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Nephrological care in Ukraine during wartime: challenges and innovations

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Abstract. The war in Ukraine has profoundly impacted the provision of nephrological care, presenting numerous challenges while also driving significant innovations. This study aims to analyze the availability and quality of nephrological care in Ukraine during wartime, focusing on chronic kidney disease stages 1–5D/T. The conflict has caused population displacement, restricted access to treatment, and disrupted healthcare logistics, adversely affecting nephrological care. Despite these challenges, the healthcare community has adapted through the implementation of virtual nephrology, incremental and extended dialysis regimens, and increased use of new therapy approaches. The war led to a decrease in the population and migration of medical personnel, particularly from southeastern to western Ukraine, causing staffing imbalances that were gradually addressed. Technological innovations, such as digital nephrobiopsy with immunohistochemical analysis and the use of cloud-based technology, allowed for rapid and remote diagnosis. Virtual healthcare and remote consultations ensured continuity of care, while kidney transplantation activities saw a notable increase, facilitated by advanced techniques and international aid. Despite initial logistical challenges and resource shortages, the resilience and adaptability of the Ukrainian nephrological care system have been evident. This study underscores the importance of robust contingency planning, international collaboration, and the adoption of innovative solutions to maintain healthcare delivery in conflict zones. The findings offer valuable insights into managing nephrological care under extreme conditions and highlight the potential for these innovations to improve care delivery globally.

Keywords: nephrological care; Ukraine; wartime healthcare; chronic kidney disease; virtual nephrology; dialysis; kidney transplantation; healthcare innovations; conflict zone healthcare; medical logistics; telemedicine; healthcare personnel migration; humanitarian aid; digital nephrobiopsy

Introduction

The ongoing war in Ukraine has significantly impacted the provision of nephrological care [1]. While the conflict has restricted access to treatment and displaced millions, it has also necessitated the development of innovative technologies and strategies to manage chronic kidney disease (CKD) [2, 3].

According to the United Nations data, Ukraine's population decreased by over 6 million during the hostilities, including at least 25 % children. Additionally, documented internal migration negatively impacted the provision of qualified nephrological care [3–5]. In Ukraine, 17.6 million people required humanitarian assistance, and 8.3 million

people received such assistance in 2023. Patients requiring nephrological care, making up about 10 % of the population, form a significant group. The most accessible statistics during martial law in Ukraine concern patients receiving renal replacement therapy (RRT). In the first six months of hostilities, 602 dialysis patients fled to the EU as refugees, and over 400 remained in temporarily uncontrolled territories [2]. However, accurate information about more than 1,000 patients receiving RRT from the pre-war registry is still unavailable [6–8].

This study aims to analyze the availability of nephrological care in Ukraine during wartime, focusing on the challenges faced and the innovative solutions that have emerged.

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The **objective** was to study clinical observation and treatment data of patients with CKD stages 1–5D/T in Ukraine during martial law.

Materials and methods

This study employs a demographic and statistical analysis of nephrological care indicators in Ukraine. Data were collected from various sources, including the national registry of CKD patients, reports from the Renal Disaster Relief Task Force of the European Renal Association, and local healthcare facilities.

The study was retrospective and prospective, examining primary documentation of patients who sought nephrological care from February 24, 2022, to February 2024. For the analysis of obtained results, publicly available data were used, subjected to SWOT analysis and, where possible, statistical processing using online calculators.

Results

Population impact and CKD registry

The war has led to a substantial reduction in Ukraine's population, with an estimated decrease of 8 million people, including a 30% reduction in the child population. Despite this, the registry of patients with stage 5 CKD has expanded. In 2022, the registry included 10,534 patients, with 602 dialysis refugees receiving therapy in the EU, 8,533 patients in Ukraine, and over 400 in territories not under Ukrainian control. This left more than 1,050 patients unaccounted for. By the end of 2023, the registry had expanded to 10,748 patients, with an additional 2,111 RRT sets available. However, no data is available on kidney conditions among military personnel.

The reports of Ukrainian regions, presented in open access Viber chat "Nephrology. Dialysis. Transplantation" by Professor Iryna Dudar on February 8, 2024, provides a detailed breakdown of the number of patients receiving various types of RRT in Ukraine and the additional capacity for new patients across several dates to February 8, 2024.

Summary of key findings

1. Total patients treated (all regions):

— The total number of patients treated with RRT increased from 8,772 on January 1, 2023, to 10,748 by October 15, 2023, showing a steady rise over the months.

— A slight decline to 10,708 was noted by February 8, 2024.

2. Hemodialysis/hemodiafiltration (HD/HDF):

— Patients treated with HD/HDF saw a significant increase from 5,061 in January 2023 to 6,628 by October 15, 2023.

— This number slightly decreased to 6,584 by February 8, 2024.

3. Peritoneal dialysis (PD):

— The number of PD patients remained relatively stable, starting at 483 in January 2023 and peaking at 523 in April 2023.

— By November 2023, detailed breakdowns showed 511 PD patients, with 206 using Baxter automated systems and 305 using manual systems (76 Baxter manual and 229 local industry manual).

4. Transplanted kidney:

— Patients with transplanted kidneys remained consistent, around 1,413 in January 2023 and gradually increased to 1,498 by October 15, 2023.

— The number slightly decreased to 1,496 by February 8, 2024.

5. Capacity for new patients:

— The additional capacity for HD/HDF treatment increased from 1,545 in January 2023 to 2,044 by February 2023 but then fluctuated, settling at 1,819 by February 8, 2024.

— The capacity for new PD patients showed a slight increase from 58 in January 2023 to 85 by February 2024.

— The capacity for new transplanted kidney patients remained stable at around 217 throughout the period.

During the hostilities, we proposed dividing the affected areas into four zones based on the characteristics of nephrological care availability (Fig. 1) [5].

Geographic disparities in care

The availability of nephrological care varies significantly across different regions. Three distinct zones have been identified:

1. Areas with no assistance. These include Luhansk, Donetsk, parts of Kharkiv, Kherson, and Zaporizhzhia regions, where the conflict has severely limited healthcare access.

2. Areas with limited care. The central part of Ukraine faces significant constraints in providing comprehensive nephrological care.

3. Areas with preserved or expanded care. Western Ukraine, particularly Lviv, has maintained and even enhanced its kidney care capacity compared to the pre-war situation.

Another significant factor determining the organization of nephrological care was the period of hostilities. We identified the following destructive factors (Fig. 2), each assessed using SWOT analysis.

The onset of war introduced several pervasive stressors including the abrupt escalation of hostilities, absence of tailored recommendations for chronic disease management, resource limitations, food shortages, insufficient bomb shelter availability, and significant communication breakdowns. Additionally, the emotional toll of losing loved ones, witnessing disabilities, and social maladaptation compounded these challenges. These adverse factors, common to conflict zones, exacerbated the strain on medical resources but could be mitigated through consensus guidelines from medical experts.

The war also precipitated a notable shift in the distribution of medical personnel. In the initial three months, up to 40 % of healthcare workers in southeastern Ukraine relocated, while western regions experienced a modest increase in medical staff. Despite some normalization within six months, the total number of healthcare personnel has not returned to pre-war levels.

Disruptions in communication between patients and healthcare providers early in the conflict necessitated the rapid adoption of virtual healthcare solutions. This led to the establishment of virtual nephrology care, which inclu-

ded consultations via messaging platforms, condition monitoring through video calls, and the use of conference calls to maintain continuity of care both within Ukraine and for those displaced abroad.

The initial phase of the war was marked by significant logistical challenges in accessing treatment sites and ensu-

ring a consistent supply of medical necessities for hemodialysis. This disruption caused considerable distress among patients and healthcare providers, contributing to reduced care quality, medication shortages, and an increase in stress-related hypertension evidenced by a 18–24% rise in systolic and a 12–17% increase in diastolic blood pressure. Timely

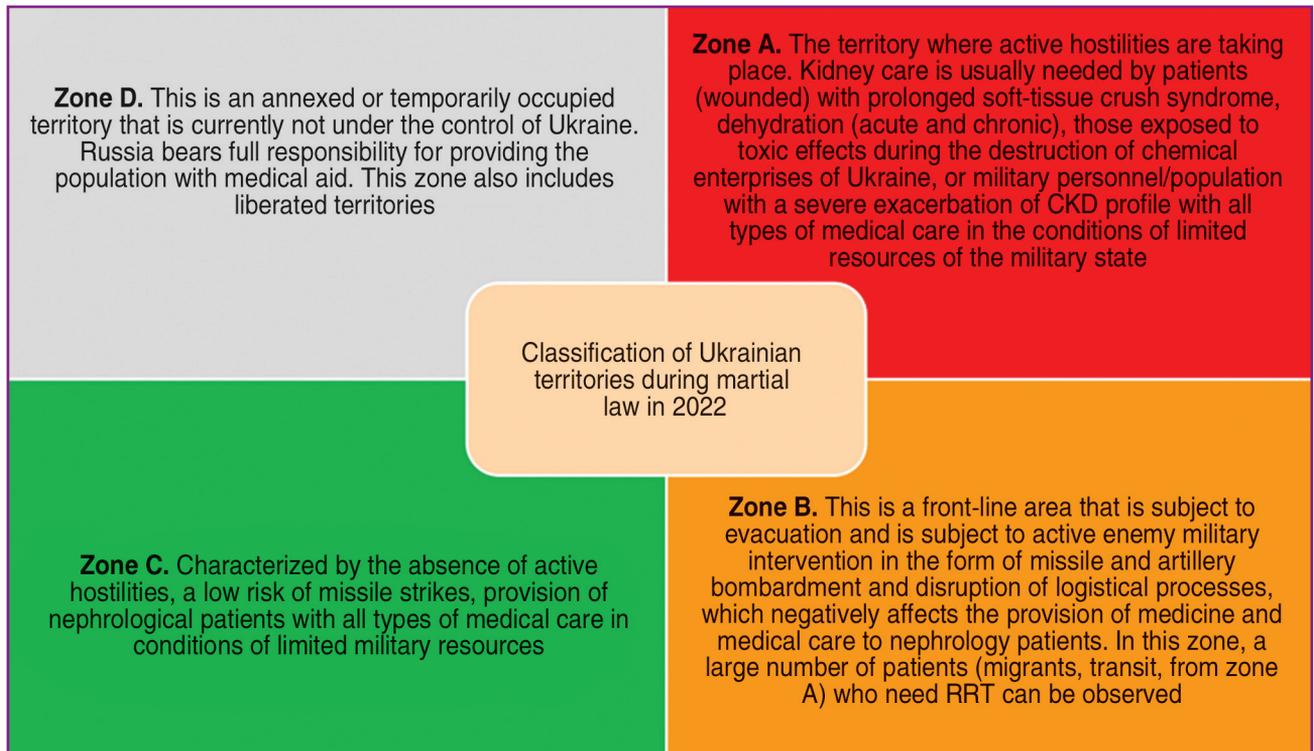


Figure 1. Availability of nephrological care

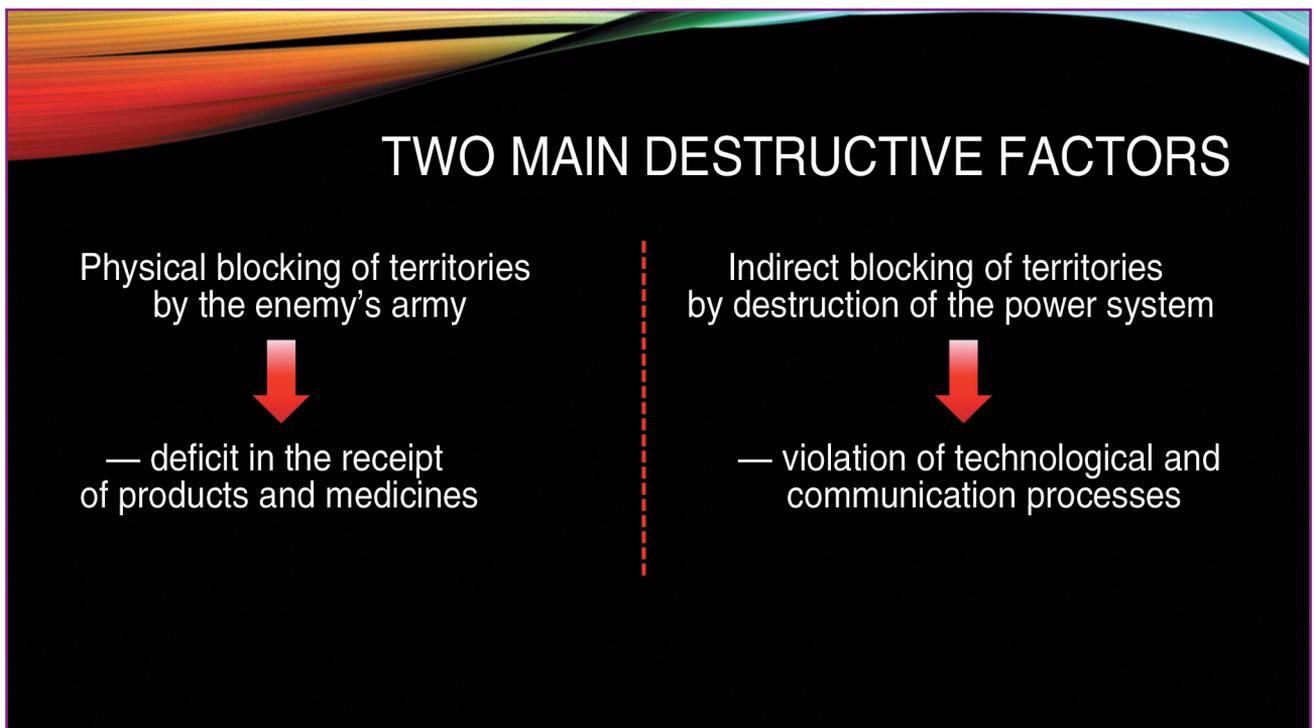


Figure 2. Destructive factors

humanitarian aid, primarily from the European Union and the United States, played a crucial role in alleviating these challenges.

Following the stabilization of logistics, the next major challenge was managing blackouts. Recognized as critical infrastructure, dialysis centers and hospitals were prioritized, mitigating significant negative impacts. However, some facilities resorted to stockpiling water and utilizing generators. Outpatient peritoneal dialysis patients in certain regions had to temporarily reduce their dialysis frequency. The situation was largely stabilized within a month through the deployment of charging stations, generators, and reallocation of some patients to hemodialysis.

Challenges in the diagnosis and treatment of renal conditions during the conflict prompted innovative solutions. The inability to send biological samples abroad for genetic research necessitated the adoption of nephrobiopsies with immunohistochemical analysis, totaling 44 biopsies. Leveraging digital and cloud technology enabled one center to conduct biopsies and deliver results within a day, surpassing the entire pre-war volume in Ukraine.

Difficulties in administering cyclophosphamide pulses, due to the necessity of hospital visits, inability to monitor serum cyclosporine levels, and limited mycophenolate mofetil supply, led to the utilization of rituximab, received through humanitarian aid, for all progressive glomerulopathies. This approach not only alleviated the nephrologists' workload but also yielded valuable experience and achieved significant positive outcomes, reducing proteinuria from 1.1 ± 0.3 to 0.3 ± 0.1 ($n = 22$). The use of rituximab infusions increased 4.5 times compared to pre-war levels.

Substantial advances were made in RRT. In areas and periods with limited resources, incremental dialysis and extended dialysis targeting a Kt/V of at least 1.2 were actively implemented.

Clinical illustration of incremental dialysis. A patient's creatinine rose to $560 \mu\text{mol/L}$, estimated glomerular filtration rate decreased to $9\text{--}11 \text{ ml/min/1.73 m}^2$, but the condition remained satisfactory. Due to dangerous levels (potassium 7 mmol/L , urea 42 mmol/L), incremental hemodialysis was recommended. A double-lumen acute hemodialysis catheter was implanted, and an arteriovenous fistula was created two months later. Initially, a patient received 5-hour hemodialysis sessions weekly, with pre-dialysis creatinine levels ranging from 320 to $410 \mu\text{mol/L}$. The need for twice-weekly dialysis sessions arose six months later.

Extended dialysis illustration. Patient B., born in 1962, diagnosed with CKD stage 5D due to polycystic kidney disease, has been receiving dialysis since October 7, 2019. The patient underwent extended hemodialysis sessions (6 hours) using Theranova 500 dialyzers. The dialysis dose was monitored monthly, achieving a target Kt/V of 1.4. This personalized approach prevented a statistically significant increase in mortality among CKD stage 5D patients. Transplant activity increased by over 60 % in adults and nearly doubled in children. However, the number of hemodialysis patients increased by 15 %.

In early 2023, a new challenge emerged: cholera in the Kherson region, similar to outbreaks during the Viet-

nam War, associated with drinking and seawater. Ukrainian cholera had a shorter incubation period of 24–36 hours and higher lethality (over 25 %). Antimicrobial resistance and a tendency to extrapulmonary dissemination were observed. CKD patients in contact zones experienced increased cholera prevalence, exacerbating their condition. Preventive measures included virtual care nephrology, high adherence, intensified renoprotective therapy, and sodium-glucose cotransporter-2 inhibitors.

Practical recommendations for implementing virtual nephrology care include organizational (avoiding war-zones, documenting diagnoses, discussing further steps, changing data storage), diagnostic (primary diagnosis recording and reviewing, remote monitoring, interpreting examination results), and treatment stages (minimizing interventions, enhancing physical health, timely testing, stress management). A consensus on nephrological care during hostilities should be formalized, and algorithms for kidney disease management should be developed and disseminated.

Virtual nephrology care in Ukraine proved a viable way to reduce medical personnel burden and address current challenges. Further data collection is essential to understand unmet needs, prevent complications, and prepare for possible subsequent waves.

Detailed observations

1. HD/HDF treatment:

— The number of patients receiving HD/HDF consistently increased over the year, indicating a growing demand for this type of therapy.

— The capacity for accepting new HD/HDF patients was initially high but showed some variability, suggesting adjustments in healthcare resources or patient influx rates.

2. PD treatment:

— While the total number of PD patients showed minor fluctuations, the capacity to accept new PD patients increased slightly, indicating efforts to expand this treatment option.

— The breakdown in November 2023 highlights a balanced utilization of automated and manual PD systems, with a notable contribution from local industry manual systems.

3. Kidney transplants:

— The number of patients with transplanted kidneys showed a gradual increase, reflecting ongoing transplantation activities.

— The capacity to accept new transplant patients remained steady, indicating consistent transplantation capabilities and resources.

Implications and recommendations

1. Increased demand for HD/HDF:

— The significant rise in HD/HDF patients suggests an increasing prevalence of severe CKD cases requiring intensive care.

— Healthcare providers should ensure the availability of necessary resources and infrastructure to meet this growing demand.

2. Stable PD utilization:

— The relatively stable number of PD patients and a slight increase in capacity suggest that PD remains a viable and scalable treatment option.

— Continued support for both automated and manual PD systems, especially local industry ones, could enhance treatment accessibility.

3. Sustained kidney transplantation:

— The steady number of kidney transplant patients and consistent capacity for new transplants indicate a robust transplantation program.

— Ongoing support for transplantation activities, including donor programs and post-transplant care, is crucial for maintaining and improving outcomes.

4. Resource allocation and planning:

— Fluctuations in the capacity for new patients highlight the need for dynamic resource allocation and strategic planning to address changing healthcare demands.

— Authorities should consider potential surges in patient numbers and ensure that facilities are equipped to handle increased loads.

This data reflects a dynamic nephrological care landscape in Ukraine, with increasing patient numbers and fluctuating capacities for new treatments. Continuous monitoring and adaptive strategies are essential to ensure the sustainability and effectiveness of nephrological care during these challenging times.

Transplantation and technological innovations

Despite the challenges, there has been a notable increase in kidney transplantations. In 2022, 274 transplants were performed, and in the first nine months of 2023, 272 were completed. Most transplants were from deceased donors, with a 54% increase in 2022 and a 63.5% increase in 2023. Pediatric transplants saw a 78% increase, mostly from living-related donors. Innovations such as laparoscopic and robotic (DaVinci®) donor nephrectomy, the use of cell-saver for significant bleeding, and kidney-assist technology have been employed. All patients underwent human leukocyte antigen typing and panel reactive antibody screening before transplantation, with post-surgery surveillance and immunosuppressants provided.

Dialysis adjustments

For CKD stage 5D patients, logistical challenges have led to a reduction in dialysis frequency. Some centers have implemented twice-weekly dialysis with increased flow and duration, aiming for a target Kt/V of 1.4. Additionally, 20 % of PD cases have utilized electric batteries to ensure energy efficiency, achieving similar effectiveness to traditional methods.

Management of CKD stages 2–4

In managing CKD stages 2–4, especially in patients with non-congenital glomerular diseases and proteinuria exceeding 0.75 g/l, rituximab therapy was employed for 1.5 years in three double doses, monitored by CD20 levels, along with daily tacrolimus and renin-angiotensin-aldosterone system inhibitor therapy. In cases of six-month treatment failure, rituximab was replaced with sodium-glucose cotransporter-2 inhibitors and

pioglitazone. This approach reduced the risk of progression to CKD stage 5D by 27 % over two years. During the COVID-19 pandemic, angiotensin-converting enzyme inhibitors were temporarily discontinued due to hypotension concerns.

Digital nephrobiopsy

A significant innovation during the war has been the implementation of digital nephrobiopsy using immunohistochemical analysis. This technology allows for kidney biopsies to be performed in a central location with results available within 24 hours through cloud-based technology, facilitating rapid and remote diagnosis.

Lessons learned and recommendations

The war's most severe negative impacts were felt in its initial months. To improve resilience under conflict conditions, several strategies are recommended:

— Training and educating personnel in emergency management for CKD patients.

— Preparing healthcare facilities and stockpiling essential medicines and consumables.

— Establishing robust communication links and external support networks.

Discussion

The onset of war in Ukraine posed unprecedented challenges for the healthcare system, particularly in providing specialized nephrological care to patients with CKD. Our study highlights several key areas where the war impacted nephrological services and how the medical community adapted to these challenges [9].

Impact on patient care and outcomes

The war significantly disrupted the continuity of care for CKD patients. Population displacement, resource shortages, and logistical barriers made it difficult for many patients to access necessary treatments. Despite these obstacles, there were notable efforts to maintain and even improve care where possible [10]. Virtual healthcare solutions became essential, allowing for remote consultations and monitoring. This adaptation ensured that patients could receive medical advice and adjustments to their treatment regimens even when in-person visits were impossible [11].

Healthcare personnel and infrastructure

The migration of healthcare personnel was a critical issue [12]. A lot of medical staff in southeastern Ukraine left, causing severe staffing shortages. However, western regions saw an influx of medical professionals, partially balancing the overall workforce distribution. This shift necessitated rapid training and integration of personnel into new settings [13, 14]. Additionally, facilities had to adapt to power outages and supply chain disruptions by stockpiling essentials and utilizing generators, ensuring that dialysis and other critical treatments could continue with minimal interruption.

Technological and methodological innovations

One of the most significant innovations was the implementation of virtual nephrology care [3]. Through teleme-

dicine platforms, nephrologists could continue to manage patients with CKD effectively. This approach not only mitigated the immediate impact of physical barriers but also laid the groundwork for long-term improvements in healthcare delivery, offering a model for other conflict zones [15].

Incremental and extended dialysis regimens were successfully employed to accommodate resource limitations and patient needs. These approaches provided flexibility and maintained patient outcomes despite the challenging circumstances. Additionally, the increased use of rituximab, facilitated by humanitarian aid, demonstrated the potential for alternative treatment protocols to address medication shortages and logistical challenges [16].

Transplantation and advanced therapies

Transplantation activities saw a significant boost, with more than a 60% increase in adults and nearly double in children. The use of advanced technologies such as laparoscopic and robot-assisted donor nephrectomies and virtual cross-matching techniques improved the precision and success rates of transplantations. This period also saw the introduction of human leukocyte antigen typing and donor-specific antibody testing, which enhanced the safety and efficacy of transplant procedures [17, 18].

Challenges and limitations

Despite these innovations, the study also identified several persistent challenges. Logistical disruptions, particularly in the initial months, led to delays in treatment and increased patient morbidity [1, 6, 11]. The war-induced stress had a measurable impact on blood pressure and overall health, underscoring the need for comprehensive stress management and support systems for both patients and healthcare providers.

Future directions

The experiences from Ukraine during the war provide valuable insights into managing nephrological care under extreme conditions. Key strategies included the rapid adoption of telemedicine, flexible dialysis protocols, and innovative treatment approaches. Moving forward, it is crucial to develop robust contingency plans, enhance training for healthcare providers, and establish international collaborations to support healthcare systems in conflict zones [5, 13, 17].

The war has undeniably tested the resilience of Ukraine's nephrological care system. However, the innovations and adaptations that emerged from this crisis have the potential to improve care delivery not only in Ukraine but also in other regions facing similar challenges. Continued research and sharing of best practices will be vital in refining these approaches and ensuring that patients with CKD receive the care they need, regardless of the circumstances [1, 13, 15, 17, 18].

Conclusions

While the war has posed significant challenges to nephrological care in Ukraine, it has also spurred the development of innovative approaches that have yielded some positive outcomes for CKD patients. The ongoing shortage of medicines and supplies remains a critical issue. However,

humanitarian aid and scientific collaboration from international colleagues have provided vital support, helping Ukrainian doctors to continue delivering essential care under difficult circumstances.

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Нефрологічна допомога в Україні у воєнний час: виклики та інновації

Резюме. Війна в Україні глибоко вплинула на надання нефрологічної допомоги, створивши численні виклики, водночас спонукаючи до значних інновацій. Це дослідження має на меті проаналізувати доступність та якість нефрологічної допомоги в Україні у воєнний час, зосереджуючись на хронічній хворобі нирок 1–5D/T стадій. Конфлікт спричинив переміщення населення, обмеження доступу до лікування й порушення логістики охорони здоров'я, що негативно вплинуло на нефрологічну допомогу. Незважаючи на ці проблеми, медичне співтовариство адаптувалося завдяки впровадженню віртуальної нефрології, поступових і розширених схем діалізу, а також збільшенню використання нових терапевтичних підходів. Війна призвела до зменшення чисельності населення та міграції медичного персоналу, зокрема з південного сходу до західної України, що спричинило кадровий дисбаланс, який поступово виправляли. Технологічні інновації (цифрова нефробиопсія з імуногістохімічним аналізом і використання хмарних технологій) дозволили швидко діагностувати хвороби нирок дистанційно. Віртуальна медична допомога та дистанційні

консультації забезпечили безперервність медичної допомоги, тоді як частота трансплантацій нирки помітно зросла завдяки передовим технологіям і міжнародній допомозі. Незважаючи на початкові матеріально-технічні проблеми та брак ресурсів, стійкість і адаптивність української системи нефрологічної допомоги були очевидними. Це дослідження підкреслює важливість надійного планування на випадок надзвичайних ситуацій, міжнародного співробітництва та впровадження інноваційних рішень для підтримки надання медичної допомоги в зонах конфлікту. Отримані дані пропонують цінну інформацію про управління нефрологічною допомогою в екстремальних умовах і підкреслюють потенціал цих інновацій щодо покращення надання медичної допомоги в усьому світі.

Ключові слова: нефрологічна допомога; Україна; охорона здоров'я воєнного часу; хронічна хвороба нирок; віртуальна нефрологія; діаліз; трансплантація нирки; інновації в охороні здоров'я; охорона здоров'я в зоні конфлікту; медична логістика; телемедицина; міграція медичного персоналу; гуманітарна допомога; цифрова нефробиопсія