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WHOLE BLOOD TRANSFUSIONS FOR PEDIATRIC TRAUMA PATIENTS ACCORDING TO AMERICAN STANDARDS

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Abstract: A full-scale russian-Ukrainian war has been going on for about nine months. Almost every day, Ukrainian cities suffer from enemy raids of missiles and drones, as a result, civilians become victims of hostilities. The prevalence of mine blast injury in these conditions is extremely high. Unfortunately, this type of injury is often accompanied by massive bleeding, which forces to make amendments in a treatment strategy. According to world standards, the first infusion solution for this category of patients should be whole blood, because of its numerous advantages. At the Multidisciplinary Clinical Hospital of Emergency and Intensive Care in Lviv, this strategy has been used almost since the first days of the war for patients of all age groups. In the article, we present a convincing evidence base of the advantages of using whole blood, as well as a clinical case of using whole blood infusion in a pediatric patient.

Keywords: whole blood, mine blast injury, transfusion, massive bleeding, war

INTRODUCTION

On the 24th of February, 2022, at 5 am, russia launched air strikes on targets in Ukraine, starting a full-scale military offensive on its territory. Missile strikes were carried out in numerous Ukrainian cities. Military facilities of the Armed Forces of Ukraine were attacked. The first strikes and military actions were taken in Kyiv, Kharkiv and the cities of eastern part of Ukraine, where the russian-Ukrainian hybrid war has been going on since 2014. Daily not only «strategic» military targets were attacked, but also civilian infrastructure, which resulted in plenty of casualties.

Western part of Ukraine, which is close to the Polish and other European borders, also was not avoided by the enemy. For example, on the 13th of March, the Yavoriv military range was covered by a russian missile strike. According to Ukrainian officials, 30 missiles were fired at the base. 35 people were killed and 134 were injured.

As a result of missile attacks, many Ukrainian military and civilians had mine blast injuries. Mine blast injury is a complex lesion of the body, which is often accompanied by massive bleeding. Whole blood transfusion is the method of choice in the management of patients with massive bleeding [1], and its advantages are proven in numerous studies and in our own clinical expierence.

EVIDENCE OF RECEIVING INFORMATION

As it is stated in Tactical Combat Casualty Care Guidelines, whole blood reduces the likelihood of coagulopathy [2], which is an independent death predictor.

The risk of post-transfusion reactions to a whole blood is extremely low [3]. Furthermore,

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whole blood that contains the correct ratio of all the necessary elements for full-fledged hemostasis and oxygen transportation and is more advantagious that individual blood products (packed red blood cells, platelets and fresh frozen plasma) in a ratio of 1:1:1 [4]. When comparing whole blood and components, it is understandable that whole blood has less volume but contains 50% more platelets and 30% more coagulation factors [5]. Important fact is that whole blood contains enough hemoglobin to increase the hemoglobin concentration in an average-sized adult by approximately 1 g/dL. In war conditions, whole blood transfusion is particularly relevant, since its use is associated with an increase in survival after mine blast injury [6]. The practical value during the war is that whole blood can be stored in a container for up to 35 days when using the preservative CPDA-1 because during this time it does not lose its functions.

During the war, Ukraine is guided by European and American standards [7][8] of whole blood transfusions and actively implements a civilian walking blood bank emergency preparedness plan [9], guided by the advice of foreign colleagues.

The most important rules for us can be taken from Circular of information for the use of human blood and blood components prepared by the Association for the Advancement of Blood & Biotherapies. As is written in in the AABB Standards for Blood Banks and Transfusion Services, all blood and blood components must be maintained in a controlled environment and stored under appropriate conditions applying the strictest rules of aseptic technique and be properly identified. Great attention is paid to inspecting the blood and blood products, usage of different medications during blood transfusion and possible adverse reactions.

From the first days of a full-scale war Municipal non-profit enterprise «Lviv Territorial Medical Union «Multidisciplinary Clinical Hospital of Emergency and Intensive Care» began to provide assistance to all victims of missile attacks in Lviv and the region, as well as to see civilian patients from places of active hostilities on the way of the second evacuation line. Moreover, for the first time in Ukraine the use of whole blood as the basic transfusion solution in patients with massive bleeding has started in a Municipal non-profit enterprise «Lviv Territorial Medical Union «Multidisciplinary Clinical Hospital of Emergency and Intensive Care».

In our hospital we are trying to implement the American Transfusion Protocol, while Americans have the largest expierence working as military doctors in Afganistan and many others war zones and they were ready to share their knowledge.

According to the American Massive Transfusion Protocol whole blood should be the first transfused solution for every urgent trauma patient who is older than 1 year. Maximum dose of whole blood should not be more than 40 ml/kg. During massive transfusion it is the utmost important to have own local protocol with written each step in it because it helps to save time. These steps should definitely include: patient identification and giving information to the blood bank; measuring of the exact time needed for blood or blood products to be transfused after patient`s hospitalization (for example, uncrossmatched "group O" whole blood or red blood cells must be available in 5 minutes, but at the same time, platelets would be ready in 15 minutes only); type of the delivery blood from bank to the emergency room (via pneumatic tube or pik-up cooler). It is worth to remember that after initial resuscitation, we should switch to goal directed therapy, transfusing products guided by laboratory results. And if patient received whole blood, during 2 days after transfusion, lactate dehydrogenase, total bilirubin, haptoglobin and reticulocytes levels should be measured.

Table 1. Dosage of blood products according to the laborathory tests results

Value	Normal	Transfusion Trigger	Product	Dose
TEG-ACT	**86-118 sec**	**> 128 sec**	**Plasma**	**20 mL/kg**
Alpha Angle	**64°-80°**	**< 60°**	**Cryo**	**1 unit/10kg**
K Value	**0-2,5 min**	**> 2,5 min**		
MA	**52-71 mm**	**< 55 mm**	**Platelets**	**15 mL/kg**
LY-30	**0-8%**	**> 3 %**	**Tranexamic Acid**	**≥12 years (adult dosing): 1 g loading dose over 10 minutes followed by a 1 g infusion over 8 hours <12 years: 15 mg/kg (max dose 1 g) loading dose over 10 minutes followed by a 2 mg/kg/hour infusion for 8 hours (max dose 1g)**
** If needed, transfusion of blood should be concurrent with transfusion of the above products				
Whole Blood	≥ 1 year old	Shock		10 mL/kg or 1 unit to a maximum of 40 mL/kg then continue with PRBCs
Packed Red Blood Cells	<1 years old	Shock		10 mL/kg no maximum

SYNTHESIS OF EVIDENCE

Based on the above evidence on the benefits of using whole blood, we would like to present our personal experience of using whole blood in children [10] with massive bleeding due to mine blast trauma on the example of a clinical case.

CASE DESCRIPTION AND RESULTS

25.04.2022

A team of emergency medical aid delivered a patient named S., 9 years old (birth date – 03.08.2012) to «Lviv Territorial Medical Union» «Multidisciplinary Clinical Hospital of Emergency and Intensive Care». He was injured by a missile attack launched by the russian federation troops on the territory of the Lviv region. According to the escorting medical staff, the young family (mother and child) were fleeing from missile attacks. The missile hits near the family stay place – the mother died during the transportation to the hospital as a result of a life-threatening injury with damage to the great vessels, the child was taken to the hospital in a terminal condition.

At the stage of transportation, the emergency medical team provided intravenous access using 2 peripheral G20 catheters and performed a bolus infusion in a volume of 500 ml of balanced crystalloids. The patient is transported fixed on the shield. He is warmed with a foil coating.

During the initial objective examination in the emergency department, it was established that the patient's consciousness is 8 points on The Glasgow Coma Scale (GCS). Pupils are symmetrical. The skin and mucous membranes are pale in color. On the patient's left cheek there is a deep wound about 8 cm long, the wound of the right brow arch is 3 cm long. Respiratory system: due to the auscultation breathing is exaggerated, weakened in the lower parts on both sides, respiratory rate – 31/min, SpO2 – 90%, oxygen therapy is performed through a nonrebreather mask at a rate of 6 l/min. Cardiovascular system: hemodynamics is unstable Ps 140/min, blood pressure – 80/40, due to the auscultation heart tones are muted, rhythmic. Capillary filling test – 4 s, peripheral pulsation of low filling and tension.

Urgent chest X-ray was performed (Th12 fracture; Bone tissue integrity abnormalities of the ribs were not detected); ultrasound examination using the protocol Focused Assessment with Sonography for Trauma (FAST): free fluid in the hepatorenal recess, a small amount of fluid in the pleural cavity on the right and left. The blood is taken for all necessary laboratory examinations.

The patient is qualified as «red». Orotracheal rapid sequence intubation of the trachea with an endotracheal tube 6.0 with a cuff was performed and the mechanical ventilation has started. Due to suspicion of intra-abdominal bleeding (hemodynamically unstable, no sources of external bleeding, the presence of free fluid according to FAST results), the patient was immediately transferred to the operating room. In the operating room, the central vein was catheterized with a 5.5 Fr catheter.

Surgical intervention was initiated – urgent laparotomy. Intra-operative diagnosis: rupture of the right kidney, hemoperitoneum (850 ml) – right-sided nephrectomy was performed and bleeding from the renal vascular pedicle was stopped with thorough surgical hemostasis.

Due to the critical patient's condition, technical difficulties in obtaining platelet mass and blood clotting factors, as well as based on the results of studies [8], which indicate the advantage of using whole blood in pediatric patients with massive blood loss, blood transfusion of single-group whole blood, previously heated in a volume of 30 ml/kg was immediately started in the operating room (the total volume of transfused whole blood was 1050 ml). During blood transfusion hemodynamic parameters were observed, the rate of diuresis was maintained, the patient's skin color changed to pale pink, and peripheral pulsation improved, which clinically indicated a positive effect of blood transfusion and the absence of acute transfusion reactions. At the end of the surgery, the patient's hemodynamics parameters were as follows: heart rate – 115/min; blood pressure – 95/55 mm Hg.

Tranexamic acid was administered at the rate of 15 mg/kg (2nd hour from the time of injury). After a blood transfusion, 10% calcium chloride 0.2 ml/kg was administered.

The volume of blood loss was 35% of VCB. The duration of the surgery was 50 minutes and in the postoperative period the patient was transferred to the intensive care unit.

When the patient was moved to the intensive care unit, his general condition was critical, due to hemorrhagic shock because of a combined injury with the right kidney rupture. Consciousness – medication sleep. The skin and mucous membranes are pale pink in color. Mechanical ventilation continues using the Hamilton C3 ventilator in PSIMV mode with ventilation parameters: Pinsp – 13, PEEP – 3, RR – 18, FiO2 40%. Due to the auscultation breathing is weakened in the lower parts. BP is 100/60, PS is 100/min, peripheral pulsation is satisfactory, capillary filling test – 3 s. The heart sounds are sonorous and rhythmic. Gastrointestinal tract: the abdomen is soft, the bandages are soaked with serous-hemorrhagic contents. Along the drains, serous-hemorrhagic discharge in a small amount (30 ml). The rate of diuresis was 35 ml/kg/h.

After preliminary stabilization of the patient's condition, all body computed tomography (CT) was performed using the lowest possible radiation doses to exclude the presence of damage to various organs and systems. Examination results: Severe brain contusion. Lungs contusion. Partial right-sided pneumothorax. Fractures of the transverse processes Th7-Th10, head of the 11th rib, compression fracture of the body Th12. Fracture of the lower branch of the sciatic bone on the right, without significant displacement of fragments.

26.04.2022 – Mixed nutrition was started: enteral nutrition through a nasogastric tube with Nutrison mixture at a rate of 30 ml/h for 4 hours, followed by checking the residual volume in the stomach and increasing the rate, if good assimilation of nutrition was observed, in parallel, parenteral nutrition with Smofkabiven mixture of 30 kcal/kg/h was started to cover energy needs.

Due to the need for prolonged ventilation, the patient underwent a replacement of the intubation tube by nasotracheal intubation.

Results of the lungs ultrasonography: sonographic signs of a damage contusion of the lower parts of the left lung, with the formation of subpleural consolidation in the L4 area.

30.04.2022 – After consulting a neurosurgeon, it was decided to install an intracranial pressure monitoring sensor. At the initial measurement – 1,3 mm Hg. Blood and sputum were collected for microbiological examination.

A clinical diagnosis of a mine blast injury was established. Closed craniocerebral injury. Severe brain contusion. Multiple head wounds. Closed vertebrate-spinal injury. Compression fracture of the body Th7, Th10, Th12, L1 on the left. Blunt trauma of the thoracic cage. Both lungs contusion. Bilateral hydrothorax. Fracture of the head of the 11th rib. Closed abdominal injury. Rupture of the upper pole of the right kidney. Hemoperitoneum. Pelvic bone fracture.

01.05.2022 – During sedation-free trial, the intracranial pressure increases to 1,47 mm Hg, at rest 0,5-0,58 mm Hg, due to this a decision to continue sedation was made.

05.05.2022 – The results of a microbiological examination of 29.04.2022 were received (Streptococcus Viridians from sputum 10^5 sensitive to Ampicillin, Laevomycetin, Tobramycin, Eeicoplanin, Cefepimum, Vancomycin, Linezolid; blood – sterile).

Due to the further need for long-term mechanical ventilation and regular rehabilitation of the tracheobronchial tree, the patient underwent a low tracheostomy.

Parenteral nutrition has been canceled, as enteral nutrition is absorbed in sufficient volume.

Rehabilitation has started.

09.05.2022 – The patient started breathing spontaneously without mechanical ventilator.

11.05.2022 – The patient in a stable condition was transferred to the neurosurgical department on the 17th day of treatment. GCS is 13 points. The skin and visible mucous membranes are pale pink and clean. Breathing spontaneously, tracheo-cutaneous fistula is seen. Cardiovascular system: heamodynamic stability, capillary filling test – 2 s. The heart sounds are sonorous, rhythmic, and clear. Gastrointestinal tract: the abdomen is soft, accessible for deep palpation, peristalsis is active. The patient is fed through the nasogastric tube, food is absorbed. Urinary system: catheter diuresis – 1500 ml/day, the stool is normal.

22.05.2022 – The patient with the improvement was transferred to a rehabilitation center for rehabilitation treatment. At the time of transfer: GCS – 14 points. Breathing is independent and adequate. Hemodynamically stable. The abdomen is soft. Nutrition is independent. The rate of diuresis is sufficient.

Treatment plan:

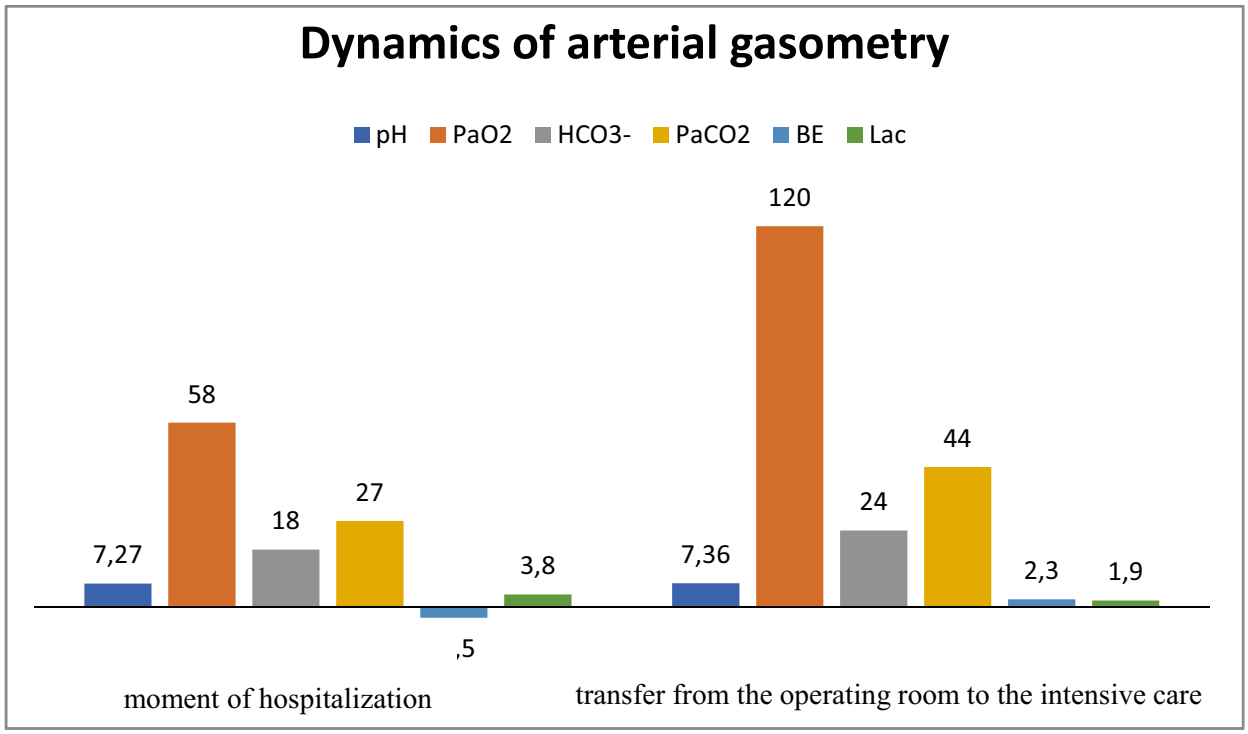
- Adequate infusion therapy (balanced crystal-loids, colloids (20% albumin))
- Blood transfusion therapy (whole blood transfusion immediately after hospitalization in the operating room and blood components after that when needed and based on laboratory results)
- Decongestant therapy (Mannitol at a dose of 0.5 g/kg) every 8 hours at first, and after installing an intracranial pressure monitoring sensor with a focus on intracranial pressure indicators
- Antibacterial therapy (Ceftriaxonum 40 mg/kg 1 time/day, Metronidazole at a dose of 30 mg/kg 1 time/day. After 10 days of treatment, the antibacterial therapy was changed by prescribing Tobramycin 300 mg 2 times/day according to the microbiology results).
- Pain relief (multimodal combined analgesia)
- Drug sedation with Midazolamum and Dexmeditomidine during the first 10 days of treatment
- Anti-ulcer therapy (Omeprazole 20 mg/day)
- Rapid provision of enteral nutrition through a tube in combination with parenteral nutrition with the gradual removal of parenteral nutrition and transition to enteral nutrition only.

Table 2. Dynamics of clinical blood analysis:

Date / indicator	WBC	RBC	HGB	PLT	GRA	LYM
25.04	23.2	3.2	64	80	54	13
26.04	13.2	3.3	80	112	56	10
27.04	12.6	2.7	92	118	61	14
28.04	10.2	3.3	105	154	66	17
29.04	7.1	3.3	102	160	67	30
30.04	8.0	4.3	100	184	71	28
01.05	8.99	4.72	110	190	56	29
02.05	9.9	4.7	108	208	55	12
03.05	10.5	4.9	119	202	59	16
04.05	16.5	4.2	125	265	62	13
05.05	16.8	4.6	116	289	61	18
06.05	10.7	4.02	120	325	63	10
07.05	9.3	4.8	123	297	68	11
08.05	6.3	4.9	130	258	62	14
09.05	8.0	4.4	132	290	69	20
10.05	8.3	4.7	136	242	63	21
11.05	7.3	4.9	140	229	60	23

Table 3. Procalcitonin dynamics

27.04	02.05	06.05	09.05	11.05
26,72	0,5	6,89	1,02	0,69



CONCLUSION

Based on analyzed literature, reports, evidence-based researches and also on the results of our clinical case, it can be concluded that whole blood transfusion to a patient of each group, even pediatric one, in a critical-terminal state with decompensated hemorrhagic shock as a result of mine blast injury, carries more than practical value – it is a mean of saving lives and has a positive effect on reducing the intensity of coagulopathy, which is one of the key factors in a positive prognosis of the dynamics of the patient's condition.

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ПЕРЕЛИВАННЯ ЦІЛЬНОЇ КРОВІ ПЕДІАТРИЧНИМ ПАЦІЄНТАМ З ТРАВМАМИ ЗА АМЕРИКАНСЬКИМИ СТАНДАРТАМИ

Резюме: Близько дев'яти місяців на теренах України точиться повномасштабна російсько-українська війна. Майже щодня українські міста потерпають від ворожих нальотів ракет та дронів, внаслідок чого стають жертвами мирні жителі. Мінно-вибухова травма – діагноз, з яким доводиться відтепер працювати постійно. На жаль, даний вид травми часто супроводжується масивною кровотечею, що змушує змінювати тактику надання медичної допомоги. Відповідно до світових стандартів першим інфузійним розчином для даної категорії пацієнтів повинна бути цільна кров, адже вже неодноразово були доведені її численні переваги. У КНП «Перше територіальне медичне об'єднання м. Львова» дана тактика застосовується ледь не з перших днів війни для пацієнтів усіх вікових груп. У статті наводимо переконливу доказову базу переваг використання цільної крові, а також особистий досвід на основі опису клінічного випадку пацієнта з педіатричної групи.

Ключові слова: цільна кров, мінно-вибухове поранення, переливання крові, масивна кровотеча, війна.

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Матолінець Н. – пошук та аналіз інформації, написання статті,
Дубров С. – дизайн дослідження та статті, збір та аналіз інформації, робота з пацієнтами,
Голкомб Дж. – аналіз інформації та редакція рукопису.