

- hypertrophic spurs on the anterior surface of the vertebral bodies;

- degeneration of the ligamentous apparatus;

- intra-abdominal adhesion and vascular fixation due to prior abdominal surgery;

- prior disk surgery (repeated operation);

- peridisc fibrosis with vascular scarring;

- radiation therapy has been carried out;

- vascular diseases (arteriosclerosis, arteriovenous malformation, arteriovenous fistula (AVF), aortic aneurysm);

- secondary weakness of the vascular wall due to ventral prolapse of the intervertebral disc;

- patient's hiccups during surgery.

2. Technical:

- use of sharp instruments;

- using a trephine to remove a herniated disc;

- lateral deviation of instruments;

- use of a pillow for the abdomen;

- violation of the intervention technique: deep immersion of instruments;

- insufficient experience of the surgeon.

Even in the absence of these factors, the threat of iatrogenic vascular injury cannot be completely denied.

It is known that the incidence of complications does not depend on the discectomy method. Thus, in addition to cases reported in microdiscectomy, vascular injury has been reported in endoscopic disc removal [35], percutaneous lumbar laser discectomy [36], and extreme lateral interbody fusion (XLIF) [37].

During cage placement, selecting its appropriate size based on preoperative image assessment and intraoperatively using special instruments is critical, as well as avoiding too deep placement of the implant. Cage migration is a common postoperative complication in posterior lateral interbody fusion (PLIF), and its forward displacement can cause damage to ligaments and/or vascular structures [16]. Biomechanical studies have shown that the posteromedial position of the cage is associated with the lowest migration and the highest fusion rate [38].

The variety of clinical symptoms is due to different localization of damage, type (arterial, venous or combined) and extent of vascular accident. S. Papadoulas et al. analysing 99 cases of damage to great vessels during discectomy, the following distribution was found by the level of damage: intervertebral disc L2-L3 of the motor segment – 2% of cases, intervertebral disc L3-L4 – 11%, intervertebral disc L4-L5 – 59%, intervertebral disc L5 -S1 – 28% [17]. The authors note that the level of surgery is usually associated with an increased incidence of damage to a certain vessel. More cranial levels are characterized by injury predominantly to the aorta and inferior vena cava, whereas damage to the iliac vessels was observed mainly during surgery at the L4-L5 and L5-S1 levels. More detailed statistics of damage to great vessels are given in the works of B. Liu et al. [16]. Thus, when analysing 77 patients, lesions of the left external iliac artery were registered in 1.3% of cases, the right external iliac artery – in 1.3%, the left internal iliac artery – in 1.3%, the right internal iliac artery – in 1.3%, the right common iliac vein – in 2.6%, the inferior vena cava – in 5.2%, abdominal aorta – in 5.2%, the left common iliac vein – in 13%, the right common iliac artery – in 13%, the left common iliac artery – in 32.5%. Cases of damage to the lumbar artery [39], middle sacral artery [40], lower mesenteric artery [41], and superior rectal artery [42] have also been described in the literature.

Rupture is usually manifested by or haemodynamic instability [22]. Other symptoms have also been reported (abdominal pain [22], pale skin [43], back pain [44], lower extremity discomfort [45], and chest pain [46]).

Damage to great vessels during discectomy can proceed according to three clinical and pathomorphological scenarios: manifestation of vessel rupture symptoms, AVF or formation of pseudoaneurysm. The frequency of these manifestations, according to different authors, varies considerably. Thus, S. Papadoulas et al. registered 30, 67 and 3% of cases, respectively [17], Bingchuan Liu et al. – 58.4, 28.6 and 13.0% [16]. M. van Zitteren et al. show the following data: acute vascular injury – 53.4% (arterial – 39.7%, venous – 3.4%, combined – 10.3%), AVF – 17.2%, pseudoaneurysm – 13.8%, AVF in combination with pseudoaneurysm – 13.8%, acute injury with pseudoaneurysm – 1.7% [47]. All indicators given in the above works are based only on the literature data, since it is impossible to collect a sufficient number of cases for analysis within the clinical practice of one surgeon or even one medical institution. Therefore, the actual incidence of complications and their type is a matter of debate.

Depending on the type of vascular injury, the damage can be recognized immediately or remain undetected for years. Arterial hypotension during or after surgery indicates vascular injury [30], postoperative hypotension with decreased haematocrit is also indicative of bleeding requiring investigation [31]. The low incidence of bleeding after trauma has been attributed to the valve mechanism of the operated disc preventing blood leakage [48]. In addition, blood leakage from damaged vessels is expected to occur in the direction of least resistance into the retroperitoneal space or from an artery into a vein in the case of AVF [30]. Abdominal distension caused by retroperitoneal hematoma and/or intestinal paresis is not a pathognomonic symptom, as it is observed in less than 20% of cases [49–51].

Acute damage to great vessels is usually diagnosed within the first 24 hours. According to various studies, the most characteristic symptoms are arterial hypotension (84.4–88.9% of cases), tachycardia (34.4%), active bleeding from the disc cavity (28.9–43.8%), decreased haemoglobin level (25%), tense abdomen (18.8%), palpation of a mass in the abdomen (6.3%), abdominal pain (15.6–22.2%), back pain (2.2–3.1 %), pain in lower extremities (2.2–6.3%), pallor and cyanotic skin (2.2–3.1%) [16, 47].

Typical clinical signs are difficult to recognize in AVF and pseudoaneurysm. Certain relevant symptoms caused by blood loss and retroperitoneal hematoma can be considered as diagnostic clues (lower extremity oedema, abdominal pain, progressive dyspnoea, systemic edema, ascites, and heart failure) [52,53]. About 13% of AVF and 50% of pseudoaneurysms have no clinical manifestations [21].

Chronic AVF formation in heart failure with high output and/or leg oedema should be denied [54, 55]. The most common clinical symptom in patients with AVF is shortness of breath on exertion [56]. Large AVFs lead to congestive heart failure, lower limb oedema and intermittent claudication. Ascites, hepatomegaly, and anuria indicate severe cardiac decompensation [41, 57]. Swelling of the scrotum and penis has also been reported [58]. Most patients report noise as if from the machinery [25, 59]. Sometimes the sound is heard at a considerable distance [25, 60]. Tremors in the abdomen, narrow pulse pressure, weakening of the femoral artery pulse and decreased humeral index value may be observed [26]. Secondary cardiomegaly usually disappears after AVF closure. In many cases, AVF simulates deep vein thrombosis or primary heart disease [59] The development of heart failure with high cardiac output in a young patient who has recently undergone a lumbar discectomy is almost pathognomonic for traumatic AVF [61]. Although dyspnoea and lower limb oedema may develop soon after discectomy, the diagnosis is sometimes missed and the patient is treated with diuretics [59, 62].

More than 25% of AVF remain unrecognized even after one year. This is due to the following factors [30, 63]:

- mild or no symptoms at first;
- moderate symptoms usually associated with primary heart disease, chronic venous insufficiency, etc.;
- lack of thorough physical examination and awareness of this complication;
- presence of morbid obesity.

There are factors that may objectively complicate the diagnosis: general compensation in young patients [45, 64], vascular compression caused by the lying position or hematoma which may temporarily block the site of injury [64], the self-sealing effect of the anterior longitudinal ligament [65].

If adipose tissue or mucosa (retroperitoneal adipose tissue or vessel wall) is found in the conchotome during disc extraction, vigilance should be immediately increased for the patient, even in the absence of intense intervertebral bleeding. To confirm the defect of the anterior longitudinal ligament, the Shelvin test is recommended to use (fill the wound with saline solution for irrigation: its rapid leakage through the disc space indicates the existing defect) [66].

Instrumental methods of intraoperative monitoring to aid in diagnosis: non-invasive blood pressure measurement (NIBP), electrocardiography (ECG), pulse oximetry (SpO_2) and end tidal $EtCO_2$ concentration. In addition, invasive monitoring of arterial and central venous pressure and periodic arterial blood gas measurements are recommended if there are risk factors or major surgical trauma.

If vascular injury has occurred during surgery, progressive hypotension and tachycardia are sensitive indicators that can be detected in addition to decreased pulse wave amplitude and decreased $EtCO_2$. Although some signs appear relatively late, pallor, hypothermia, and weak pulse also have some diagnostic value, especially after sufficient blood volume replacement and appropriate positive inotropic therapy.

A rapid and accurate choice of diagnostic methods is essential for prompt treatment. Typically, non-invasive diagnostic testing involves ultrasound examination, computed tomography (CT) and magnetic resonance imaging (MRI). Bedside ultrasound is a convenient and effective method, whereas CT and MRI, especially with contrast, can confirm the site of bleeding and differentiate between arterial and venous injury [45, 64].

As a type of invasive examination, interventional angiography is an important standard for establishing an accurate diagnosis and is recommended as the first diagnostic method of choice, because of its potential therapeutic benefits [22, 45]. For some conditions, interventional angiography is limited by medical technologies and the severity of the disease, so timely abdominal cavity examination is more appropriate [67]. If acute vascular injury is suspected, balloon occlusion should be performed immediately over the suspected site to stop continuous bleeding and to stabilize the circulating blood volume (CBV) with blood transfusions as soon as possible.

Due to the advantages of effective haemostasis and vessel walls repair, traditional open surgery is optimal for critical situations, as immediate identification of the lesion site and repair under direct view contribute to stopping continuous bleeding. However, anatomical differentiation can be difficult if the defect is surrounded by a large hematoma or is deeply localized. In addition, increased risks caused by secondary laparotomy should be considered [22].

End-to-end anastomosis and bypass graft are considered as alternative methods if suturing fails. Some authors emphasize that in the presence of these risk factors, vascular prosthetics is mandatory due to the high risk of vascular suture failure.

Endovascular technology is increasingly used to eliminate different types of injuries, but the risk of stenosis and thrombus formation, as well as the need for long-term use of antithrombotic drugs, should be considered. The interventional technique seems to be more appropriate in the treatment of AVF and pseudoaneurysm [44, 52, 64]. The advantages of interventional surgery (minor surgical trauma and short hospital stay) are more practical in some circumstances [68].

Compared with the examination of the abdominal cavity and traditional treatment, endovascular technology has some disadvantages:

- inability to recognize the presence of arteriovenous damage;
- inability to tightly cover the choroid fissure, which is associated with re-expansion of vessels after adequate blood supply;
- difficulties for guidewire passage through a long-segment or transverse vascular injury.

To reduce the incidence of abdominal vascular injuries caused by lumbar surgery: 1) the patient's comorbidities should be carefully evaluated to identify potential risk factors, 2) surgeons should avoid certain manipulations (gross or deep disc removal), 3) suspected iatrogenic vascular injury requires rapid examination of the abdominal cavity and restoration of vascular integrity, 4) immediate balloon occlusion may help stop continuous bleeding.

Management of haemorrhagic shock in case of large vessels injury during lumbar discectomy

Team approach. Effective management of massive bleeding (MB) requires a team approach and the simultaneous involvement of a sufficient number of experienced physicians, paramedical personnel, and allied diagnostic services [69]. The team should be coordinated by an experienced, effective and authoritative team leader.

Control of the source of bleeding. The efforts of both surgeons and anaesthesiologists should be directed towards controlling the source of bleeding as soon as possible. No anaesthetic manipulation should delay the start of surgery aimed to definitely stop bleeding. The timeliness of detection of vascular injury and surgical correction of the vascular defect depend on the availability of a qualified vascular surgeon in the institution or the possibility of the quick arrival of such a consultant from another medical institution.

In many cases, the diagnosis of injury to a large vessel passing behind the peritoneum is made after the development of symptoms of haemorrhagic shock, therefore, in addition to the detection and elimination of vascular damage by surgery, the key factors in patient survival are haemostatic resuscitation and early and effective treatment of haemorrhagic shock by blood transfusion.

Use of the Cell Saver erythrocyte preservation device. If a Cell Saver device is available in the facility, it should be used immediately to collect blood during surgical haemostasis. The use of Cell Saver to collect and wash erythrocytes significantly and reliably reduces the volume of transfusion of erythrocyte mass required for the treatment of a patient with MB [70]. Low availability of this device and high cost of consumables (sterile kits/sets) significantly limits the use of this method in Ukraine.

Collection of blood for autotransfusion. If, during emergency surgery to control the source of critical (life-threatening) bleeding, it is determined that the blood that has spilled into the abdominal cavity and retroperitoneum is in a liquid state (not clotted) and uncontaminated, then efforts should be made to collect this blood. Sterile utensils should be used with an appropriate amount of anticoagulants added. If, after blood collection, a life-threatening situation arises for a person with critical bleeding, and the medical treatment facility does not have a supply of donor blood components, the anaesthesiologist and surgeon can make a concerted decision to autotransfuse the patient's own uncontaminated blood, collected from the abdominal cavity and retroperitoneum.

Basic principles of intensive care of massive bleeding and haemorrhagic shock

Blood collection for tests and compatibility determination. In most cases, the blood type and Rh factor are known prior to spinal surgery. However, if MB is suspected, blood should be drawn both for tests and for compatibility testing with donor blood.

Tranexamic acid. In haemostatic resuscitation, tranexamic acid has been proven to be effective in reducing intraoperative blood loss [71], therefore, after the diagnosis of MB, 1 g of tranexamic acid should be administered intravenously, and then infusion of another 1 g should be started within 1–8 h. A meta-analysis of several studies demonstrated that the use of moderate doses of tranexamic acid (total dose – 20 mg/kg body weight) has a better efficacy/safety profile than the use of higher doses [72].

Establishing reliable venous and arterial access. According to most current treatment algorithms for traumatic MB, two large-diameter peripheral catheters should be installed early (before the development of MB and haemorrhagic shock). The advantages of short peripheral catheters are that more blood can be transfused through them than through long catheters placed in central veins. A central venous catheter is appropriate if the patient is to be treated with high-dose vasopressors for a prolonged period of time. Since vascular injury during lumbar discectomy is unpredictable, adequate vascular access often has to be established after this complication has occurred. Establishing reliable venous access should be done simultaneously with the work of surgeons to stop bleeding. It should never delay it.

Catheterization of the radial artery (a. radialis) and setting up an invasive (direct) blood pressure (BP) determination may be necessary for effective management of severe haemorrhagic shock, as well as for monitoring blood gas composition. In developed countries, invasive BP determination is the standard of monitoring in the management of haemorrhagic shock caused by MB.

Monitoring. Basic intraoperative monitoring in MB should include automatic non-invasive determination of BP (NIBP), body temperature, SpO_2, capnography ($EtCO_2$), ECG [73, 74].

Additional parameters that are reasonable to determine and evaluate in dynamics may include [75,76]:

- invasive (direct) blood pressure determination; for this purpose, the radial artery is most often catheterized;
- gas composition of arterial and central venous blood:

- lactate level (Lac);

- base deficit (BE);

- calculation of arterio-venous oxygen difference (A–V O_{2diff}), threshold value – 3.7 mL/100 mL);

- calculation of the arterio-venous carbon dioxide difference (A–V C O_{2diff}), threshold value is 6 mm Hg;

- level of haemoglobin, hematocrit, fibrinogen, platelet count;
- blood clotting time, prothrombin time, activated partial thromboplastin time (aPTT), international normalization ratio (INR);
- thromboelastography;
- blood electrolyte composition, primarily Ca^{2+}, K^+, Na^+, Cl^-;
- rate of diuresis;
- pulse pressure variations during artificial lung ventilation (threshold value – 13%);
- perfusion index (PI); its significant decrease compared to the initial indicator suggests vasoconstriction.

Massive transfusion. Massive transfusion (MT) is performed for massive and life-threatening bleeding that cannot be stopped rapidly by surgery. More commonly, MT is defined as transfusion of 10 units of blood components (equivalent to CBV) or more within 24 h or ≥4 units in 1 h [77]. MT is definitively spoken of retrospectively, when it has already been performed, therefore it is not so much a clinical concept as an organisational one. Its prospective value is most often to predict the need to order significant quantities of blood components and blood products by activating the MT protocol, as well as to implement activities to search for these components and blood products. The principles of MT are summarised below.

Prevention of the death triad (hypothermia, acidosis, coagulopathy). In case of progression of severe haemorrhagic shock, the so-called triad of death – hypothermia, acidosis and coagulopathy occurs. These components reinforce each other, creating a false circle that leads to death. Active measures (warming the patient, transfusion of sufficient donor red blood cells to counteract acidosis and sufficient donor coagulation factors to counteract the progression of coagulopathy) should be taken to break this false circle.

Correction of hypothermia and maintenance of normothermia. With the progression of MB and haemorrhagic shock, the patient's body temperature constantly decreases, this leads to impaired function of enzyme systems of the coagulation cascade, which is manifested by increased coagulopathy and increased blood loss. To prevent hypothermia, the patient should be covered with multiple sheets in such a way as to minimize the body surfaces through which heat loss occurs. Preference should be given to special heat reflective bedsheets, which are used to warm patients at the pre-hospital stage. All components, blood products and other transfusion solutions should be heated to 37 ºC. In case of already formed hypothermia, neither passive warming by wrapping the patient's body with heat-retaining means, nor heating solutions to correct hypothermia is enough. The only effective way to correct such hypothermia is to actively warm the patient with the help of special mattresses or blankets through which warm air is circulated.

Maintaining permissive hypotension until the arrest of bleeding. Since the rate of bleeding from injured vessels depends on the value of BP, BP should be maintained at the level of moderate or moderate hypotension until the final surgical arrest of the MB. There are no single agreed blood pressure levels, the maintenance of which, on the one hand, significantly reduces bleeding and, on the other hand, provides acceptable perfusion of internal organs. Most often, the literature recommends an mean arterial pressure (MAP) as systolic BP + 1/3 pulse BP not lower than 65 mm Hg, but this level is quite conditional. For example, at BP 85/55 mm Hg (which corresponds to a MAP of 65 mm Hg) in young women prone to arterial hypotension, these figures are close to the norm and will not significantly reduce bleeding. In contrast in a patient with severe hypertension and working BP of 180/100 mm Hg such arterial hypotension as 85/55 mm Hg would be clinically significant and lead to the progression of shock. Therefore, the degree of permissible hypotesion is determined individually, taking into account a number of factors (the amount and rate of blood loss, the prospects of surgical haemostasis, the presence/absence of a supply of blood components and products, the presence of significant comorbidities, etc.).

Infusion therapy. In ongoing treatment of MB, infusion therapy should be minimal until MB is stopped, so as not to intensify dilutional coagulopathy, transfusion therapy should be actively used instead. The value of infusion therapy and its volume after stopping MB depend primarily on whether adequate transfusion therapy has been achieved. In case of adequate and complete transfusion therapy for MB, the volume of crystalloid infusion may be moderate or minimal.

In the treatment of moderate ongoing bleeding, infusion therapy should also be limited until it stops, and once the bleeding has stopped, it may be important to stabilize the CBV.

When selecting an infusion therapy agent, preference should be given to balanced crystalloid solutions with reduced amount of chlorine, and lactate or acetate are present instead. Since colloid solutions have not demonstrated clinically significant advantages over crystalloids in numerous high-quality randomized trials, crystalloids should be used as a first choice [76,78].

Use of vasopressors. When clinically significant arterial hypotension occurs, which may lead to ischemia of internal organs (primarily kidneys and intestines), it is important to stabilize blood pressure at an acceptable level in a timely manner. It is optimal to correct blood pressure by carrying out a rapid transfusion of blood components or whole blood, but this is not always possible. In such cases, early vasopressor support may be required. Early administration of vasopressors is considered safer and more effective than massive infusion of colloids or crystalloids, which was routine practice decades ago. Of the vasopressors, noradrenaline is favoured, in its absence, a combination of phenylephrine (Mesaton) and adrenaline can be used. Dopamine is no longer a first-line vasopressor, so it should not be routinely used for the treatment of arterial hypotension in haemorrhagic shock.

Organ support and replacement therapy. If haemorrhagic shock has been prolonged due to a deficiency of blood components and preparations, clinically significant ischemia of internal organs (primarily the lungs and splanchnic area) may develop.

In case of development of "shock lung", the need for long-term oxygen therapy and respiratory support should be assessed.

After elimination of shock, acute renal failure may occur and progress, requiring acute haemodialysis. If ischemic intestinal damage occurs, enteral nutrition should be started gradually according to the principles of "trophic nutrition". If for 2-3 days it is not possible to reach 50-75% of the daily requirements of the body in energy and protein, then the issue of combined enteral and parenteral nutrition should be considered.

To prevent the development of septic complications, antibiotic prophylaxis should be carried out in a way that reduces the likelihood of developing nosocomial infections (taking into account the microbiological passport of the intensive care unit).

Principles of transfusion therapy

We try to formulate general principles of transfusion therapy for submassive and massive bleeding, worked out in medical treatment facilities in Ukraine, which often face the problem of MB. The most important aspects of MB transfusion therapy, typical for civil and military medicine have been stated in developed countries one of even two decades agoo, but still insufficiently described, regulated and little implemented in Ukraine.

Organizational aspects of readiness for treatment of MB and performance of MT. The volume and efficiency of transfusion therapy depend on many factors characterizing the preparation of a medical institution for MB cases:

- presence of a blood bank in the medical institution, in its absence – the blood service or the person responsible for creating and maintaining banks of blood components and preparations;
- the number of banks of blood components and preparations, primarily of erythrocyte mass of O(I) group and fresh frozen plasma of AB(IV) group;
- Approval and implementation in medical and preventive institutions of the MT protocol, which regulates the provision to the operating theatre of a standard set of 4-6 bags of red cell mass, 3-4 bags of fresh frozen plasma and platelet mass, cryoprecipitate or fibrinogen concentrates and other coagulation factors;
- the availability of a document, such as a standard operating procedure regulating the involvement of staff and the allocation of their responsibilities in the event of development of the MB;
- experience of medical staff regarding the diagnosis and treatment of MB and performing MT.
- Since preparation for MT may vary considerably across different treatment facilities on many of the mentioned points, the availability of transfusion therapy for MB also varies widely.

Ordering blood before surgery. In preparation for elective surgery with probable MB, ordering donor blood components is a key aspect. First of all, erythrocytes (red blood cells – RBSs) and fresh frozen plasma should be ordered in volumes close to the amount of planned blood loss in a ratio of 1:1 to 2:1 [69,79,80]. If thrombocytopenia is detected, then a platelets is additionally ordered. If a decrease in the level of fibrinogen or other coagulation factors is detected, cryoprecipitate, fibrinogen products or concentrates of coagulation factors are prepared. It is the low fibrinogen level that often plays a leading role in the development of hypocoagulation in MB, and its correction can improve treatment outcomes [81]. Because vascular injury in lumbar discectomy is unpredictable, blood components and blood preparations are rarely ordered prior to surgery.

Creation of blood banks in a health care facility. Health care facilities where MBs occur frequently should have a supply of donor blood components and blood products in proportion to their use during the treatment of MB. In health care facilities where submassive and massive bleeding is rare, building up large blood supplies will result in expiry of red cell mass and platelet concentrate. In this case, many components and preparations with the expiration date will be disposed of, which is unethical and economically impractical.

In developed countries, hospitals, where MBs rarely occur, they do not stock all blood groups, but only blood components from universal donors – erythrocyte mass of the O(I) group and plasma of the AB(IV) group. This makes it possible to adjust MB while the necessary blood group is delivered from the blood bank or the patient is transported to a medical institution where there is a blood bank and other opportunities for effective treatment of MB.

It is also promising to create a stock of lyophilized plasma, which has a long storage period and is quickly dissolved with a warm solution of 0.9% NaCl, that is, it does not require long-term thawing and warming.

Principles of transfusion therapy depending on the massiveness of blood loss and prospects for stopping bleeding. To choose the tactics of transfusion therapy, in particular, the number of doses of blood components and blood preparations, as well as the rate of blood transfusion, it is necessary to at least approximately determine the volume of blood loss or the percentage of CBV, as well as the severity of haemorrhagic shock. Human blood volume is about 6-8% of the body weight. So, a woman with an average body weight of 67 kg has about 4,000 mL of blood, and a man with an average body weight of 83 kg has about 5,000 mL of blood. Blood loss is clinically significant, resulting in haemodynamic changes that can be characterized as initial shock. This is usually a blood loss corresponding to one third of CBV and requires transfusion therapy. Blood loss is massive, causing severe shock with life-threatening consequences (with the loss of more than half of the CBV). In the case of MB, activation of the MT protocol is required.

Determining the magnitude of blood loss and bleeding rate. Since ongoing bleeding constantly changes the amount of blood loss, it is difficult to accurately determine the amount of blood loss even when performing a spiral CT with contrast in the trauma mode or performing an ultrasound according to the e-FAST protocol. Therefore, it is necessary to constantly assess the amount of blood loss and the rate of bleeding using clinical indicators, such as blood pressure, pulse, the rate of restoration of the capillary bed filling, skin colour, respiratory rate, the degree of dispnea, the level of consciousness (its depression or loss of consciousness). There are no separate indicators that could indicate that blood loss and bleeding have reached the level necessary to establish a diagnosis of MB. What is important is the dynamics of these indicators: if the rate of deterioration persists or increases, the severely injured/injured person most likely has a life-threatening MB.

The decision to start blood transfusion. There are not and cannot be uniform criteria for the initiation of blood transfusion. For ongoing blood loss, decisions are most often made when blood loss becomes haemodynamically significant and causes symptoms of shock, or these symptoms are likely to appear soon. With ongoing blood loss, the haemoglobin level should NOT be the primary criterion for initiating blood transfusion. The haemoglobin level should be taken into account already after the bleeding has stopped and the shock has been eliminated.

In hemodynamically stable patients who have no symptoms of acute myocardial or cerebral ischemia, for more than 20 years the indication for anaemia treatment by blood transfusion has been a haemoglobin level <70 g/l.

Recently, monitoring of central venous oxygen saturation ($ScvO_2$) and A–V O_{2diff} has received increasing attention when choosing the transfusion therapy tactics. A decrease in $ScvO_2$ <70% and an increase in A–V O_{2diff} >3,7 mL/100 mL of blood suggest a benefit from blood transfusion, whereas $ScvO_2$ >70% and A–V O_{2diff} <3,7mL/100 mL indicate that the decision on transfusion can be postponed [82,83].

Acute blood loss, which is a third of the CBV (for example, 1300 mL in a person with a body weight of 67 kg and 1700 mL in a person with a body weight of 80 kg) shows initial symptoms of shock, but the compensatory mechanisms of the body are preserved. The most important initial symptoms of shock are:

- a moderate decrease in blood pressure and an increase in heart rate (HR), the Allgower's shock index (HR/SBP) often exceeds 1, but rarely reaches 1.5;
- signs of centralization of blood circulation – a moderate decrease in the pulse wave amplitude, pallor of the mucous membranes, decreased skin temperature on the periphery of the limbs, acrocyanosis);
- moderate decrease in the rate of diuresis;
- moderate increase in lactate concentration (>2 mmol/L) and BE base deficit (up to –4 mmol/L);
- a moderate decrease in haemoglobin level (in the absence of its dilution during infusion therapy).

Here are the principles of transfusion therapy in case of blood loss not exceeding a third of the CBV, and bleeding that has been definitively stopped or partially stopped, which can probably be stopped permanently in the near future. In such cases, transfusion therapy should be fast enough (for timely treatment of shock), but limited in volume (up to half of the lost blood), and should be carried out in compliance with all the rules and principles that increase its safety:

- use of blood of the same group only (if available);
- erythrocyte mass and plasma ratio of 1:1 or 2:1;
- ordering platelets and blood coagulation factors (factor concentrates, cryoprecipitate) is optional;
- full compatibility testing:

- donor's erythrocytes and recipient's plasma in a ratio of 1:4;

- heating the Petri dish in a water bath to a temperature of 37 ºC;

- assessment of agglutination "by eye", as well as under a microscope;

- small volume of rapid infusion (5–10 mL) with infusion stopped for a few minutes to check the presence of symptoms of immediate allergic reactions.

Acute blood loss exceeding half of the CBV is manifested by overstrain and decompensation of the adaptive mechanisms of the cardiovascular system, symptoms of severe shock and poses an immediate threat to the patient's life. The main symptoms are most often:

- a significant and progressive decrease in blood pressure and an increase in heart rate, the Allgower's shock index often exceeds 1.5 and often reaches 2;
- distinct and progressive centralization of blood circulation – a sharp decrease in the pulse wave amplitude up to the loss of the peripheral pulse;
- progressive decrease in body temperature;
- decrease in the rate of diuresis to anuria;
- progressive increase in lactate concentration (>4 mmol/L) and BE base deficit (>6 mmol/L);
- significant decrease in haemoglobin level even in the absence of its dilution during infusion therapy.

In case of blood loss exceeding half of the CBV, and in the presence of bleeding that cannot be stopped soon, **transfusion therapy should be based on the principles of damage control resuscitation and haemostatic resuscitation**. The principle of damage control resuscitation is that with an ongoing MB, the rate of transfusion should be at least as high as the rate of blood loss. Such resuscitation sustains life and gives surgeons time to stop the bleeding. Haemostatic resuscitation with MB consists in the administration of only oxygen-carrying liquid (erythrocytes) or coagulation factors (plasma, platelets, coagulation factor concentrates). Neither crystalloids nor colloids are included in resuscitation, damage control, or haemostatic resuscitation protocols, so a large number of blood components and products are required for effective resuscitation. In recent years, most treatment protocols and clinical guidelines have emphasized: the greater the blood loss, the less crystalloid infusion should be, but the greater the transfusion of blood components and preparations or whole blood. With ongoing MB, the haemoglobin level should NOT be the main criterion for either starting or stopping blood transfusion. When assessing haemoglobin level, it should always be taken into account whether crystalloid infusion has already been carried out and in what volume.

The situation is most difficult in the case of ongoing MB, in the absence of required amount of blood products. In such cases, the following alternatives should be considered to save the patient's life at the beginning of resuscitation:

- if possible, activate the MT protocol (if it has been approved in the medical treatment facility and implemented in clinical practice);
- involve additional medical personnel in the patient's care, who will be engaged in the search for blood products or blood components, and if these are not available, will resolve the issue of whole blood transfusion; the anaesthesiologist providing anaesthesia should focus on its administration, rather than dealing with organizational issues associated with transfusions;
- order a sufficient quantity of both components and blood products:

- in the blood service of a medical treatment facility or the nearest blood bank;

- make efforts to order, in addition to erythrocyte mass and plasma, platelets and blood coagulation factors (concentrates of factors, cryoprecipitate);

- find out how much blood of the same type, as well as blood from a universal donor, is available in the medical institution, and try to urgently involve these resources to treat a patient with MB;
- find out whether it is possible to involve in urgent blood donation persons tested for the presence of the human immunodeficiency virus, hepatitis and other infectious diseases that can be transmitted with blood, with preference given to donors with low antibody titres;
- explain to relatives the details of the patient's condition, traditional approaches to transfusion therapy and possible alternatives;
- it is essential to order platelets and blood coagulation factors (factor concentrates, cryoprecipitate) in sufficient quantities;
- in case of immediate threat of circulatory arrest due to MB and the presence of erythrocyte mass or whole blood ready for use, a full test for individual compatibility is not conducted in developed countries, its use is not clearly regulated in Ukraine. Such a test is carried out in case of at least partial stabilization of the patient's condition in the presence of necessary resources (qualified personnel and equipment);
- in case of immediate threat of circulatory arrest due to MB, manifested by marked arterial hypotension, tachycardia, and hypothermia, a biological test is not performed in developed countries, as it is uninformative, and in Ukraine its use is not clearly regulated. Such a test is performed after at least partial stabilization of the condition (normalization of blood pressure and temperature);
- in case of continued MB and progression of coagulopathy and preservation of a real threat to life, the only life-saving measure is urgent transfusion of blood or its components according to the MT protocol. Transfusion of

erythrocyte mass, plasma, and platelet mass is performed in a 1:1:1 ratio [69,79,80];

- in the absence of blood products or blood components (in particular, platelet mass), the possibility of transfusion of warm whole donor blood should be considered (if possible, tested for human immunodeficiency virus, hepatitis B and C and with a low antibody titer), in women of childbearing age, the blood should be from Rh-negative (Rh–) donors if possible.

Blood transfusion without testing for individual compatibility. In developed countries, *in vitro* testing for individual compatibility is performed in a blood bank and is almost never done at the patient's bedside or in the operating room. Physycians planning emergency transfusions collect the patient's blood and send it to a blood bank, where the blood is centrifuged, plasma is collected and combined with donor red blood cells. All this is done under standardized conditions (in a water bath at a temperature of 37 ºC) and compatibility is assessed under a microscope. After that, the compatible blood is sent to the clinician. All these procedures take at least 15 minutes, so if emergency blood transfusions are required in MB before compatible blood is ready, both in the emergency room and in the operating room, several available blood bags are used without compatibility. With MB without compatibility, the erythrocyte mass of group O(I) or whole blood of group O(I) is most often transfused [84–86]. After that, the blood bank sends several bags of compatible blood to the operating room at once, and clinicians start using it. The safety and efficacy of emergency transfusions of incompatible blood have already been confirmed and proven in a number of studies [87–91].

Prospects for the use of whole blood. The safety and efficacy of whole donor blood transfusions over the past two decades have been repeatedly proven in wartime conditions. The practice of using whole blood in the USA for trauma and wounds is gradually being introduced into civilian medicine [92–94]. In recent years, there are more and more publications in which transfusion of the same group of whole blood is compared with the transfusion of its components in the most effective ratio of 1:1:1 [95]. Following the positive results of transfusion of both single-group whole blood and erythrocyte mass from a universal donor of group O(I), the use of whole blood of group O(I) from donors with low antibodies titers is increasingly being reported in military and civilian medicine [96–100]. Thus, in a prospective observational study conducted in Texas, in 1377 patients, the use of whole blood group O(I) was compared with transfusion of its components (erythrocytes, plasma and platelets in a 1:1:1 ratio). Logistic regression analysis based on the severity of the patient's condition revealed that infusion of whole blood of group O(I) was accompanied by clinically significant and reliable improvement in treatment results [88].

Regulation of the use of blood and its components in Ukraine. The documents regulating the use of blood do not consider all aspects of its use that have proven efficacy in high-quality clinical trials and relate to the best clinical practice in developed countries. Such documents are:

1. Instructions for blood transfusion and its components, approved by order of the Ministry of Health of Ukraine No. 164 of 07/05/1999. This document states that:

a) whole donor blood can be used only in extreme conditions in the absence of necessary components;

b) blood transfusion directly from the donor to the patient without stages of stabilization and preservation is called the direct method of transfusion. Only whole blood can be transfused with this method, and it can be used only in the absence of blood components.

2. Law of Ukraine "On the safety and quality of donor blood and blood components" as amended of 12/15/2021 No. 1962-IX. In this document aspects of MB, application of whole blood and blood components from universal donor are not considered.

3. Order of the Ministry of Health of Ukraine No. 418 dated 05.03.2022 "On approval of Methodical recommendations concerning application of the protocol of mass transfusion of blood components to victims at evacuation stages":

a) if the victim's group and Rhesus affinity are unknown, then transfusion of erythrocyte blood components of group O(I)Rh– ("universal donor") to a recipient with any group and Rhesus affinity should be used;

b) in an exceptional case, if there are no blood components and sources of their supply, it is allowed to perform direct transfusion of blood to the victim without preliminary carrying out the necessary set of examinations;

c) haemoglobin cannot be used independently as an indicator of transfusion efficiency, it should be interpreted in the context of the state of haemodynamics, perfusion of organs and tissues.

4. Standards of medical care "Provision of medical care to victims of haemorrhagic shock at pre-hospital and hospital stages of trauma", approved by the Order of the Ministry of Health of Ukraine No. 1192 of July 11, 2022:

a) one study showed a potential survival benefit of using fresh whole blood during resuscitation after severe combat wounds, and another study showed that the use of fresh whole blood was equivalent to component therapy;

b) if Rh-negative blood components and/or preserved donor blood (whole) are not immediately available, the use of Rh-positive components is possible in the presence of haemorrhagic shock;

c) if the victim’s group and rhesus affinity are unknown, transfusion of erythrocyte blood components of group O(I)Rh– ("universal donor") and/or plasma of fresh-frozen group AB(IV)Rh– should be used to a recipient with any group and Rhesus affinity;

d) in an exceptional case, if there are no blood components and sources of their supply, it is allowed to carry out direct blood transfusion to the victim without preliminary fulfilment of the necessary set of examinations. It is necessary to conduct a test for individual compatibility before direct transfusion, as well as a clinical and biological compatibility test.

These documents do not regulate the urgent use of whole blood and blood from a universal donor in acute MB in the operating room. Moreover, some sections of these documents directly or indirectly argue for the need to use outdated approaches involving the use of single-group blood components without taking into account the fact that many of these components may not be available. Therefore, these documents provide little or no protection for a doctor who wishes to provide full-fledged emergency care to a critically ill patient with life-threatening MB. By full-fledged, we mean care, using transfusion methods with proven efficacy in clinical trials, which are implemented in clinical practice in developed countries. For the protection of a doctor who wants to do everything possible to provide full-fledged emergency care within the legal framework, there is a certain basis in the Fundamentals of Ukrainian legislation on health care. Thus, the main document regulating the provision of emergency care, in particular for patients with MB, is Article 37. It states that medical workers are obliged to immediately provide the necessary medical care in case of emergency in a patient. Article 139 of the Criminal Code of Ukraine provides for criminal liability for failure to provide assistance. Therefore, if MB occurs, this condition can be considered urgent, the situation with the lack of sufficient number of single-group components is extreme, and blood transfusion with MB requires medical aid. In MB, sometimes to save the patient's life in the absence of other options, it is necessary to use options with a high evidence base, but not regulated by orders of the Ministry of Health, instructions or methodical recommendations. In this case, a council should be convened, after which the participants should clearly and thoroughly document the circumstances of the clinical case in the medical history, argue and agree on the decision and approve it with personal signatures. As long as the transfusion of red cell mass and plasma from a universal donor, whole blood or transfusion of red cells without individual compatibility are not properly regulated, these methods should be considered as forced therapeutic measures in an extreme situation. They are used when sudden MB develops and in the absence of erythrocyte reserves, fresh frozen plasma, platelets, cryoprecipitate and other coagulation factors in the doctor's supply. If possible, these circumstances and your decision should be explained to the patient, his relatives or other legal representatives, and informed written consent should be obtained from them. The informed consent should emphasize the urgency of the need for blood and blood components, the extremity of the situation, i.e. the severity of the patient's condition, and the limited alternatives available, i.e. the inability to provide blood products or blood components by other means. This will mitigate the risk of a medical worker being held criminally liable under Article 140 (improper performance of professional duties by a medical worker) and Article 131 (improper performance of professional duties resulting in the infection of a person with human immunodeficiency virus or another incurable infectious disease).

Conclusions of the intensive care of MB. In the case of large vessels injury and occurrence of MB, the success of treatment depends on a number of factors, the key of which is the coordinated teamwork of surgeons and anaesthesiologists, whose joint efforts should be focused on establishing control over the source of bleeding as soon as possible.

Intensive care measures to be emphasised include the following:

1. Assessment of the magnitude of blood loss and the ongoing rate of blood loss.
2. Engaging additional personnel to ensure adequate blood supply.
3. Collecting the hospital's existing supply of blood components and preparations.
4. Search and coordination of alternative sources of supply of components, blood products or whole blood.
5. Prevention of the development of the triad of death (hypothermia, acidosis, coagulopathy) by effective warming of the patient and adequate transfusion therapy.
6. In case of long-term persistence of shock, development of shock lung, ischemia of the splanchnic area, and the occurrence of acute renal failure, indications for long-term organ replacement therapy, primarily respiratory support and acute haemodialysis, should be evaluated.

The fact that the efficiency of providing care to patients with damage to great vessels is directly proportional to the rate of diagnosing the complication that has arisen and stopping the bleeding seems obvious and natural. In addition, the vessel diameter and the size of the defect are critical. It has been observed that an injury to the abdominal aorta has the worst prognosis compared to an injury to the common iliac artery [27]. In 2019, Bingchuan Liu et al. published a simple algorithm of diagnostic and therapeutic measures performed on suspected injury to great vessels during discectomy ***(Fig. 2).***

The proposed sequence of actions can be of great practical importance, since most surgeons are not prepared for the occurrence of these complications. The problem is complicated by the fact that the injury is located outside the surgical access and requires emergency and non-standard actions.

It is a common tendency to regard injury to the main vessels during discectomy as a complication that can occur even with careful adherence to surgical technique and extensive surgical experience, and therefore does not constitute clinical negligence [39]. Accordingly, the disciplinary consequences for the surgeon are determined not by the very fact of a complication itself or even the final consequence, but by the rate and completeness of the measures to detect and eliminate the injury [46].

Conclusions

Vascular injury during lumbar discectomy is quite rare, but the most dangerous complication for the patient, which can occur even with careful adherence to surgical technique. The general vigilance of surgeons regarding the possibility of such a problem, knowledge of the symptom complex, quick and clear adherence to the algorithm of diagnostic and treatment measures, as well as a team approach in active cooperation with a team of anaesthesiologists are critical not only for minimizing the consequences, but also for saving life. Timely and complete transfusion therapy according to the principles of haemostatic resuscitation is the key among measures of anaesthetic management and intensive care.

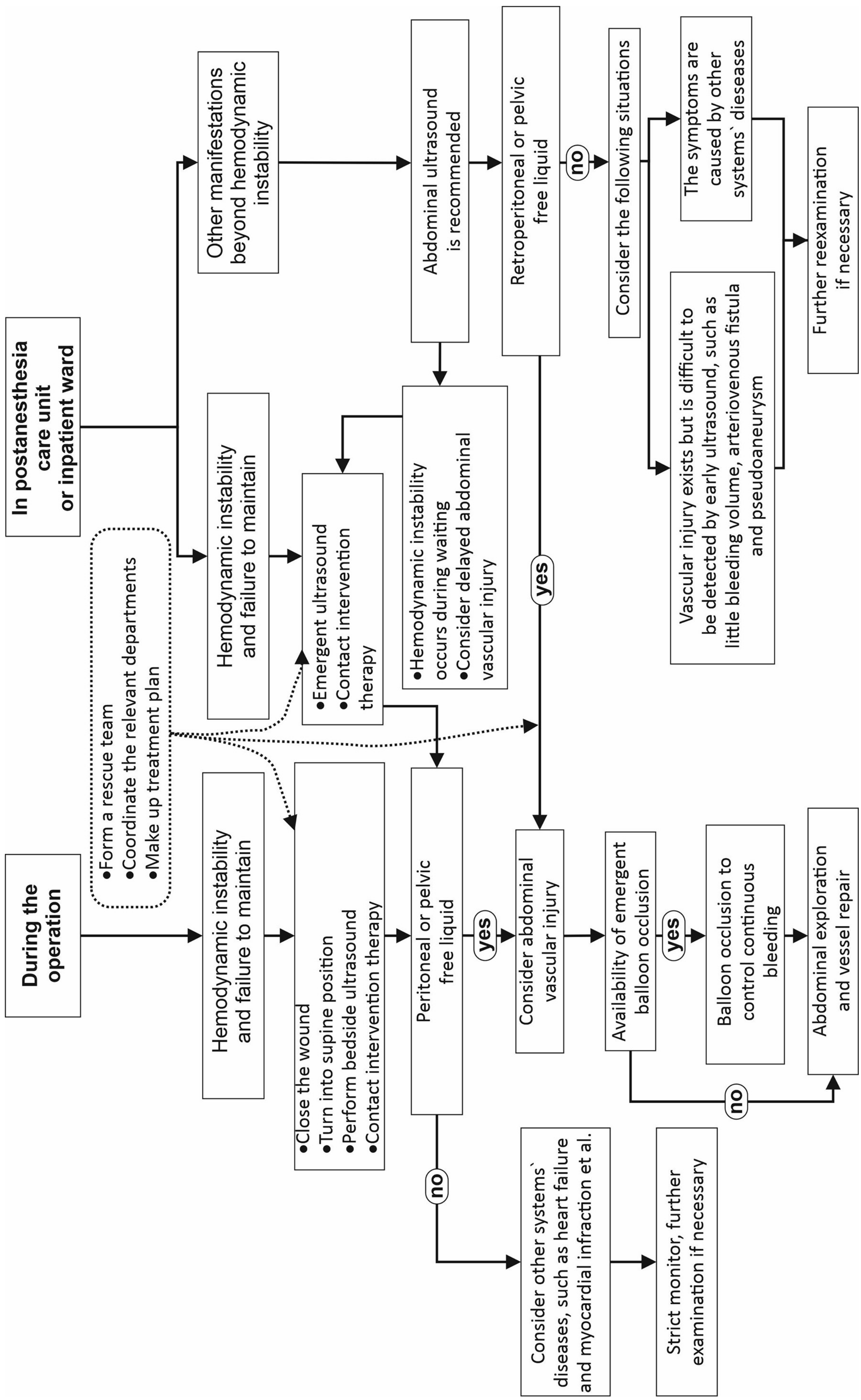

Fig. 2. Algorithm of diagnostic and therapeutic measures for suspected damage to great vessels during discectomy [16]

Disclosure

Conflict of interest

The authors declare that they have no conflict of interest and no financial interest in the preparation of the article.

Ethical guidelines

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