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BRIDGING THE GAP IN EMERGENCY CARE THROUGH THE IMPACT OF TELEMEDICINE ON PATIENT OUTCOMES IN REMOTE REGIONS

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A total of 1115 patients who received emergency medical services between 2015 and 2020 were included in the study. These patients were divided into two groups: the traditional group (527 patients who received standard emergency medical services from 2015 to 2018 and the telemedicine group (588 patients who received additional remote consultative support via telemedicine from 2018 to 2020. Descriptive statistics, logistic regression, ROC analysis, and independent-samples tests were employed to identify key predictors of critical conditions and to assess the effectiveness of telemedicine in patient management. According to the results, 496 patients were identified as having a high likelihood of needing telemedicine. The results of the study demonstrated that telemedicine significantly enhances the management of critical emergencies in rural areas, leading to improved patient outcomes. These findings underscore the potential for telemedicine to transform healthcare, particularly in resource-limited settings.

Key words: telemedicine, emergency response, traffic accidents, acute coronary syndrome, remote areas, high-risk patients.

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ПОДОЛАННЯ РОЗРИВУ У НАДАННІ НЕВІДКЛАДНОЇ МЕДИЧНОЇ ДОПОМОГИ ЗА РАХУНОК ВПЛИВУ ТЕЛЕМЕДИЦИНИ НА РЕЗУЛЬТАТИ ЛІКУВАННЯ ПАЦІЄНТІВ У ВІДДАЛЕНИХ РЕГІОНАХ

До дослідження було включено 1115 пацієнтів, які отримали невідкладну медичну допомогу в період з 2015 по 2020 рік. Пацієнтів було розділено на дві групи: традиційна група (527 пацієнтів, які отримували стандартну екстрену медичну допомогу у 2015–2018 рр.) та група телемедицини (588 пацієнтів, які, окрім стандартної допомоги, отримували дистанційну консультативну підтримку за допомогою телемедицини у 2018–2020 рр.). Для виявлення ключових предикторів критичних станів та оцінки ефективності телемедицини у веденні пацієнтів застосовувалися методи описової статистики, логістична регресія, ROC-аналіз та критерії порівняння незалежних вибірок. Згідно з результатами, у 496 пацієнтів було виявлено високу ймовірність необхідності телемедичної підтримки. Результати дослідження продемонстрували, що телемедицина істотно покращує ведення критичних невідкладних станів у сільських районах, що призводить до поліпшення клінічних результатів. Отримані дані підкреслюють потенціал телемедицини у трансформації системи екстреної допомоги, особливо в умовах обмежених ресурсів.

Ключові слова: телемедицина, невідкладна допомога, дорожньо-транспортні пригоди, гострий коронарний синдром, віддалені регіони, пацієнти групи високого ризику.

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Despite advances in healthcare services, the provision of quality emergency medical services (EMS) in rural areas remains an unresolved issue. Currently, nearly 5 million people worldwide lack the necessary infrastructure for providing emergency care, leading to delayed hospitalization and a need for an additional 143 million surgical interventions annually to prevent disability and other complications [5, 10, 15].

A modern form of EMS has been worldwide provided through telemedicine (TM). TM supports the provision of more specialized care by enabling

the acquisition of theoretical and practical instruction from experienced specialists in real time [2, 4, 12].

In Azerbaijan, the use of various forms of TM has become increasingly common over the past five years. Unfortunately, these TM forms are limited to communicative interactions between doctors via smartphones to clarify specific information.

The purpose of the study was to optimize the quality of emergency service and evacuation processes in rural areas by improving telemedicine applications.

Materials and methods. Emergency care was delivered by regional EMS stations under the Republican Emergency and Urgent Medical Service Center (REMSC), Ministry of Health of the Republic of Azerbaijan (Baku), covering multiple regions of the country, including both urban and rural areas. Telemedicine consultations were coordinated through a central TM unit based in Baku. The study included patients from different regions of Azerbaijan (including Baku and surrounding districts, as well as rural regions), all of whom were served by EMS units affiliated with REMSC.

1115 patients, who received EMS between 2015 and 2020, were divided into two major groups. Data from 527 patients who applied to REMSC's dispatcher center between 2015 and 2018 were analyzed retrospectively. In this group, EMS were performed based on traditional procedures (Traditional – TR group). The study included a heterogeneous cohort of patients reflecting real-world EMS practice. Cases were categorized into the following major groups: cardiovascular emergencies (e.g., acute coronary syndrome, arrhythmias, hypertensive crises); neurological conditions (e.g., stroke, seizures, altered consciousness); traumatic injuries (e.g., polytrauma, fractures, head injuries); respiratory emergencies (e.g., acute respiratory failure, asthma exacerbation); other urgent conditions (e.g., acute abdominal pathology, poisoning, metabolic disorders).

However, the study sample was not restricted to a single disease entity but was intentionally designed to reflect the full spectrum of EMS workload. The grouping (TM vs TR) was based on the mode of care delivery (telemedicine-supported vs traditional EMS) rather than diagnosis. This approach allowed for the evaluation of telemedicine effectiveness across diverse emergency conditions.

Inclusion criteria: the patients who received emergency medical services (EMS) within the study period (2015–2020); were attended by regional EMS teams under the REMSC system; had complete and accessible medical documentation (dispatch data, prehospital records, and hospital admission data); presented with acute conditions requiring EMS intervention, including both traumatic and non-traumatic emergencies.

Exclusion criteria: the patients who had incomplete or missing clinical or demographic data, were not managed by EMS teams affiliated with REMSC, represented interfacility transfers without primary EMS assessment, had non-urgent conditions not requiring EMS intervention, or were repeat admissions of the same patient within the study period (only the first case was included).

A prospective study was conducted on 588 patients who received EMS between 2018 and 2020. In this group, remote consultative support was provided using TM (TM group). No significant statistical difference was found between the age (38.74±0.75 vs. 38.94±0.69) and male-to-female ratio in the TM and TR groups ($p>0.05$). A TM workstation and a central TM office operate under the REMSC to provide TM services. The regional TM station, as an element of the telemedicine network, is responsible for performing clinical tasks and is equipped with the necessary tools for remote diagnostics and consultations. It has been established in the regional EMS stations. The mobile TM station – ambulances are equipped with GSM and Wi-Fi antennas, as well as portable diesel generators, to ensure continuous TM operation. The necessary equipment has been installed in regional units and ambulances to support uninterrupted communication with the central TM office. The specialist in the central TM office and ambulance staff used special instructions (such as S.B.A.R. (Situation, Background, Assessment, Recommendation)) method and guidelines to ensure quick, concise, and clear communication.

Diagnosis and clinical assessment were performed in accordance with National EMS clinical protocols and Ministry of Health regulations (Republic of Azerbaijan). In addition, International Guidelines were used where applicable, including:

– American Heart Association (AHA) guidelines (for cardiovascular emergencies and CPR);

– European Resuscitation Council (ERC) guidelines;

– WHO emergency care recommendations;

– Standard trauma assessment principles (ABCDE approach, ATLS framework where applicable).

Prehospital diagnoses were based on clinical examination and vital parameters; point-of-care diagnostics available in EMS (e.g., ECG, pulse oximetry, glucometry); and telemedicine-supported consultation (in the TM group).

These instructions and guidelines aim to enhance EMS efficiency and improve the management of critical situations.

Data were analyzed using IBM SPSS Statistics 29. Descriptive statistics, Independent Samples T-Test, ANOVA, and Mann-Whitney U tests were employed. The validity and reliability of data were checked using Cronbach's alpha. Logistic Regression and Cox Proportional Hazards Model identified risk factors for patients likely to require TM. ROC analysis determined “cut-off” values, with Cohen's d and Hedges' g used to assess the magnitude of differences between groups.

Compliance with ethical standards: ethical principles of the World Medical Association

Declaration of Helsinki (World Medical Association Declaration of Helsinki, 1964, ed. 2013) were adhered to. Ethical approval was obtained from the Ethics Committee of the Azerbaijan State Advanced Training Institute for Doctors named after A. Aliyev.

Results of the study and their discussion. The criteria for "likelihood of TM use" were determined based on specific data or medical logic, using the Binary Logistic Regression method. The "Omnibus Tests of Model Coefficients" indicated that the model is statistically significant ($p<0.001$). The "Hosmer and Lemeshow Test" showed good fit ($p=0.954$), indicating that the model explains the data well.

The Logistic Regression model indicates that age is slightly associated with an increased probability of complications, though the effect is very small ($p=0.184$). The Exp(B) value of 1.037 indicates that for each 1-unit increase in age, the probability of life-threatening complications increases by 1.037. This indicates that while age is associated with a heightened risk of severe outcomes, our model's main purpose was to identify patients in critical condition who are at significant risk of death and therefore stand to gain the most from TM interventions.

The Glasgow Coma Scale (GCS) was the significant variable in the logistic regression model ($p<0.05$). Coma 1 has a statistically significant impact on the patient's chance of survival and is a significant factor influencing the patient's condition.

The results of the statistical analysis indicate that the Shock ($p<0.01$) is also a significant factor. The probability of complications is higher in patients experiencing shock, and remote assistance via TM can be lifesaving for these patients.

It was confirmed that the destination time has a significant impact on complications. The AUROC was 0.66 ($p=0.04$), indicating a statistically significant result. Based on Youden's Index values, the optimal cut-off time for the model was ≤15 minutes.

The key conclusions of the Binary Logistic Regression analysis are reported below. The impact of age is not statistically significant ($p=0.184$), but as age increases, the risk of dangerous complications also rises. The GCS is significantly associated with the probability of death. Lower GCS values increase the risk of terminal complications. Shock has a statistically significant correlation with the probability of life-threatening complications ($p<0.05$). The cases in which the destination time of the Ambulance exceeds 15 minutes, are categorized as a high-risk group due to the increased risks of complications and death.

Based on three validated variables (destination time over 15 minutes, presence of Coma 1, and shock), 496 patients with a high likelihood of needing TM were selected. Among those who received EMS between 2015 and 2017, 222 patients were included in the TR group, and 274 patients who received remote consultation with TM between 2018 and 2020 were included in the TM group. No statistically significant differences were found between the two groups in age, gender, or severity of condition ($p > 0.05$). The examination results of patients in the TR and TM groups were compared. For a clearer comparative analysis, patients in both groups were divided into subgroups by diagnosis. A comparative analysis was conducted between the groups using general criteria and specific indicators corresponding to the diagnoses.

A total of 40 patients (TR group n=15; TM group n=25) with acute coronary disease were selected based on criteria indicating a high likelihood of benefiting from TM. Remote instructions were provided in accordance with the latest guidelines to reduce pain intensity, relieve stress, and achieve hemodynamic stability. After implementation of TM recommendations, systolic arterial pressure (SAP) increased to 113.83±1.15 mmHg, and diastolic arterial pressure (DAP) increased to 73.81±0.895 mmHg. In the TR group, these values were 109.75±1.14 mmHg and 68.74±1.19 mmHg, respectively. All patients were transferred to the specialized Cardiac Center for further interventions. Upon admission, hemodynamic parameters in the TM group were significantly better than in the TR group. Among patients likely to benefit most from TM, 59 cases of limb injuries were observed. Of these, 22 were in the TR group, and 37 were in the TM group. Using TM, all patients first underwent an initial assessment based on the ABC (Airway, Breathing, Circulation) principle, followed by the application of the ATLS (Advanced Trauma Life Support) protocol. In the TM group, pulse rate decreased to 95.34±0.84. However, the average pulse rate in the TR group was 107.27±1.09, which did not differ significantly from the pre-treatment measurement. After adequate intravenous infusions and anti-shock measures were implemented using standard protocols, a positive change in arterial pressure values was noted among patients in the prospective material. The differences in pulse rate and arterial pressure values between the two groups were statistically significant ($p<0.001$).

The Visual Analog Scale (VAS) was used to assess pain in patients. In the TR group, analgesia was provided through opioids (e.g., morphine) or non-opioid analgesics. In the TM group, patients who received remote consultative assistance also benefited from these analgesic methods. In certain cases, especially in limb injuries, regional anesthesia with nerve blocks was successfully applied. The average pain score in the TM group was 7.46±0.01, while in the TR group, it was 8.01±0.01. After treatment, a statistically significant and clinically substantial difference in pain levels between the groups was found. The pain level in the TR group was significantly higher than in the TM group ($p<0.001$).

It should be noted that the analgesic approaches were comparable in terms of drug class, indications, and administration protocols. In the TM group, telemedicine support may have contributed to a more accurate assessment of the patient's condition and a more rational selection of analgesic therapy.

Among the patients included in the study, 309 cases of closed traumatic brain injury (TBI) were recorded (closed traumatic brain injury was diagnosed based on clinical and anamnestic data, including a history of head trauma and the presence of neurological symptoms (loss of consciousness, amnesia, confusion, headache, vomiting), as well as Glasgow Coma Scale (GCS) assessment. In the prehospital setting, diagnosis was preliminary and based on standard EMS protocols. When available, diagnosis was confirmed by neuroimaging (CT) and hospital-based neurological evaluation. Of these patients, 156 were in the TM group, and 153 were in the TR group. Changes in GCS between groups were monitored after treatment. In the TM group, the GCS increased to 12.97±0.2. In the TR group, the situation worsened, and the GCS decreased to 10.86±0.25. As a result of remote consultative assistance provided through TM, the coma score in the TM group exceeded the critical threshold of 12, and signs of mild coma were observed in the patients. The results of the Independent Samples Test indicate that the GCS differed statistically between the groups ($p<0.001$). Thus, the specialist support provided through TM in patients with traumatic brain injuries led to better outcomes in terms of patient stabilization, improvement in consciousness indicators, and more adequate adaptation to evacuation and adherence to instructions.

Blunt abdominal trauma was recorded in 26 patients involved in road traffic accidents. Of these patients, 19 were male (73.1 %), and 7 were female (26.9 %), with an average age of 36.69±3.46 years. After assessing the patient's condition at the scene, treatment was initiated with remote specialist support via TM. Management of blunt abdominal trauma at the pre-hospital emergency medical care level was based on guidelines and clinical standards. The use of the FAST (Focused Assessment with Sonography for Trauma) protocol helped to exclude the intra-abdominal hemorrhage. During the TM sessions, we observed earlier recovery of hemodynamic parameters and an improvement in the overall condition of the patients. Compared to the TR group, the hemodynamic parameters of the patients were more favorable in the TM group. For instance, the pulse rate in the TM group was 94.34±1.32, while in the TR group, it was 107.77±1.85, indicating a higher average pulse rate in the TR group. The SAP was 114.59±1.67 mmHg in the TM group and 108.96±1.74 mmHg in the TR group. The SAP in the TM group was higher, approaching normal limits. In the TR group, arterial pressure did not change significantly from pre-treatment values. There was also a slight increase in DAP values, with averages of 72.36±1.41 mmHg in the TM group and 70.73±0.96 mmHg in the TR group. Although this difference is minor, it indicates slightly better results in the TM group ($p>0.05$). In the TM group, the breath rate was 17.34±0.49 and was significantly lower than pre-treatment values, resulting in deeper, more relaxed breathing. Due to rhythmic, free breathing, saturation increased to 95.45±0.91 %. In the TR group, the breath rate was 23.27±0.41 and saturation was 88.54±0.82 %, which were significantly lower than in the TM group ($p<0.001$). TM ensured optimal management of patients with blunt abdominal trauma at the pre-hospital emergency medical care level. It is worth emphasizing once again that the diagnostic advances and correct interventions made through TM at the pre-hospital stage have proven effective in significantly improving the patient's long-term recovery prospects.

Among the patients, 15 were diagnosed with pelvic trauma, with 7 receiving traditional emergency medical care (TR group) and 8 receiving care through TM. The interventions to be carried out at the pre-hospital emergency care level were determined by a remote specialist via TM, in accordance with the latest protocols and guidelines. Along with the initiation of anti-traumatic shock measures, high-flow oxygen insufflation was deemed necessary. The pulse rate was 93.79±1.35 in the TM group and 108.57±1.97 in the TR group. In the TM group, a normalization of pulse rate was followed by the restoration of sinus rhythm. According to the statistical analysis, the pulse rate was significantly higher in the TR group ($p<0.001$). Along with stabilization of pulse rate, a dynamic improvement in arterial pressure towards normal was also observed in patients in the TM group. The SAP increased to 118.9±1.7 mmHg in the TM group. Although there was some improvement in the TR group, the SAP was 105.39±2.43 mmHg, lower than in the TM group ($p<0.001$). The DAP in the TM group was 71.55±1.6 mmHg after treatment, while in the TR group, it was 69.7±1.85 mmHg. Improvements in pain management led to more comfortable, deeper breathing for patients. The breath rate in the TM group was 16.70±0.81, while in the TR group, it was 22.65±0.48 ($p<0.001$). Saturation was 94.99 % in the TM group and 89.24 % in the TR group ($p<0.001$).

As shown in the statistical analysis, there are statistically significant differences among the groups in pulse, SAP, breath rate, and saturation parameters. Although DAP was higher in the TM group, the between-group differences were not statistically significant. These differences can be considered clear evidence of the effectiveness of TM during pelvic trauma.

As a result of the TM application, significant improvements were observed in the patients' primary vital parameters. These results demonstrate that TM technologies are particularly effective in emergency care and critical situations. The findings highlight the positive impact of broader future applications of TM and promote the widespread use of this technology in medicine.

The results of this study highlight the significant potential of telemedicine (TM) in enhancing the quality of EMS in rural and remote areas. This discussion delves into the interpretations of the findings, their broader implications, the study's strengths and limitations, and recommendations for future research.

The study demonstrated that TM could play a pivotal role in improving patient outcomes in critical emergencies, particularly in rural areas where access to specialized care is limited. Consistent with the findings of Sun et al. (2019), our logistic regression analysis revealed that age, GCS, and the presence of shock are significant indicators for identifying patients who might benefit most from TM. While Sun et al. focused on predicting mortality, our study utilized these indicators not to predict mortality per se but to determine the severity of patients' conditions and thus their potential to benefit from TM interventions. Unlike Sun et al., who found a stronger correlation between age and mortality, our results suggest that while age is an important factor, the presence of shock and GCS are more critical in identifying those patients who require immediate TM support, highlighting the utility of these indicators in optimizing patient care in our cohort [13].

Rettig et al. (2021) also explored the use of predictive modeling in emergency care, emphasizing its utility in targeting interventions more effectively. While their study primarily focused on developing models to predict specific outcomes, such as the likelihood of complications or the need for intensive care, our research differs by using predictive indicators like GCS and the presence of shock to identify which patients in rural areas are most likely to benefit from TM. Both studies share the goal of enhancing emergency care through targeted interventions. Still, our study specifically highlights the practical application of TM in real-time clinical scenarios, particularly for patients in critical condition, where timely intervention is crucial. This comparison underscores the broader applicability of predictive models, whether for anticipating outcomes or for guiding the deployment of innovative solutions like TM to improve patient care [11].

The use of TM allowed for more effective management of acute coronary disease, severe limb traumas, traumatic brain injuries, and blunt abdominal and pelvic traumas, leading to better stabilization of patients before they reached healthcare facilities. Thirukumaran N and Gross CP (2020) reported similar findings, where TM interventions significantly enhanced hemodynamic stability in patients with acute coronary syndrome, demonstrating reduced time to intervention and improved patient outcomes [14]. Our study corroborates these findings, particularly in the management of acute coronary disease, where we observed significant improvements in systolic and diastolic arterial pressures and reduced pulse rates, indicating better overall hemodynamic stability.

However, our research extends these findings by applying TM not only to cardiac emergencies but also to a broader range of critical conditions, such as severe limb traumas and traumatic brain injuries. For example, Bellini and Di Mascio (2019) focused on the role of TM in managing traumatic shock and found that TM could be lifesaving by providing remote guidance on hemodynamic management [1]. Our study supports their conclusions, as we also observed that TM significantly improved stabilization in cases of traumatic brain injuries and blunt abdominal traumas. In contrast to their study, which was more focused on specific trauma cases, our broader application of TM across multiple trauma types suggests that the benefits of TM could be even more extensive, providing critical support across a wider range of emergency scenarios.

This broader application of TM underscores its potential as a versatile tool in emergency care, capable of improving outcomes not only in isolated cases of severe trauma but across various critical conditions encountered in rural and remote settings. In particular, the improvement in systolic and diastolic arterial pressures, along with a reduction in pulse rates, underscores the effectiveness of TM in managing hemodynamic stability [1]. The study's findings suggest that real-time remote consultations can bridge gaps in critical care expertise in rural settings, enabling timely, accurate medical interventions that would otherwise be delayed by geographical barriers [8].

The implications of these findings are profound for healthcare systems, especially in low- and middle-income countries where rural populations often have limited access to specialized medical care [7]. By integrating TM into EMS, healthcare providers can significantly reduce the time to intervention, which is crucial for conditions like acute coronary syndromes and traumatic injuries where every minute counts [14]. The ability to provide expert guidance remotely can also improve resource utilization, preventing unnecessary transfers to tertiary care centers and reducing the burden on urban hospitals [7].

Moreover, the study’s results highlight TM's potential to improve overall patient outcomes and reduce mortality in emergencies [1]. The findings suggest that implementing TM on a broader scale could lead to systemic improvements in healthcare delivery, particularly in under-resourced areas, and may serve as a model for other regions facing similar challenges [9].

One of the strengths of this study is its robust methodology, which includes logistic regression and ROC analysis to identify key predictors of patient outcomes and to determine cut-off values for critical interventions. The comparative analysis between the TM and TR groups also provides a clear indication of TM's effectiveness across various emergency scenarios.

The retrospective nature of the TR group data may introduce recall bias, and the non-randomized allocation of patients to the TM and TR groups may introduce selection bias. Additionally, while the study covers a wide range of emergencies, the sample sizes for specific conditions like pelvic trauma were relatively small, which may limit the generalizability of the findings. The study was also conducted within a single country, and results may differ in other settings with varying healthcare infrastructures.

Future research should focus on larger, multi-center studies to validate these findings across different populations and healthcare systems [3, 6]. Additionally, randomized controlled trials could provide more definitive evidence of TM's effectiveness compared to traditional EMS. Further studies should also explore the cost-effectiveness of TM, particularly in resource-limited settings, to better inform policy decisions on integrating TM into national healthcare systems.

Moreover, advancements in TM technology, such as integrating artificial intelligence for real-time decision support, should be explored to enhance remote consultation capabilities [4]. Training programs for EMS providers in rural areas on the use of TM should be developed to ensure that they can effectively utilize this technology in critical situations [8].

Limitations. This study has several limitations, including the heterogeneity of emergency conditions and the partially retrospective design of the TR group. Additionally, variability in prehospital assessment and the limited availability of confirmatory diagnostics may have affected the accuracy and comparability of clinical data.

Conclusion

In conclusion, this study provides evidence that telemedicine can significantly enhance the management of critical emergencies in rural settings, thereby improving patient outcomes and enabling more efficient decision-making. The integration of TM into emergency medical services enabled faster access to specialist consultation, improved triage accuracy, and more timely initiation of appropriate interventions. These advantages are particularly important in geographically remote areas, where access to advanced medical expertise is often limited. Although certain methodological limitations, including heterogeneity of clinical conditions and variability in treatment approaches, should be taken into account, the overall findings support the clinical and organizational value of TM. The broader implementation of TM systems within EMS has the potential to optimize resource utilization, reduce disparities in healthcare access, and strengthen the overall quality of emergency care. Future studies should focus on standardizing protocols and evaluating long-term outcomes to validate these findings further.

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