

ACTUAL PROBLEMS OF MEDICAL EVACUATION АКТУАЛЬНЫЕ ПРОБЛЕМЫ МЕДИЦИНСКОЙ ЭВАКУАЦИИ

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EVALUATION OF THE EFFICIENCY OF WORK AND PROSPECTS FOR THE DEVELOPMENT OF AMBULANCE AVIATION IN THE CONDITIONS OF A MEGAPOLIS ON THE EXAMPLE OF THE CITY OF MOSCOW

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Abstract. *The objectives of the study are to develop a structural and functional model, principles and algorithms of organizational and methodological support of helicopter evacuation of patients to specialized medical organizations of megapolis; to evaluate their effectiveness analysing the results of treatment of patients with significant urgent pathology.*

Materials and research methods. The results of treatment of 241 patients with urgent pathology at the treatment facilities of the Moscow Health Department — City Clinical Hospital No.15 named after O.M. Filatov, S.S. Yudin State Clinical Hospital and N.S. Sklifosovskiy Research Institute of Emergency Medicine in 2016-2019 — were analyzed. Inclusion criteria: patients with bleeding (isolated or in combination with acute trauma) requiring surgical intervention; with acute coronary syndrome (unstable angina pectoris, myocardial infarction with and without ST-segment elevation); with vascular pathology of central nervous system or cranio-cerebral trauma, requiring emergency hospitalization of the patient in a specialized medical institution — provided that the time of delivery of all these patients to the hospital was at least 30 minutes from the time of call.

Exclusion criteria: patients with mental illness, infectious-inflammatory processes, severe comorbid somatic diseases in decompensation stage (established by anamnesis, examination or autopsy reports); incurable cancer patients and any urgent patients whose delivery time to the specialized hospital was less than 30 minutes from the time of call.

All patients included in the study were divided into 2 groups:

The main — 1st group — included 112 patients delivered to the profile medical institution of the megapolis on a medical helicopter. The comparison group — 2nd group — consisted of 129 patients with similar urgent pathology, hospitalized to the specialized hospitals of the city by ground ambulance transport.

Research results and their analysis. The analysis of the study results showed:

- performance of air medical teams is comparable to or exceeds that of ground ambulance teams;
- number of total bed-days in the group hospitalized by air ambulance was higher than in the comparison group;
- inpatient outcomes and long-term outcomes were comparable in both groups;
- pilot study of the use of mobile diagnostic ultrasound in providing emergency and urgent medical care allows us to consider this method as a promising one, but it requires further evidence accumulation.

Thus, the performance of medical aviation is not inferior to the performance of ground ambulance teams, and in some aspects, even exceed them, which confirms the high potential of its use in megapolis conditions and in remote and hard-to-reach areas.

Key words: : air ambulance, air medical teams, algorithms, development prospects, efficiency, megapolis, Moscow, organization, patients, urgent pathology

Conflict of interest. The authors declare no conflict of interest

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ОЦЕНКА ЭФФЕКТИВНОСТИ РАБОТЫ И ПЕРСПЕКТИВ РАЗВИТИЯ САНИТАРНОЙ АВИАЦИИ В УСЛОВИЯХ МЕГАПОЛИСА НА ПРИМЕРЕ г.МОСКВЫ

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Резюме. Цели исследования – разработать и внедрить в практическое здравоохранение структурно-функциональную модель, принципы и алгоритмы организационно-методического обеспечения вертолетной эвакуации пациентов в профильные медицинские организации мегаполиса; оценить их эффективность на примере результатов лечения пациентов со значимой ургентной патологией.

Материалы и методы исследования. Для сравнительной оценки работы санитарной авиации в условиях мегаполиса были проанализированы результаты лечения 241 пациента с ургентной патологией, осуществлявшегося в лечебных учреждениях Департамента здравоохранения г.Москвы (ДЗМ) – городской клинической больницы (ГКБ) №15 им. О.М.Филатова, ГКБ им. С.С.Юдина и НИИ скорой помощи им. Н.В.Склифосовского – в 2016–2019 гг.

Критерии включения в исследование – пациенты с кровотечениями (изолированными или в сочетании с острой травмой), требующими оперативного вмешательства; с острым коронарным синдромом (нестабильная стенокардия, инфаркт миокарда с подъемом и без подъема сегмента ST); с сосудистой патологией центральной нервной системы (ЦНС) или черепно-мозговой травмой (ЧМТ), требующими экстренной госпитализации пациента в профильное медицинское учреждение – при условии, что время доставки всех указанных пациентов в стационар составляло не менее 30 мин от момента вызова.

Критерии исключения из исследования – пациенты с наличием, помимо основной ургентной патологии, психических заболеваний, инфекционно-воспалительных процессов, тяжелых сопутствующих соматических заболеваний в стадии декомпенсации (установленных по анамнезу, обследованию или по протоколам вскрытия); инкурабельные онкологические пациенты и любые ургентные пациенты, время доставки которых в профильный стационар составляло менее 30 мин от момента вызова.

Все пациенты, включенные в исследование, были разделены на 2 группы:

В основную – 1-ю – группу вошли 112 пациентов, доставленных в профильное медицинское учреждение мегаполиса с использованием медицинского вертолета.

В группу сравнения (2-ю группу) вошли 129 пациентов с аналогичной ургентной патологией, госпитализированных в профильные стационары города наземным транспортом скорой медицинской помощи (СМП).

Результаты исследования и их анализ. Анализ результатов исследования показал:

- проанализированные в ходе исследования показатели эффективности работы авиамедицинских бригад (АМБр) сравнимы или превышают таковые у наземных бригад СМП;
- количество общих койко-дней в группе госпитализированных санитарным вертолетом было больше, чем в группе сравнения;
- результаты лечения в стационаре и отдаленные исходы у пациентов обеих групп были сравнимы;
- пилотное исследование использования мобильного диагностического УЗИ при оказании неотложной и экстренной медицинской помощи пациентам АМБр позволяет расценить данный метод как перспективный, но требующий дальнейшего накопления доказательной базы.

Таким образом, показатели эффективности работы санитарной авиации не уступают аналогичным показателям наземных бригад СМП, а в некоторых аспектах – даже превышают их, что подтверждает высокий потенциал использования АМБр в условиях мегаполиса и большие перспективы применения авиамедицинских бригад на удаленных и труднодоступных для автомобильного транспорта территориях.

Ключевые слова: авиамедицинские бригады, алгоритмы, г.Москва, мегаполис, организация, пациенты, перспективы развития, санитарная авиация, ургентная патология, эффективность

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In our country and abroad every third inhabitant applies annually for emergency medical assistance (EMT), and every tenth of them are immediately hospitalized afterwards. The reasons for people seeking EMT are: in 45-55% of cases – diseases of the cardiovascular system; 15-20 – diseases of the central and peripheral nervous system; in 8-10% of cases – respiratory diseases and acute surgical abdominal pathology. In Moscow in 2018, emergency and urgent medical care was provided to more than 3.9 million people. [1-7].

In addition, the number of emergencies in the world is increasing every year, including man-made ones, accompanied by a large number of victims, requiring emergency medical care and often requiring immediate medical evacuation [4, 8, 9]. World experience shows that the use of medical helicopters for evacuating victims and patients to hospitals leads to a high survival rate and a decrease in the level of disability [10-14].

In the Russian Federation, the development, improvement and new aspects of the use of helicopters for

emergency medical evacuation in metropolitan conditions require the development of an appropriate organizational structure and regulatory legal framework. At the same time, it should be noted that direct extrapolation of foreign experience to the conditions of Russia is impossible, given the significant socio-economic peculiarities of regions and, especially, megacities.

The aim of the study is to develop and to implement in practical healthcare a structural and functional model, principles and algorithms of organizational and methodological support of helicopter evacuation of patients to specialized medical organizations of a megacity with assessment of their efficiency.

Principles of air ambulance operation in the megacity

At the present time the work of the sanitary aviation of Moscow is realized by the interaction of two departments — the Moscow Health Department and the Moscow Department of Civil Defense and Fire Safety, the work of which is coordinated by the Moscow City Government. Based on the regulations, in day-to-day operation mode it is now possible for an air ambulance helicopter to fly over the administrative territory of the city; in emergency mode, an air ambulance helicopter can fly to any place in Moscow region or any other region, provided it is able to return safely to its base and Moscow mayor issues relevant directives.

The work of sanitary aviation in the megacity begins with training of highly qualified personnel. The Moscow Territorial Scientific and Practical Center of Disaster Medicine of the Moscow Department of Health has formed individual training programs for all specialists participating in the process of medical and air ambulance evacuation. The main principles of training of the medical specialists are: understanding of the mechanisms of pathological processes in patients during takeoff, flight and landing of the helicopter, as well as the skills of their prevention and correction.

Important components of the work of aviation medical teams (AMTs) specialists are: knowledge and observance of helicopter safety techniques; observance of the algorithm of interaction with flight personnel, employees of medical organizations and other services involved in transporting and providing assistance to patients; organization of safe work on board the air ambulance helicopter and near the aircraft.

The development of air ambulance and the increase in the number of indications for the use of AMTs in the metropolitan area required additional medical resources, which were calculated on the basis of the population of the city and the need for emergency medical care. Since January 2016, 3 helicopters have been on permanent duty in Moscow, which is optimal for the metropolis; 2 more helicopters, if necessary, can fly to an emergency with a large number of victims at any time. Given the optimization of the service, the number of flights increased from 222 — in 2005-2007 to 743 — in 2017-2019 years, that is 3.35 times.

In addition, the following algorithms for the use of a helicopter to provide medical assistance to the population of Moscow have been developed and, since 2009, have been successfully used:

- "Arrival of helicopter before ambulance";
- "Arrival of helicopter after ambulance";
- "Medical evacuation from medical facilities";

- "Work of AMT in an emergency situation";
- "Transfer of a victim from the ambulance to the ambulance if the flight is impossible".

The use of these algorithms allows in each case to determine the most optimal indications, to reduce time and to adapt approaches to the hospitalization of patients in specialized medical institutions using a medical helicopter in a metropolitan area.

An important criterion in providing medical care is the time of doctor's arrival to the patient. The overwhelming majority of EMTs (78.6%) arrived to patients within 15 min from the moment of call. The average time taken to prepare an ambulance helicopter for a flight was: in 2005-2007 — (26.48 ± 1.91) min; in 2017-2019 — (10.97 ± 1.34) min.

Thus, in 2017-2019, the total time — from call receipt to arrival to the patient — in 91.8% of flights did not go beyond 40 min, while in 2005-2007, only 88.3% of flights fell within this time frame. The time of flight to and return of a patient from the place of his localization to the specialized medical institution was not more than 10 min, the average time — (6.83 ± 0.49) min, in 2007 and 2019 it actually did not differ.

Materials and methods of the research. For a comparative assessment of air ambulance performance in metropolitan conditions, we analyzed the results of treatment in 2016-2019 of 241 patients with urgent pathology, carried out in specialized departments of hospitals of the Moscow Department of Health: City Clinical Hospital No. 15 named after O.M. Filatov, City Clinical Hospital named after S.S. Yudin, and Research Institute of Emergency Medicine named after N.V. Sklifosovsky.

Inclusion criteria — patients with bleeding (isolated or combined with acute trauma) requiring surgical intervention; with acute coronary syndrome (unstable angina pectoris, myocardial infarction with and without ST-segment elevation); with vascular pathology of central nervous system (CNS) or craniocerebral injury (CCI), requiring emergency hospitalization and medical evacuation to specialized medical institution; medical evacuation time — at least 30 min from the moment of call.

Exclusion criteria from the study — in patients with urgent pathology: mental illness, infectious inflammatory processes, severe comorbid somatic diseases in decompensation stage, established on the anamnesis, examination or autopsy reports; incurable cancer patients and any urgent patients whose evacuation time to a specialized hospital was less than 30 minutes from the time of the call.

Taking these criteria into account, all the patients under study were divided into 2 groups:

The main (1st) group consisted of 112 patients delivered to the profile medical institution of the metropolis by medical helicopter, whose causes of hospitalization were acute coronary syndrome (ACS), acute stroke, traumatic brain injury and bleeding of various genesis, requiring urgent surgical intervention.

The control group comprised 129 patients with the similar urgent pathologies hospitalized to the specialized hospitals of the city by ground ambulance transport.

The distribution of patients in the study groups by age and sex is presented in Table 1.

There were no significant differences between the number of men and women in the main group and the comparison group, $p=0.893$. There were also no differences in the distribution of men and women within age groups,

$p=0.794$. The mean age of patients hospitalized for emergency indications was: in the main group — (59.9 ± 1.7) years; in the comparison group— (61.1 ± 1.7); no significant differences were found, $p=0.47$.

Methods of medical evacuation of patients to the hospital

A. Hospitalization using an ambulance

In the comparison group, a class C ambulance was used to transport patients to the specialized departments of hospitals.

These resuscitation ambulances are designed to perform therapeutic measures of emergency medical care by a resuscitation or specialized team, as well as to evacuate and to monitor the condition of evacuated patients in the prehospital period.

B. Hospitalization using an air ambulance helicopter

BK-117C-2 helicopters were used for medical evacuation of the main group patients to medical treatment facilities.

Each aircraft is equipped with a dielectric floor, which allows performing electropulse therapy in flight. All equipment used for the work is certified for use on aircrafts.

The stock of drugs and dressing material in the helicopter is designed for 25 patients. For mobile work, medical personnel of AMTs use medical offloading vests with a set we developed.

Both in ambulances and in air ambulance helicopters, patients were examined to confirm the main diagnosis and possible concomitant pathology, including electrocardiography (ECG), pulse oximetry, glucometry in all patients, as well as ultrasound examination, conducted on portable diagnostic ultrasound scanners in patients of the main group: in 22 cases for combined trauma; in 24 cases for cardiac pathology and suspected pulmonary embolism; and in 69 cases for the purpose of ultrasound navigation during central vein catheterization.

Comparing the standard equipment of ambulance helicopter and ambulance car class C, we can note the presence in the ambulance basic set of medical equipment and equipment, similar to those used in medical helicopters, except for medical vest unloading, which allows to optimize the work of AMT doctor in conditions of lack of time and limited space.

Conditions in the air ambulance helicopter allow intensive therapy at the scene and in the process of medical evacuation of patients, including full resuscitation and anesthesia allowance — in a volume sufficient to maintain a stable condition of severe and extremely severe somatic patients and victims of emergencies during their medical evacuation to the hospital.

In the pre-hospital period the methods of treatment in the ambulance and ambulance helicopter were almost identical and were carried out in accordance with the standards

of medical care — the orders of the Department of Health of Moscow dated 27.01.2016 and 10.10.2018. All patients were admitted to the hospital within 118 minutes of first contact with a medical professional. Treatment of patients in the hospital was carried out in accordance with international and Russian clinical guidelines.

Total number of invasive interventions (surgeries) performed was: in the main group — 112 patients — 102 interventions (91,1%); in the comparison group — 129 people. — 107 interventions (83,0%).

The patients of both groups were examined 6 months after discharge from the hospital to assess the long-term results of treatment.

Statistical analysis of the data was performed using the software package IBM SPSS Statistics 26. The data for the analysis were preliminarily prepared and analyzed for outliers. In all statistical studies, the level of significance of differences was taken as 0.05.

Results of the study and their analysis. The spectrum of nosologies (main and concomitant pathology) and the distance of patients from the specialized hospital were studied in hospitalized urgent patients of both groups. The main diagnosis, which was made by the doctors of emergency medical teams taking into account clinical examination data and objective examination methods, was confirmed in the specialized hospital, where a comprehensive clinical and diagnostic examination was carried out. The comparative number of nosologies encountered in the study groups is presented in the figure.

The main and concomitant pathologies occurred in the groups with approximately equal frequency. Overall, more than 2/3 of those hospitalized (81.7%) had one or more comorbid chronic diseases that were in remission and therefore patients did not require additional treatment.

The remoteness of patients from the specialized medical institution is presented in Table 2.

The mean distance from the patient's location to the specialized hospital was: in the main group — ($62,6 \pm 2,1$) km; in the comparison group — ($12,7 \pm 1,1$) km, thus, there were significant differences between the groups with regard to this parameter, $p < 0,05$.

The maximum distance from the patient's location to the specialized hospital was: in the study group, 129.2 km; in the comparison group, 50.3 km.

In order to assess the efficiency of air ambulance use in a metropolitan area, we performed a comparative analysis of a number of indicators: duration of stay of patient groups in hospital departments; mortality rate and long-term results of treatment.

At the initial examination the condition of patients in the study groups was as follows: satisfactory condition — 7 persons. (2,9%); moderate — 79 (32,8%); severe — 133

Таблица 1 / Table No. 1

Распределение пациентов по возрасту и полу

Distribution of patients by age and gender

Возраст, лет Age, years	Основная группа, n=112, чел./% Main group, n=112 pers./%		Итого, % Total, %	Группа сравнения, n=129, чел./% Comparison group, n=129, pers./%		Итого, % Total, %
	М / Male	Ж / Female		М / Male	Ж / Female	
20-40	12/10,7	5/ 4,5	15,2	24/18,6	0/0	18,6
41-60	26/23,2	9/8,0	31,3	25/19,4	5/4,7	24,0
61 и старше 61 and older	35/31,3	25/22,3	53,6	33/25,6	41/31,8	57,4
Всего / Total	73/65,2	39/34,8	100,0	82/63,6 %	47/36,4	100,0

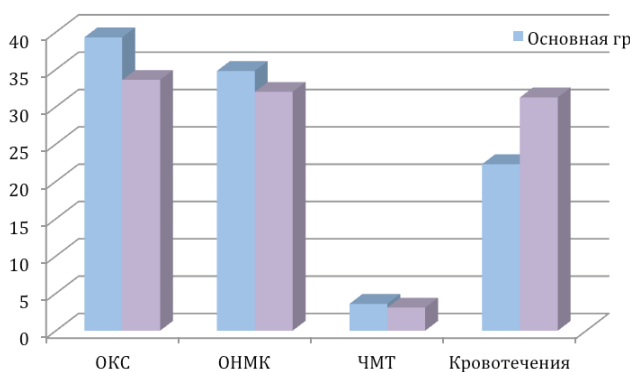


Рисунок. Нозологии в сравниваемых группах, %
Figure Nosologies in compared groups, %

(55,2%); extremely severe — 22 persons. (9,1%). The patients of the main group were hospitalized in a more severe condition. Severe and extremely severe were 77 patients (68.8%) in the study group and 78 patients (60.9%) in the control group; impaired consciousness of varying severity was detected in 11 patients (9.8%) in the study group and in 1 patient (0.8%) in the control group.

Cardiopulmonary resuscitation (CPR) was performed by helicopter in 12 cases (10.7%) and only in one case (0.8%) in a comparison group patient — by ambulance. The indication for resuscitation measures was cardiac arrest. There were no complications of mechanical chest compressions using an automatic compression device. All patients of both groups were delivered to the hospital alive.

The efficacy of central venous catheterization using ultrasound on a mobile scanner was confirmed: in the main group — in 83 cases of invasive procedures with 100% success; in the comparison group — in 94 successful cases (91.3%) out of 103 attempts with the "blind" method.

The use of diagnostic ultrasound during air ambulance evacuations can be considered as a near-term prospect, since in some cases the presence and approximate volume of intracranial hematomas can be diagnosed, including by indirect signs (optic nerve edema). The technique requires high proficiency in diagnostic ultrasound and experience in performing such examinations — it is currently at the stage of implementation and accumulation of experience.

During the initial examination, use of an ultrasound on a mobile device allowed 11 patients of the main group to be

admitted directly to the operating room of the surgical hospital, without additional diagnostic and therapeutic measures in the emergency room or in the anesthesiology and intensive care unit of the hospital. At the time of surgery, intracavitary bleeding of 1.5 liters or more was present in 6 patients with helicopter ultrasound and in 13 patients without it. Thus, if ultrasound and laparoscopy were performed on an emergency patient with in-hospital bleeding, it resulted in time loss and increased mortality from 9.1 to 28.6%. When the diagnosis was confirmed in flight with the mobile ultrasound from the moment of helicopter arrival to the hospital until the start of surgery, it took 2.5 times less time, which allows us to recommend its use by all AMT doctors and ambulance service for suspected intracavitary bleeding.

One of the controversial points of using prehospital ultrasound in an emergency patient in an air ambulance helicopter is the possible loss of time for the examination. However, if rationally organized, in-flight ultrasound can be performed quickly and without compromising other therapeutic and diagnostic manipulations. According to scientific publications, the average duration of pre-hospital ultrasound examination of an emergency patient usually does not exceed 5-6 min [15, 16].

The mean number of bed-days spent in the intensive care unit was (2.93±0.38) and (3.3±0.41) in patients in the study and control groups, respectively. Daily mortality during hospitalization by ambulance was 5.5%, during hospitalization by ambulance helicopter — 2.8%. Total mortality in the main group and comparison group was 16.1 and 19.5%, respectively.

The total number of bed-days was 1.91 more in the main group, which could be explained by a more severe contingent and almost 2 times higher mortality in the comparison group in the first day of hospitalization. When patients who died in the first day were excluded from our statistics, this difference was insignificant at 1.7 bed-days, 10.6 and 8.9 bed-days, respectively.

There was no correlation between the distance to the specialized medical organization and mortality in the studied groups. Priority in hospitalization by ambulance helicopter in a metropolitan area should be given to patients in severe and extremely severe condition, since no lethal outcomes were observed when it took up to 30 minutes to get to a profile hospital from the moment of doctor's call to the patient.

This confirms the fact that with ACS, CCI, stroke and massive bleeding, there is a correlation between the outcome of the disease and the time it took to get to a specialist. And we are talking not only about hours, but also — in some cases — about minutes.

During the hospitalization of patients with urgent pathology, the following patients received high-tech medical care: in the main group — 47 patients (45.9%), in the comparison group — 40 patients (32.3%), which emphasizes the effectiveness of the created algorithms of hospitalization when providing medical care by AMT doctors in a megapolis.

Within 6 months after discharge from the specialized hospital, the disability was established in 79 patients, 35 (31.3%) in the main group and 44 (34.8%) in the comparison group, mainly as a consequence of neurological pathology. According to the results of treatment of patients with bleeding disorders, disability was observed only in

Таблица 2 /Table No. 2

Распределение пациентов по удаленности от профильного стационара, чел./%

Distribution of patients by distance from the specialized hospital, pers./%

Расстояние от профильного стационара, км / Distance from the specialized hospital, km	Группы, чел./% / Groups, pers./%		Итого, чел. Total, pers.
	основная группа/ main group, n=112	группа сравнения/ comparison group, n=129	
0-10	3/2,7	74/57,4	77
11-15	0	27/20,9	27
16-20	1/0,9	18/14,0	19
21-25	5/4,5	7/5,4	12
26-30	5/4,5	0	5
31-50	18/16,1	3/2,3	21
Более 51 / More than 51	81/71,4	0	81
Всего / Total	112/100,0	129/100,0	241

one patient when the main diagnosis was combined with pelvic bone fractures. Disability as an outcome of ACS 6 months after the event was a rare issue: one patient in the main group versus three in the comparison group, which shows a high level of medical care for this category of patients in Moscow and is a natural result of the coordinated and algorithmic functioning of the "heart attack" network of vascular hospitals in the capital [17].

The need for palliative care in patients of both groups was not recorded.

Conclusion

1. The main directions of improvement and development of AMTs operation in the metropolitan area include: training and education of qualified AMT personnel; equipping the ambulance helicopter with modern medical equipment; using pre-hospital diagnostic ultrasonography in flight; improving and strictly observing the algorithms of interaction between AMT personnel and employees of ground services and medical organizations; determining the optimal number of helicopters used in a particular locality.

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2. The application of the developed algorithms for the use of ambulance aviation in a megacity makes it possible to evacuate urgent patients from remote areas of the megacity to specialized medical institutions in the same time as it takes ambulances to pick up patients within a radius of up to 15 km from the hospital; at the same time daily and overall mortality during hospitalization by ambulance helicopter was lower and was 2.8 and 16.1% respectively; total number of bed-days in the study group was greater than in the comparison group — 10.36 and 8.45 respectively — due to more severe contingent hospitalized and comparable figures of ICU stay (3.12 — in the study group; 3.27 — in the comparison group). The proportion of persons who were disabled after discharge from hospital was comparable in both groups (31.3% — in the main group; 34.8% — in the comparison group).

Thus, the performance indicators of the air ambulance are not inferior to those of ground ambulance teams and even, in some aspects, exceed them, which makes the use of air ambulance promising and indicates its great potential when used in remote areas of the metropolis.

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