Prospects of the high-speed multimedia data transmission technologies use in the structure of the system for providing aid to injured persons having a gunshot defect of soft tissues.

I.A. Lurin[1,6A,F], I.P. Khomenko[1A,E,F], V. V. Nehoduiko[3A,B,C,F], S. V. Tertyshnyi[4A,B,D,E], B.Weiss[5B] E. Kvasnevskyi[4C,E],O. Kvasnevskyi[4C,E]*

[1]National Academy of Medical Sciences of Ukraine, Kyiv
[2] National Military Medical Clinical Center of the Ministry of Defense of Ukraine, Kyiv
[3] Kharkiv Medical Academy of Postgraduate Education, Kharkiv
[4] Military Medical Clinical Center of the Southern Region of the Ministry of Defense of Ukraine, Odesa
[5] Humboldt University of Berlin, Charité University Clinic, Germany
[6] State Scientific Institution "Scientific and Practical Center of Preventive and Clinical Medicine" of the State Administration of Affairs, Kyiv, Ukraine

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation; D – writing the article; E – critical revision of the article; F – final approval of the article

ABSTRACT

The aim: To improve the results of providing medical care in the conditions of a full-scale war in Ukraine due to the use of medical technologies

Materials and methods: From the first days, the Military Medical Clinical Center of the Southern Region provided medical assistance to the persons wounded as a result of the Russian Federation's armed aggression. The presented multidisciplinary observation includes data received from 24.02.22 to 26.05.22. During this term, the multidisciplinary team assisted by the Teladoc Health system (the connection between the Charite Clinic, Berlin, and the MMCC of the Southern Region, Ukraine) performed 39 reconstructive and remedial operations in the MMCC of the Southern Region (Department of Surgical Infection).

Results:

It has been found that the implementation of differentiated surgical tactics (developed in cooperation between Charite clinics, Berlin, and MMCC of the Southern Region, Ukraine, using the Teladoc health system) in wounded patients with gunshot defects of soft tissues at the III and IV levels of medical care improves functional results, increases indicators of satisfactory from 46.9 % to 53.7 %, reducing the relative number of unsatisfactory from 18.8 % to 11.6 %.

Conclusions: The information exchange in the Teledoc Health system is performed in telephone mode through protected communication channels. It enabled real-time treatment strategy recommendations and improved functional outcomes, increasing

the satisfactory rate from 46.9 % to 53.7 %, and reducing the relative unsatisfactory rate from 18.8 % to 11.6 %.

KEY WORDS: telemedicine ,teladoc health system, multimodal algorithm, gunshot wound, multidisciplinary observation.

INTRODUCTION

Nowadays, electronic communications are the part of the daily life of the majority of people around the world. They include text messages between loved ones, communication in social networks, photo and video materials transfer, and numerous multimedia channels allowing to receive and transfer information at lightning speed. The electronic communication technologies expansion in the field of medicine has transformed into what is now known as telemedicine [1,2].

Long-distance communication between people originated as signaling by burning bonfires, waving colorful flags, etc. The continuous technologies' improvement process ensured the creation of devices that allowed information transmission over much greater distances. The telegraph was invented in the early 1800 by Samuel Morse, who developed the famous code that is called by his name. It was the first time when international and transatlantic communication became available almost instantly. Telegraphs were used to transmit casualty lists and requests for medical supplies during the war. This can be considered the beginning of telemedicine, as the telegraph may have been used for medical consultations.

In 1876, Alexander Graham Bell has patented the first telephone. As telephone technologies improved, people's ability to communicate with each other increased dramatically [1].

The invention of television can be considered a turning point in the telemedicine field. The television, invented in 1927 by Philo Taylor Farnsworth, provided a visual image with real-time sound.

The sources dating back to 1905 are indicating the transmission of electrocardiograms over long distances by a Dutch doctor named Willem Einthoven. In France 1920–1940, radio consultations were carried out to patients on ships at sea. Thus, the doctors in the United States carried out the X-ray images' transmission[2] .

Telemedicine development has accelerated during the last decade due to rapid technological progress. The possibilities of telemedicine are growing rapidly, which makes the challenge of its technologies' integration into the health care system and new telemedicine programs development.

THE AIM

The aim was to increase the efficiency of diagnostics and treatment of wounded with gunshot defects of covering tissues by implementing the Teledoc health telecommunication system at various stages of providing medical care in conditions of military conflict

MATERIALS AND METHODS

A clinical examination was carried out with the help of a multidisciplinary team through the Teladoc health system (Picture 1) and a surgical (reconstructive-restorative) one after the agreement of both parties. In the course of diagnostics, multimodal screening was used, which specialists of the Charité Berlin clinic and the military-medical clinical center of the Southern region used to objectify the gunshot transformation of damaged anatomical structures.

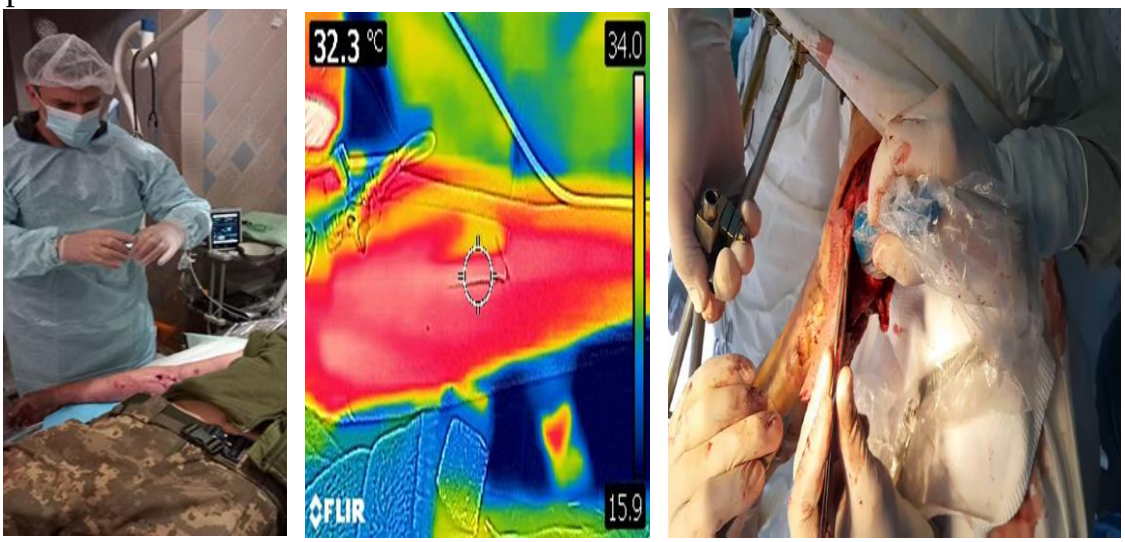
Picture 1 Teladoc health system

With the help of multimodal dynamic screening, 39 wounded people aged 23 to 58 were treated at the second, third and fourth levels of medical care. All the injured were male with gunshot defects of covering fabrics.

An additional component of the examination, in addition to preoperative, intraoperative and postoperative control, was a multimodal monitoring system, which consisted of the use of dynamic digital thermography and audio doppler (at the second level of medical care) and sonographic monitoring by an expert class system at the third and fourth levels of medical care. The multidisciplinary team consisted of the following specialists: reconstructive - plastic surgeon, traumatologist, vascular surgeon in case of damage to main vessels, abdominal surgeon in case of damage to the abdominal cavity, thoracic surgeon in case of damage to the chest and neurosurgeon in case of damage to the head and spinal cord. In the pre-operative period, after admission to the structural unit, a conference was held with the Charite clinic (Berlin), where additional examination options were established, if necessary, and a plan for reconstructive and plastic restoration of the damaged anatomical area. The second stage of using the Teladoc health system was postoperative monitoring in the dressing room every 3 days. Factors of objectification were indicators of digital thermography of the affected anatomical structure (comparative analysis with a symmetrical undamaged

structure) and sonographic monitoring of perforating vessels at the base of the flaps that "closed" gunshot defects.

Special attention was paid to the preparation of the wound defect, which consisted of: debridement, pulse lavage, ultrasonic cavitation of the wound surface and the use of controlled negative pressure systems. Indicators of readiness of the wound for closure were the main factors: stabilization of the general condition of the wounded and vital functions, restoration of general blood analysis norms, absence of inflammatory phenomena (stable leukocyte formula and stable indicators of biochemical blood analysis), the norm in the proteinogram and the indicator of total protein. Additional factors were: 4 K (according to NATO standards), a temperature indicator from the wound surface of 31.5 °C, an increase in the speed and volume of blood flow in the affected area by 20% compared to the indicators upon admission to the hospital . Picture 2



A B C

Picture 2 A - *thermographic monitoring of the wound surface of the forearm (working distance 50 cm), B - thermographic monitoring indicator (thermographic camera), C - doppler audio monitoring of the perforating vessel after flap rotation by 180 degrees.*

Statistical processing of research results was performed on a PC using Microsoft Excel software package.

RESULTS

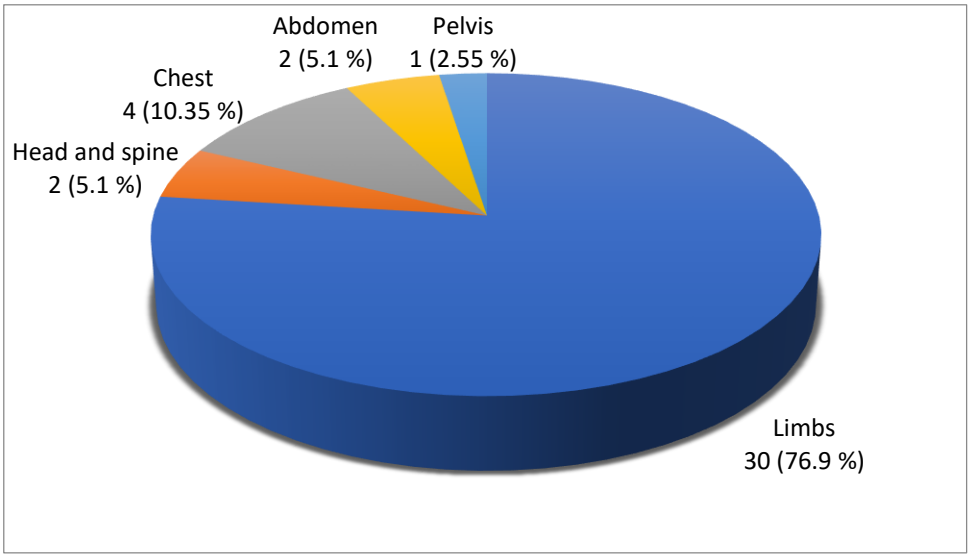
From the first days, the MMCC of the Southern Region provided medical assistance to the persons wounded as a result of the Russian Federation’s armed aggression. Taking into account the human dignity of this terrible problem in Ukraine, the international Charite clinic (Berlin, Germany) after preliminary agreements created a Telemedicine project for cooperation in providing medical care to persons injured with soft tissue defects. The presented multidisciplinary observation includes data received from 24.02.22 to 26.05.22.

INJURIES ACCORDING TO ANATOMICAL AREAS

Head	2	Penetrating - 2	Eyes injuries -
		Non-penetrating -	Jaws injury -
Neck	1	With vascular damage - 1	Spine -
		With trachea damage -	esophagus -
Chest	4	With rib cage injury - 3	With lung, heart injury -
		Hemopneumothorax - 3	With diaphragm injury -
Abdomen	2	Liver -1 , Spleen -	Colon - 7
		Small intestine - 1, stomach - 1	Kidneys - 1, ureters - 3
		Gallbladder -, rectum - 2	Bladder - 2
Limbs	U - 10	Soft tissues - 30	Fiery hip fracture -
	L - 20	With vascular damage - 4	Fiery tibia fracture - 3
		With nerves damage - 5	Fiery joint disorder - 4
		Fiery forearm fracture - 8	Fiery shoulder fracture - 7
		Fiery hand fracture - 8	Fiery foot fracture - 7

The total number of wounded — 227. During this term, the multidisciplinary team assisted by the Teladoc Health system (the connection between the Charite Clinic, Berlin, and the MMCC of the Southern Region, Ukraine) performed 39 reconstructive and remedial operations in the Military Medical Clinical Center of the Southern Region (Department of Surgical Infection). Of which gunshot defects of the soft tissues of the limbs were observed in 30 patients (76.9 %), the head and spine — 2 (5.1 %), the chest — 4 (10.35 %), the abdomen — 2 (5.1 %) and the pelvis — 1 (2.55 %). Figure 1.

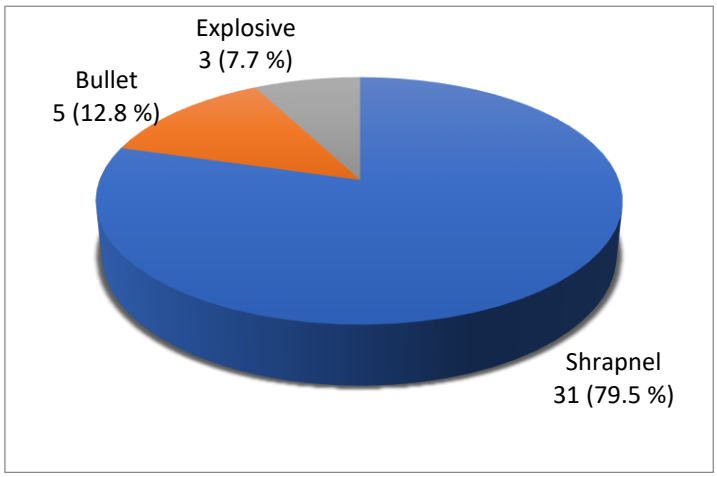
Figure 1 Injuries distribution according to anatomical



Those wounded persons who received damage to various anatomical structures of the human body in the form of soft tissue defects: chest, abdomen, pelvis, and limbs were selected for observation. The average age was 33.7 ± 4.1 years. The vast majority of the treated wounded persons received shrapnel

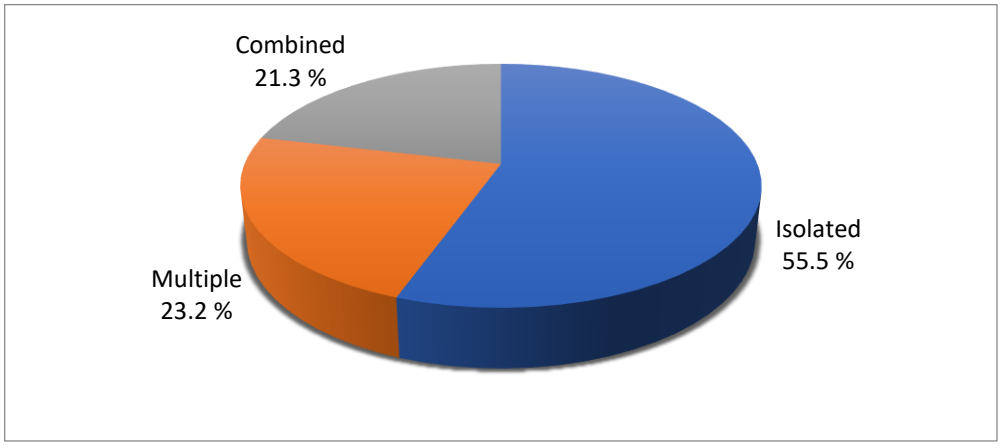
wounds — 31 (79.5 %), bullet wounds — 5 (12.8 %), and explosive wounds — 3 (7.7 %) Figure 2.

Figure 2 Injuries distribution according to the damaging factor nature



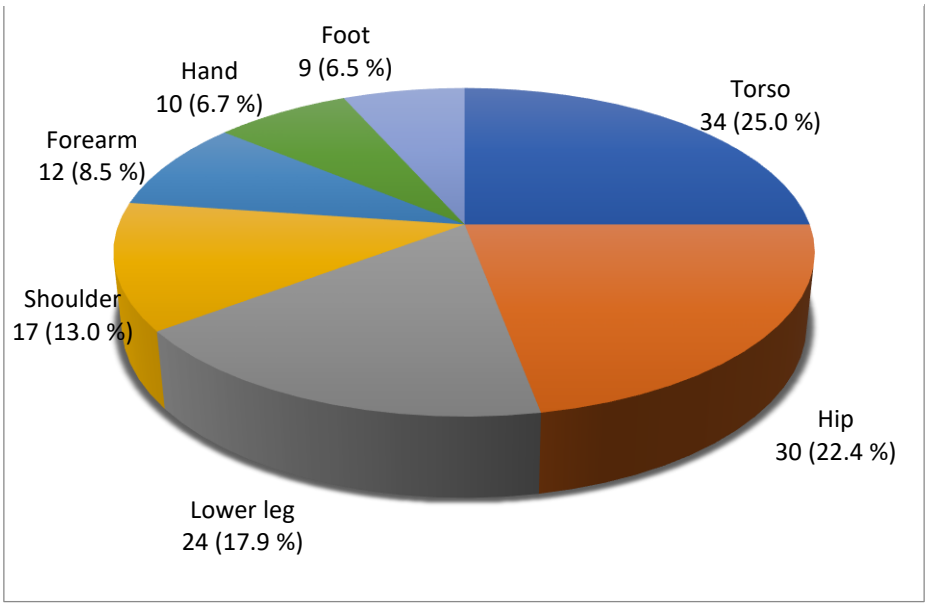
The isolated combat surgical injury was observed in (55.5 %), multiple in (23.2 %), and a combined 30 (21.3 %) Figure 3.

Figure 3 Injuries distribution according to the number of injuring shells and damaged anatomical areas



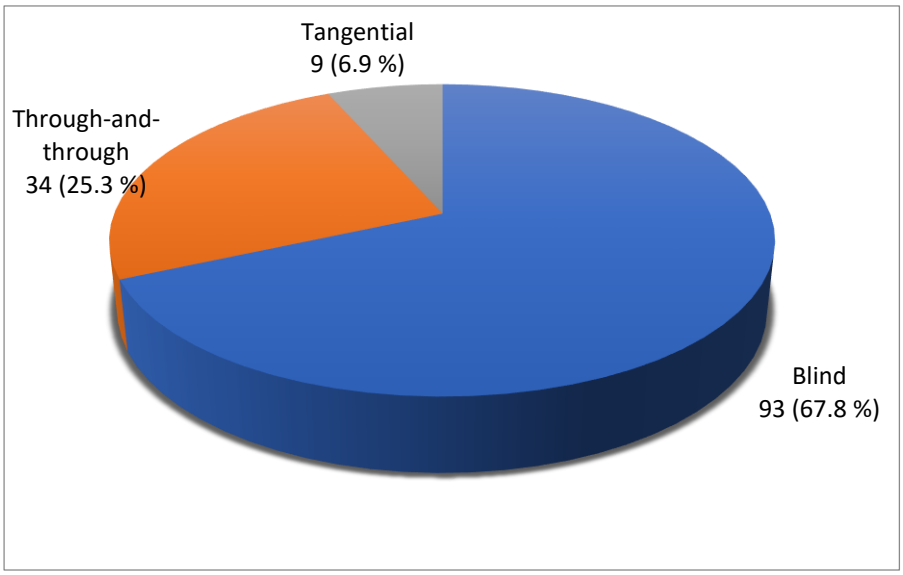
The torso — 34 (25.0 %), hips — 30 (22.4 %), lower legs — 24 (17.9 %), shoulder — 17 (13.0 %), forearm — 12 (8.5 %), hands — 10 (6.7 %) and feet — 9 (6.5 %) were the dominant injuries Figure 4.

Figure 4 Isolated injuries distribution according to anatomical localization



According to the characteristics, 93 (67.8 %) cases of wounds were blind, through-and-through were observed in 34 (25.3 %) and 9 (6.9 %) were tangential Figure 5.

Figure 5 Injuries distribution according to the wound channel nature



In order to determine the main metric characteristics of the wounds, the length (the greatest distance between the ends of the wound), the width (the greatest perpendicular to l segment h), and the depth (the greatest perpendicular from the plane to the bottom of the wound d) were measured. The wound's area (S) in square centimeters was determined by the formula:

$S = l \times h / 2$, where l is the length of the wound, and h is the width of the wound. When conducting planimetric studies of the wound defect, in addition to the total area of the wound, the volume of the wound defect was determined in cubic centimeters using the formula: $V = l \times h / 2 \times d / 4$, where h is the width of the wound, d is the depth of the wound. The definition of differentiated surgical tactics for closing soft tissue defects was carried out on the basis of the gunshot wounds metric classification developed at the Ukrainian Military Medical Academy [5,9]. The needs for fast and dynamic screening were based on a multimodal algorithm: a combination of dynamic digital thermography and audio doppler.

The data analysis received from the dynamic thermography and audio doppler made it possible to change the tactics of primary or secondary surgical treatment in the MMCC of the Southern Region conditions: the necrotic tissues' excision volume was decreased, the time for surgical intervention was shortened.

In the absence of inflammation signs, the primary and delayed sutures were applied to the wounded who were referred from the II and III levels. The primary sutures were not applied and no plastic surgery was performed for wounded patients with clinical signs of wound infection after primary surgical treatment. Tissue defects were healed by secondary tension under the bandage before applying secondary sutures at the III and IV levels.

The autodermoplasty with a split-skin graft was the optimal method for closing medium-sized surface defects having a shortage of donor resources. The advantages of the method: instantaneous closure, low level of trauma, and technical simplicity.

The plastic surgery by local tissues was used for wounded patients with deep defects of small areas, and the edges mobility was ensured by sufficient mobilization and the use of hypodermis and muscles. The duration of treatment was significantly reduced when using NPWT systems and ultrasonic cavitation. The wounded patients with large soft tissue defects were evacuated to the III and IV levels. Plastic surgery with full-layer local flaps was used to close wounds, which provided better functional results, but had a higher risk of complications, in particular. Excessive soft tissue defects require highly specialized treatment at the IV level [9].

DISCUSSION

Telemedicine provides a unique opportunity to solve many problems faced by doctors, medical administrators, and patients. It has been found that about 74% of patients would prefer online consultations to a personal visit to a doctor [1,4]. In addition, reducing the number of visits to the doctor provides significant financial benefits and time savings. [2,3].

The provision of specialized assistance to patients in remote rural communities remains to be one of the most important areas of telemedicine use. Such patients travel long distances and face long waiting at appointments. Telemedicine increases access to healthcare, resulting in fewer missed appointments and better observation.

Telemedicine, as a new direction in the patients' treatment, has its problems and difficulties. The creation of the infrastructure necessary for telemedicine programs involves personnel training in Internet technologies, uninterrupted access to the Internet, and the medical service providers' wide integration into a single telecommunications system [5,6].

Given the rapid and unpredictable nature of hostilities during the armed conflict with the Russian Federation, surgeons often encounter severe soft tissue defects of gunshot origin that require a multidisciplinary approach (with the involvement of several specialists: abdominal surgeon, thoracic surgeon, traumatologist, vascular surgeon). Therefore, the question of considering timely specialized medical care and staffing the initial levels of medical care by specialists with a narrow specialization, or the implementation of other options, becomes relevant [7].

In our opinion, Telemedicine use during the medical assistance provision to a person wounded with gunshot defects of soft tissues can be an alternative option for a multidisciplinary team at all levels of medical assistance provision in the military and medical forces of the Armed Forces of Ukraine.

In cases of previous agreements with leading institutions of other countries of the world, Telemedicine acquires not only the world level of medical assistance provision to injured with GDST but also allows considering the solution of complex situations "under the guidance" of the most experienced doctors[7,8,9].

During the work with the wounded persons assisted by the Teladoc Health system, a conference was held between the Charite clinic, Berlin, and the MMCC of the Southern region. The implementation of the multimodal screening scheme and the analysis of its indicators were coordinated, thorough preoperative preparation was carried out, and optimal ways of reconstruction and monitoring in the postoperative period were discussed. During the analysis of the condition of the wounded person and the wound of the damaged anatomical area, the following specialists were additionally involved: the department of plastic surgery, the department of traumatology, the department of anesthesiology and resuscitation, which reflected the multidisciplinary approach of the created project.

According to the developed metric classification of soft tissue defects, small gunshot wounds were observed in 7 (18 %), medium in 21 (54 %), large in 9 (23.9 %), and extra-large in 2 (4.1 %) cases. The structure of explosive injuries was significantly different from shrapnel and bullet injuries due to an increase in the area and volume of limb damage, the predominance of large and very large soft tissue defects (χ 2 $p < 0.001$, respectively) was observed. There was no significant difference between the structure of shrapnel and bullet wounds (χ 2 = 4.13; $p = 0.248$). The mentioned above results made it possible to distinguish surgical, triage and evacuation principles at the medical care levels depending on the place of injury, taking into account metric characteristics. The combination of wound defects' metric characteristics by area and volume with the wounds' localization in one classification made it possible to propose a comprehensive approach to sorting

the wounded according to the medical care level and determining further surgical tactics for closing soft tissue defects [9].

It has been found that the implementation of differentiated surgical tactics (developed in cooperation between Charite clinics, Berlin, and MMCC of the Southern Region, Ukraine, using the Teladoc health system) in wounded patients with gunshot defects of soft tissues at the III and IV levels of medical care improves functional results, increases indicators of satisfactory from 46.9 % to 53.7 %, reducing the relative number of unsatisfactory from 18.8 % to 11.6 %.

CONCLUSIONS

The cooperation project of the Charite Clinic, Berlin, and the MMCC of the Southern Region, Ukraine, using the Teladoc Health system, gives the possibility of communication in electronic correspondence mode using a secure information exchange system, provides the prompt exchange of current information on health status, the severity of gunshot damage and feedback with recommendations on the current volume and type of assistance at the III and IV levels of medical assistance. It adds visual information in the form of photos and videos for the local status qualitative assessment, etc.

The information exchange in the Teladoc Health system is performed in telephone mode through protected communication channels. It enabled real-time treatment strategy recommendations and improved functional outcomes, increasing the satisfactory rate from 46.9 % to 53.7 %, and reducing the relative unsatisfactory rate from 18.8 % to 11.6 %.

The two-way stream transmission of information with the simultaneous use of video and audio formats in the online conference has shown that the created project of using Teladoc Health can practically be an alternative to live communication, and in the conditions of hostilities acquires new
expediency and opens alternative ways of introducing high-speed data transmission technologies into the medical support system of the Armed Forces of Ukraine.

CONFLICT OF INTEREST: Athors have no conflict of interest to declare.

REFERENCES

1.Ryu S. History of telemedicine: evolution C, and transformation. Health Inform Res. 2010;16(1):65-6. https://doi.org/10.4258/hir.2010.16.L65.

2.Stephens M. History of television. https://www.nyu.edu/classes/stephens/History%20of%20Television%20page.htm

3.Waibel KH, Cain SM, Huml-VanZile M, et al. Section 718 (Telemedicine): virtual health outcomes from regional health command Europe. Mil Med. 2019;184 (Supply 1):48-56.

4.E Visit. 10 Pros and cons of telemedicine. 2018.; https://evisit.com/resources/10pros-and-cons-of-telemedicine/

5.Research G. Telemedicine Market Size, Share & Trends Analysis Report By

Component, By Delivery Model, By Technology, By Application (Tele radiology, Tele psychiatry), By Type, By End Use, By Region, And Segment Forecasts, 2020 - 20272020.
6.Congressional Research Service, the Special Registration for Telemedicine: In Brief, (December 7, 2018)
7.Kim T, Zuckerman JE. Realizing the potential of telemedicine in global health. J Glob Health. 2019;9(2):020307.
8.Worth T. Telehealth: the balance between access and ethics. Med Econ. 2015;29:31.
9. Lurin IA, Khomenko. IP, Gumeniuk KV, Negoduiko VV, Tertyshnyi SV , Grinchuk MM,Maidanyuk VP, Popova OM. Case report of multimodal approach during reconstruction of gunshot defects the soft tissue of the forearm and wrist. Klinichna khirurhiia. 2021 November/December; 88(11-12):93-95.

Corresponding author Serhii V. Tertyshnyi - MD PhD, MBA, Military Medical Clinical Center of the Southern Region, Odesa, Lieutenant Colonel of the Medical Service, Head the Department of Surgical Infection, 2 Pirogovska street, 65044, Odesa, Ukraine
+380677522559
Email tertyshnyi.sergey@gmail.com
Orcid.org/0000-0002-4949-5409

Igor A. Lurin , MD, DSci (Med), Academician , National Academy Medical Sciences of Ukraine, Vice President of the National Academy of Medical Sciences of Ukraine, Professor Doctor of Medical Sciences, Major-General of the Medical Service, Address, 12 Hertsena st., 04050, Kyiv, State Scientific Institution "Scientific and Practical Center of Preventive and Clinical Medicine" of the State Administration of Affairs, Address: 5 Upper st., 01014, Kyiv
+380501353039
email:lurinnamn@ukr.net
Orcid.org/0000-0001-6280-1725

Igor P. Khomenko - MD, DSci (Med), National Academy Medical Sciences of Ukraine, Kyiv, Corresponding Member of the National Academy of Medical Sciences of Ukraine,Professor, Doctor of Medical Sciences, Major General of the Medical Service,8 Yuriya Kondratyuka Str., 04201, Kyiv, Ukraine,
+380503580279
hip65@ukr.net
Orcid.org/0000-0002-8199-5083

Volodymyr V. Nehoduiko MD, PhD, Military Medical Clinical Center of the Northern Region. Ministry of Defense, Ukraine, Kharkiv City, Associate professor of

the department of Surgery Kharkiv National Medical University, 5 Kultury street, Kharkiv, Ukraine
+38(067)7593334
email:vol-ramzes13@ukr.net
Orcid.org/0000-0003-4540-5207

Björn Weiß PD Dr. med. CHARITÉ - UNIVERSITY MEDICINE BERLIN
Clinic for anesthesiology with a focus on surgical intensive care medicine
Campus Mitte & Campus Virchow – Clinic
Deputy clinic director CVK
Augustenburger Platz 1 | 13353 Berlin
Internal site address: Mittelallee 3 | 2nd floor | Zi: 2.1122
Telefon +49 30 450 - 651051
e-mail: bjoern.weiss@charite.de
ORCID. http://orcid.org/0000-0003-3139-595X

Ievgen Y. Kvasnevskyi, MD, Phd, associate Professor
Associate Professor (docent) of surgery department 3 of Odesa National medical university ,Valikhovskiy lane,2, Odesa, 65082, Ukraine;
Tel : +38(048)723-42-49
E-mail : arztev@icloud.com
Orcid : https://Orcid.org/0000-0002-0753-7666

Oleksandr H. Kvasnevskyi, MD Phd, associate Professor
Associate Professor (docent) of general and military surgery of Odesa National medical university ,Valikhovskiy lane,2, Odesa, 65082, Ukraine;
Tel : +38(048)723-42-49
E-mail : aleksandrkvasnevskij@gmail.com
Orcid : https://orcid.org/0000-0001-6630-0143

Figure 1 Injuries distribution according to anatomical

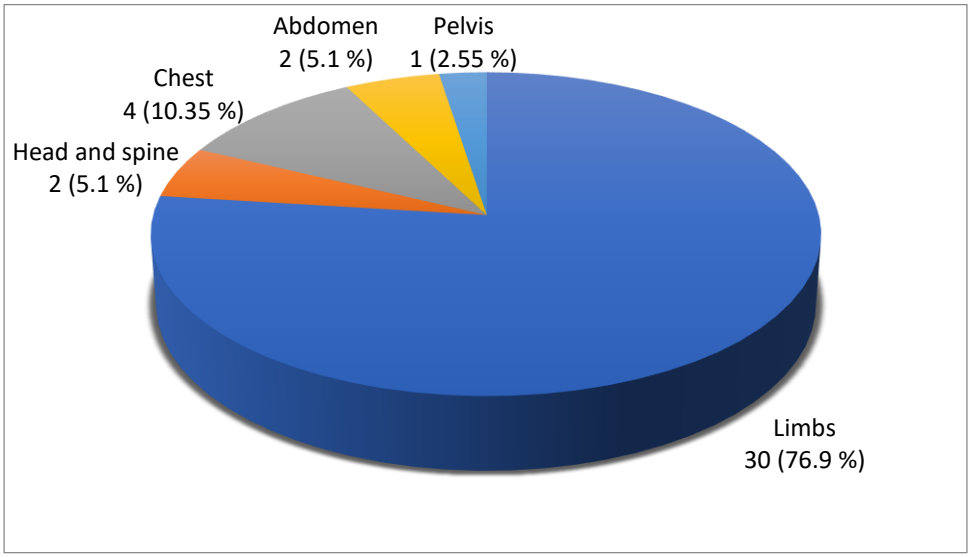


Figure 2 Injuries distribution according to the damaging factor nature

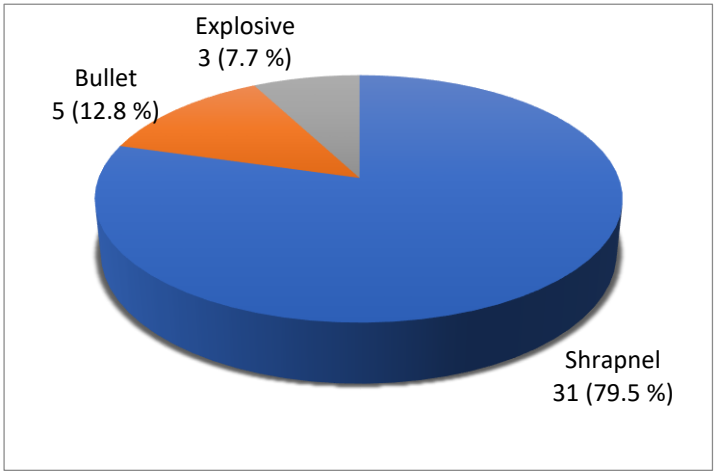


Figure 3 Injuries distribution according to the number of injuring shells and damaged anatomical areas

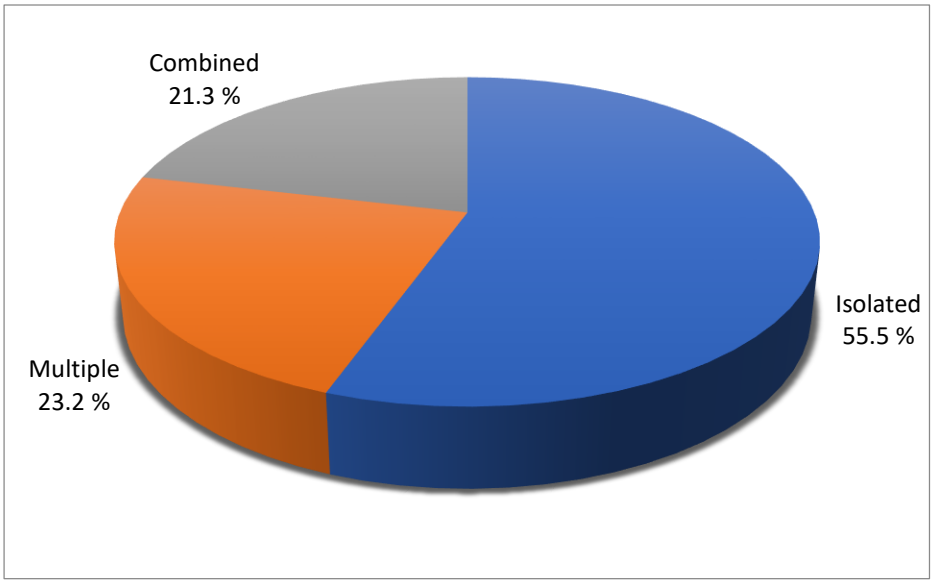


Figure 4 Isolated injuries distribution according to anatomical localization

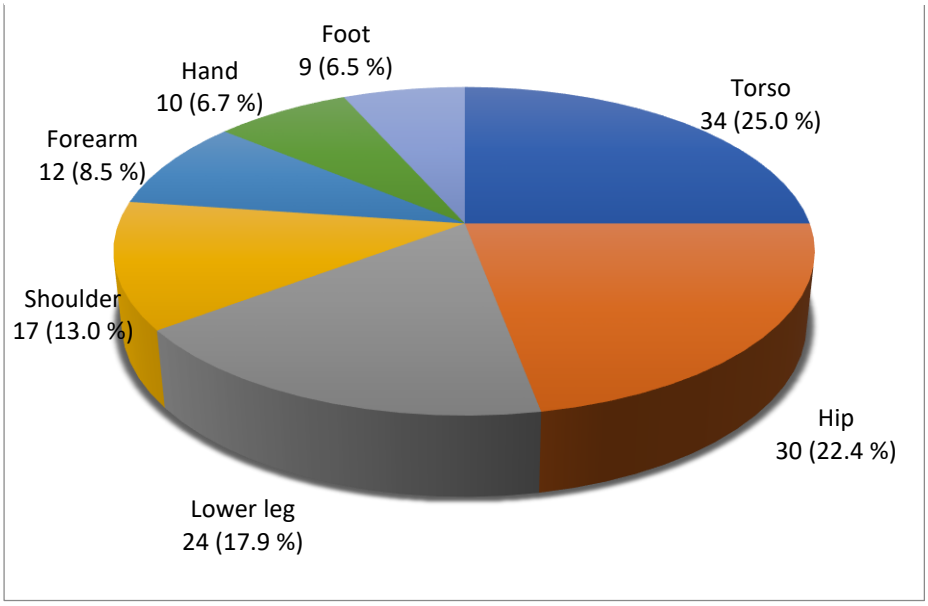


Figure 5 Injuries distribution according to the wound channel nature