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E.M. Khoroshun[1], V.V. Makarov[1], V.V. Nehoduiko[1], P.F. Shchapov[2], S.V. Tertyshnyi[3,4], I.V. Veryovkin[5], R.M. Suprun[2]
Military Medical Clinical Centre of the Northern Region of the Command of Medical Forces, Armed Forces of Ukraine, Kharkiv
[1]Kharkiv National Medical University, Kharkiv
[2]National Technical University "Kharkiv Polytechnic Institute", Kharkiv
[3]Military Medical Clinical Centre of the Southern Region of the Command of Medical Forces, Armed Forces of Ukraine, Odesa
[4]Odesa National Medical University, Odesa
[5]National Military Medical Clinical Centre, Kyiv

ALGORITHM OF PATIENTS WITH GUNSHOT FOREIGN BODIES MIGRATION TREATMENT

e-mail: ehoroshun@i.ua

The purpose of the study was to create an algorithm for gunshot foreign bodies migration diagnoses. We analyzed 90 cases of gunshot shrapnel blind wounds of different localization where there was a foreign body migration in different ways. The wounded admitted to the Military Medical Clinical Centre of the Northern Region of the Command of the Medical Forces of the Armed Forces of Ukraine were examined by X-ray and, as indicated, using videoendoscopic methods. Thoracoscopy, laparoscopic, and arthroscopic surgical interventions were performed. The surgical interventions performed in one stage prevailed in the case of gunshot foreign bodies migration. They were performed in 64.4 % of cases. Two-staged surgical interventions were done in 32.3 % of cases and in three stages in 3.3 % of cases. The authors state that the use of the original algorithm for patients' treatment with gunshot foreign body migration allows step-by-step, taking into account indications, to perform the necessary amount of surgical intervention depending on the direction of treatment in the presence or absence of indications for operative treatment, to make the correct tactical decision. A fundamental approach with the use of general theoretical, experimental, and laboratory, including mathematical and statistical analysis methods, is critical in the case of a considerable number of patients with gunshot wounds of the body and its individual parts. The original algorithm of diagnostic and therapeutic actions and the analysis of new conceptual approaches regarding the migration of gunshot foreign bodies will be useful for medical science and practical health care in the peaceful time of state reconstruction after the war.

Key words: gunshot wound, migration, foreign bodies, algorithm of treatment.

Е.М. Хорошун, В.В. Макаров, В.В. Негодуйко, П.Ф. Щапов, С.В. Тертишний, І.В. Вєрьовкін, Р.М. Супрун

АЛГОРИТМ ЛІКУВАННЯ ПАЦІЄНТІВ З МІГРАЦІЄЮ СТОРОННІХ ТІЛ ВОГНЕПАЛЬНОГО ПОХОДЖЕННЯ

Метою дослідження було розробити алгоритм діагностики міграції сторонніх тіл вогнепального походження. Ми проаналізували 90 випадків вогнепальних сліпих поранень різної локалізації, де була міграція стороннього тіла різними шляхами. Поранені проходили обстеження та лікування у Військово-медичному клінічному центрі Північного регіону і були обстежені променевими та за показами відеоендоскопічними методами. Застосовували торакоскопічні, лапароскопічні та артроскопічні оперативні втручання. При міграції сторонніх тіл вогнепального походження переважали оперативні втручання виконані в один етап у 64.4 % випадків, потім в два етапи у 32.3 %, а в три етапи – у 3.3 % випадків. Максимальні параметри лікувальної значущості відповідають трьом першим варіантам тактичних рішень алгоритму лікування. Автори констатують, що застосування алгоритму лікування пацієнтів з міграцією сторонніх тіл вогнепального походження дозволяє покроково з урахуванням показів виконати необхідний обсяг оперативного втручання в залежності від напрямку лікування при наявності або відсутності показів до оперативного лікування прийняти правильне тактичне рішення. При наявності значної кількості пацієнтів з вогнепальними пораненнями тіла та окремих його частин вкрай важливим є загальнофундаментальний підхід із застосуванням загальнотеоретичних, експериментальних, лабораторних, в тому числі й математичних і статистичних методів аналізу. Автори впевнені, що оригінальний алгоритм діагностично-лікувальних дій та аналіз нових концептуальних підходів стосовно міграції сторонніх тіл вогнепального походження будуть корисними для медичної науки та практичної охорони здоров'я у післявоєнний мирний час відбудови держави.

Ключові слова: вогнепальне поранення, міграція, сторонні тіла, алгоритм лікування.

The study is a fragment of the research project "Development of modern methods of diagnosis and treatment of purulentseptic complications in combat surgical trauma", state registration No 0120U101834.

We met a significant increase in the number of gunshot wounds of various localization in the general structure of all wounds while providing medical aid to both military personnel and the civilian population during the large-scale enemy invasion into the territory of Ukraine [2, 5]. Consequently, military doctors register a rare phenomenon in peacetime medicine, i.e., the foreign bodies migration in conditions of human gunshot injury [1, 5, 8].

Foreign bodies being penetrated inside tissues in case of gunshot wounds remain within the wound channel [13]. Foreign bodies are known to be migrated to a significant distance from the place of their initial penetration as the result of specific reasons, such as patients' active movements, the wound channel insufficient treatment, purulent complications formation with tissues "melting", anatomical cavities (tendons' sheaths, paranasal sinuses) blind injuries, etc. [2, 5].

Thus, the foreign body's absence inside the wound channel with anamnestic and clinical signs of its presence indicates the fact of its migration, which requires appropriate attention and response. Usually, the direct migration of a foreign body is limited by the cavity merging together with the length and diameter of the natural or pathological pathway [2]. One could distinguish the following ways of gunshot foreign bodies migration – in one direction (towards the respiratory, gastrointestinal, and urogenital tract, vascular bed, pleural, abdominal, pericardial, joints cavities, in soft tissues in case of suppuration, when the foreign body moves along the pus flow) and in several directions that means arithmetical combination of several paths [2, 4, 6, 8].

While performing military medical work during the Antiterrorist operation and Operation of the United Forces and throughout the military invasion against Ukraine, we accurately analyzed the radiological and videoendoscopic results of gunshot combat trauma wounded diagnosis and treatment where the migration of foreign bodies was recorded [1, 2, 4–7, 9]. As a result, an original classification of gunshot foreign bodies migration was developed [12]. The proposed classification provides significant help in the case of adequate and rapid diagnosis requirements, determination of the immediate process and direction of migration, and effective treatment of gunshot wounds with the phenomenon of gunshot foreign bodies migration.

And now, on the background of critical analysis of our experience of surgical care provided to patients with gunshot wounds with foreign body migration, we come to a conclusion concerning the necessity to systematize the existing data with the forthcoming methodological developments.

One of the principal ideas is to develop a systematic algorithm that would consider both the diagnostic and the subsequent treatment measures based on the diagnostic parameters. Therefore, we proposed an algorithm of diagnostic and treatment measures in case of gunshot foreign bodies migration aimed to prevent faults during complex diagnostic and therapeutic interventions in this cluster of patients.

The purpose of the study was to create an algorithm for diagnosing gunshot foreign body migration.

Materials and methods. We analyzed 90 cases of gunshot blind wounds of diverse localization with a foreign body migration in different directions. All the wounded were treated at the Military Medical Clinical Center of the Northern Region from 2014 to 2023. All the wounded were men. Their average age was 43.2±4.1 years. 104 foreign bodies migrated.

The data from anamnesis, objective clinical and laboratory studies, and the results of instrumental diagnostics were analyzed. The injured were inspected by X-ray and, as indicated, with the help of videoendoscopic methods.

Depending on the wound location, all the injured were subjected to multispiral computed tomography (MSCT) of the head, chest, and abdominal cavities using "Toshiba Activion 16" (Japan) device with a tomograph step of 0.5 mm with and without tomohexol contrast.

Thoracoscopy, laparoscopic, and arthroscopic surgical interventions were performed using OLYMPUS VISERA 4K UHD OTV-S400, 2021 (Japan) videoendoscopy stand, ureteroscopy using "Karl Storz" (Germany), 2021 videoendoscopy stand.

Intraoperative radiographic examinations were performed using the electronic-optical converter "Siemens Siremobil Compact, 2017" (Germany) and "CARMEX RK FP, 2022" (USA).

Videoesophagogastroduodenoscopy and videocolonoscopy were performed with the help of videoendoscopic system "Olympus CV-170, 2016" (Japan). Videobronchoscopy was performed with the help of the videoendoscopy stand "OLYMPUS CV-170, 2017" (Japan).

The following surgical magnetic tools were used for the removal of ferromagnetic foreign bodies that migrated: a magnetic multifunctional tool for metal ferromagnetic foreign body diagnosing and removing, a flexible device for metal ferromagnetic foreign bodies removal, a surgical magnetic device with shape memory for foreign bodies removing from the heart, a tool magnetic for endovideoscopic diagnosis and metal ferromagnetic foreign bodies removal from abdominal and pleural cavities, endosurgical magnetic tool with a variable angle of the magnetic part inclination, endoscopic magnetic

device for foreign bodies removing, magnetic tool for ferromagnetic foreign bodies removing during arthroscopic surgical interventions [2, 6, 8].

The data obtained were presented as absolute indexes and were calculated statistically using the nonparametric Kruscall-Wallis test with the help of the software "Statistica 10" (USA). The minimum statistical probability was determined at $p<0.05$.

Results of the study and their discussion. The main directions of gunshot foreign body migration treatment should consider the following data: the place of injury (MP), the place of migration beginning (the end of the wound channel), and the spot of foreign body position or fixation.

The examined patients' distribution according to surgical intervention ways was the following (Table 1). With strict dependence upon indications, surgical interventions in case of gunshot foreign bodies migration might be performed in one stage (in case of urgent indications), in two stages with 1-3 days intervals after the first surgical intervention (delayed surgical interventions), or in three stages in case of foreign body re-migration after the first two stages.

Table 1

Distribution by direction of surgical intervention

No.	Direction of surgical intervention	The place of surgical intervention	Number abs. (%)
1	One	Place of injury	4 (3.8)
		Place of migration beginning	11 (10.6)
		Spot of foreign body position or fixation	20 (19.2)
2	Two	Place of injury + place of migration beginning	5 (4.8)
		Place of migration beginning + spot of foreign body position or fixation	44 (42.4)
		Place of injury + spot of foreign body position or fixation	15 (14.4)
3	Three	Place of injury + place of migration beginning + spot of foreign body position or fixation	5 (4.8)
		Totally:	104 (100)

The "swing" symptom is observed often in case of gunshot foreign body re-migration when the foreign body changes its initial location, is determined in another place during surgery, and then returns to its original place. Such phenomenon was observed in 3 cases when foreign bodies migrated, among which 2 cases demonstrated migration along the pulmonary artery and 1 case showed foreign body migration along the renal vein, which led to repeated surgical interventions aimed at foreign body extraction.

We used mixed tactics once: wound primary surgical treatment and brachial trunk prosthesis were done during the first stage, then we followed the foreign body throughout 3 days when it was located in the abdominal part of the aorta and only after its removal was performed endovascularly with the help of arteriotomy through the femoral artery.

One could also see the cases of intermediate migration points in the whole foreign bodies' migration process. This phenomenon is related to foreign bodies' natural peculiarities and the space in which they move.

Operative interventions in the case of migration by foreign bodies are divided into three stages. The one-stage surgical interventions prevailed (in 58 cases), and the surgical interventions were performed in two (29 cases) and three (3 cases) stages. We performed two-staged operations mainly in case of foreign bodies migrating through the vascular bed and in case of damage to inner hollow organs.

It is essential that the degree of surgical intervention might be changed with a close correlation to existing indications. Part of the directions to which the surgical intervention is aimed may not be implemented due to the lack of indications for specific types of surgical intervention.

According to the direction of the place of the wound, the wound's primary surgical treatment can be performed or not performed in the absence of indications.

The different stages of surgical intervention are possible according to the direction of the foreign body's place of migration initiation: suturing of the defect, the defect area resection, the defect prosthetics, or any interventions in case of a lack of indications.

Depending on the foreign body's position or its fixation, it is possible to remove the foreign body, dissect the tissues and remove the foreign body, or any interventions aimed at the foreign body extraction.

We used dynamic observation and conservative tactics in case of a lack of indications for surgical intervention.

Resuming our tactic in surgical treatment of patients with gunshot foreign body migration, we proposed the following algorithm of treatment (Fig. 1).

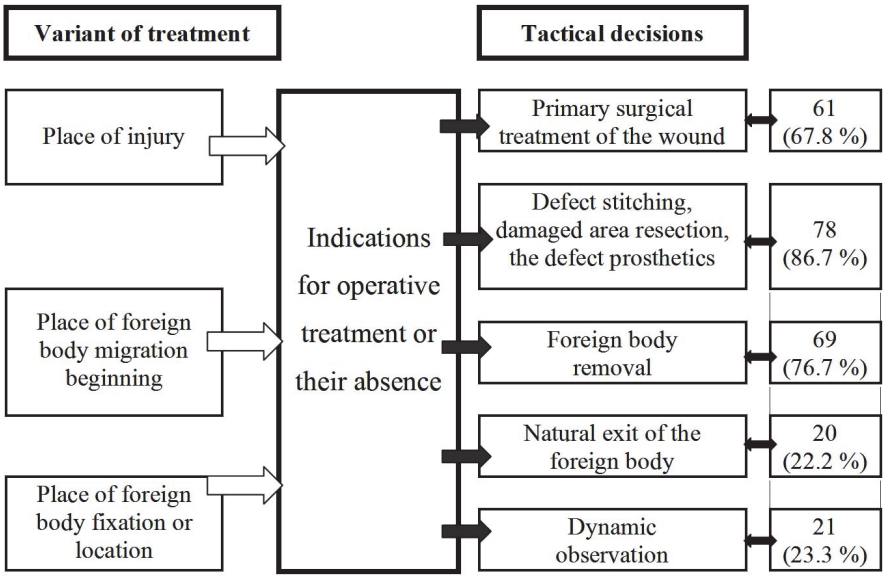

Fig. 1. Original algorithm for patients' treatment with gunshot foreign bodies migration.

Our further actions were connected to the efforts of mathematical equations creation aimed at effective and adequate surgical measures in the direction of their automation in case of the specified contingent of patients with a gunshot of foreign bodies migration treatment.

Hence, scientific results were considered using the original treatment algorithm for the combined group of patients (n=90) for main and comparative groups.

We will consider that according to the abovementioned treatment algorithm, the total number of operative solutions used is N_{OR}=249.

For each (K=5) operative decision, the number (n_j, j = 1, 2, K) of patients who received the appropriate treatment is indicated.

There are three successive stages of treatment significance parameters statistical evaluation:

1. Point assessment of the coefficient of general medical redundancy:

$$\lambda = \frac{N_{OR}}{N} \text{ (1/patient)}$$

2. Point assessment of surgical procedures relative frequencies for each of the variants of tactical decisions:

$$\varepsilon_j = \frac{nj}{N_{OR}}, j=1, 2, \ldots, K$$

3. Point assessment of therapeutic significance parameters (φ_j) for variants of tactical decisions:

$$\varphi_j = \lambda \bullet \varepsilon_j \text{ (1/patient)}$$

Below, we present the results of the calculations for λ=2,767 (1/patient) (Table 2).

Table 2

Results of the therapeutic significance parameters statistical evaluation

Tactical solutions of the treatment algorithm, j=1, 2, …, K	The absolute number of operational solutions, n_j	Relative frequencies of procedures, ε_j	Parameters of therapeutic significance, φ_j
Primary surgical treatment of the wound	61	0.245	0.678
Suturing the defect	78	0.313	0.867
Foreign body extraction	69	0.277	0.767
Foreign body exit	20	0.081	0.222
Dynamic observation	21	0.084	0.233

One can see above that the maximal parameters of therapeutic significance keep up a correspondence with the first three variants of tactical solutions of the treatment algorithm for patients with gunshot foreign bodies migration. These calculations' statistical adequacy corresponds to the following condition: the sum of all parameters of significance (φ_j) is equal to the coefficient of general significance (λ=2.767 (1/patient).

Thus, the main result of our report is the development of an algorithm for patients' treatment with gunshot foreign body migration, which permits step-by-step, taking into account the indications, to perform the required amount of surgical intervention quickly and efficiently. We suppose it's important that, depending upon the direction of treatment, the original algorithm of therapeutic activity in conditions of the presence or absence of indications for operative treatment allows us to make the correct tactical decision.

While discussing the data obtained and the original conceptual classification of gunshot foreign bodies migration, we would like to highlight the following:

Firstly, the surgical interventions in the case of gunshot foreign body migration prevailed in one stage in the case. They were performed in 58 (64.4 %) cases. Two-staged surgical interventions were done in 29 (32.3 %) cases and in three stages – in 3 (3.3 %) cases. Two-staged operations were mainly performed in case of foreign bodies migration through the vascular bed and in case of hollow organ damage.

On the other side, everybody should understand that the process of gunshot foreign bodies migration goes away from the wound itself [2, 9, 12]. A gunshot wound itself is part of the migration process. Therefore, the gunshot foreign bodies migration is quite another type of a gunshot wound manifestation and has its characteristics, which obviously should be taken into account during treatment [1, 2, 3, 5, 7].

We consider it essential to remember that foreign body migration is dynamic. That's why gunshot wounds become dangerous and uncertain, relating to the direction of probable migration [11]. The critical task appears to stop this migration when its initiation becomes clear. We believe there is an exact place for methods of probabilistic analysis used together with conceptual mathematical and statistical requirements [10] that allow, firstly, to trace the likelihood direction and path of migration and, secondly, to determine the foreign body's final location.

Thirdly, the system analysis used in the gunshot foreign bodies migration concept of monitoring [2, 12] is essential in military surgery. It already has specific progress by our colleagues and allows us to systematize the entire migration process from beginning to end, diagnostic search, surgical tactics, and prognosis. That's why a fundamental approach with the use of general theoretical, experimental, and laboratory, including mathematical and statistical analysis methods, is critical in the case of a considerable number of patients with gunshot wounds of the body and its parts. Such a systemic approach permits the creation as quickly as possible of the most correct decision regarding treatment tactics and/or ways of the further evacuation of a specific patient with the risk of foreign bodies migration for the highly qualified medical care provision.

Our experience proves similar conceptual and methodological approaches to validation with critical analysis of each specific patient and all management aspects at all stages of medical evacuation and high-quality medical care provision [2, 4, 6]. The diagnostic search and subsequent treatment actions algorithms development allow the prevailing clinical cases to achieve significant efficiency using similar mathematized algorithms of surgeons and medical personnel step-by-step action in the presence of gunshot foreign bodies migration.

Fourthly, our logical premises are confirmed by proven facts of proposed algorithm sequence of actions used for highly effective diagnosis and treatment of wounded servicemen from the beginning of the enemy's aggression on our territory [1, 2, 5, 7]. We want to stress that information processing mathematical and statistical methods allow us to determine the diagnostic importance of various factors, influence surgeons' decision-making, and significantly improve the results of surgical treatment [1, 2, 5, 12].

We are sure that the original algorithm of diagnostic and therapeutic actions and the analysis of new conceptual approaches regarding the gunshot foreign bodies migration will be helpful for medical science and practical health care in the post-war peaceful time of state reconstruction.

Conclusions

1. The surgical interventions performed in one stage prevailed in the case of gunshot foreign body migration. They were performed in 58 (64.4 %) cases. Two-staged surgical interventions were done in 29 (32.2 %) cases and three stages – in 3 (3.4 %) cases.

2. The maximal parameters of therapeutic significance correspond with the first three variants of tactical solutions of the treatment algorithm for patients with gunshot foreign body migration.

3. The use of the original algorithm for patients' treatment with gunshot foreign body migration allows step-by-step, taking into account indications, to perform the necessary amount of surgical

intervention depending on the direction of treatment in the presence or absence of indications for operative treatment, to make the correct tactical decision.

4. A fundamental approach with the use of general theoretical, experimental, and laboratory, including mathematical and statistical analysis methods, is critical in the case of a considerable number of patients with gunshot wounds of the body and its parts.

5. Such a systemic approach allows us to create as quickly as possible the most correct decision regarding treatment tactics and/or ways of the further evacuation of a specific patient with the risk of foreign bodies migration for the highly qualified medical care provision.

6. The original algorithm of diagnostic and therapeutic actions and the analysis of new conceptual approaches regarding the gunshot foreign bodies migration will be helpful for medical science and practical health care in the post-war peaceful time of state reconstruction.

Prospects for further research include further common studies of medical and mathematical specialists to provide a new effective algorithmic approach practical in conditions with time-limited surgical aid to persons suffering from gunshot wounds of the whole body and create a new concept of systemic diagnostic-treatment analysis of effective medical activities in case of gunshot foreign bodies migration.

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