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Original Research Article

Impact of Military Conflict on Emergency Medical Services in Khartoum Province, Sudan

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ABSTRACT

Background: Sudan has endured prolonged military conflicts, severely impacting its healthcare infrastructure. Emergency medical services (EMS), crucial for immediate medical response, have faced significant challenges because of the ongoing instability and resource constraints. **Methods:** A comprehensive evaluation was conducted across 25 EMS facilities in the Khartoum province of Sudan, which includes Khartoum, Bahri and Omdurman cities, with analysis of 22 responses. Data were collected through standardized questionnaires addressing theoretical frameworks from the Anglo-American and Franco-German EMS models to contextualize Sudan's EMS structure. The study also incorporated assessing operational capacity, resource availability, and response efficacy. **Results:** Findings revealed critical vulnerabilities in Sudan's EMS, such as resource shortages, inadequate training, and disrupted communication networks. Theoretical analysis highlighted structural and operational gaps, compared to the established EMS models. Additionally, sociopolitical and logistical barriers were identified as significant hindrances to effective emergency medical response. **Conclusions:** The study underscores the urgent need for targeted interventions to strengthen Sudan's EMS. Recommendations include enhancing resource allocation, improving training programs, and addressing sociopolitical barriers to ensure effective EMS during and after conflicts.

Keywords—*Emergency medical services (EMS), Sudan, Military conflict, Healthcare infrastructure, EMS models.*

INTRODUCTION

Emergency Medical Services (EMS) are comprehensive systems that coordinate personnel, facilities, and equipment for the effective and timely delivery of health and safety services to victims of sudden illnesses or injuries.[1] The primary goal of EMS is to provide prompt care to individuals experiencing life-threatening emergencies, thereby preventing unnecessary mortality and long-term morbidity. EMS functions can be categorized into four main components: accessing emergency care, providing care in the community, delivering care enroute, and facilitating care upon arrival at healthcare facilities.[2]

Since the 1970s, two main models of EMS have emerged: the Anglo-American Emergency Medical Services System (AAS) and the Franco-German Emergency Medical Services System (FGS). Although these models were distinct during the late 20th century, the most contemporary EMS systems incorporate elements from both approaches.[3]

Systems of EMS fundamentally differ in their approach, with the AAS focusing on bringing the patient to the doctor and relying heavily on paramedics for prehospital care, while in the FGS doctor is taken to the patient, with emergency physicians playing a central role. In the FGS, specialized physicians, assisted by paramedics, provide comprehensive on-scene care, leading to potentially better outcomes, although at a higher cost. Conversely, the AAS, developed due to physician shortages and economic considerations, emphasizes rapid transport and paramedic intervention, which may be more cost-effective but could compromise quality of care if implemented improperly.[4]

Adopting FGS in Khartoum could present significant challenges, including physician shortages, inadequate infrastructure, and high costs for establishing necessary training and systems, making AAS's physician-led approach potentially more suitable for the current Sudanese context.

According to the World Health Organization (WHO), there should be 1 hospital per 100,000 people in urban areas, and in rural areas, there should be one central hospital per district or region, with smaller clinics in larger villages. According to WHO, requirement of physicians is based on a ratio of 3.5 physicians per 1,000 persons. Additionally, international guidelines recommend one ambulance per 25,000 people. Ambulances must be equipped with essential medical equipment, such as ventilators, oxygen supply, and basic life-saving medications. International standards recommend an ideal EMS response time of 8 minutes for urban areas and 15 minutes for rural areas.[5]

A research conducted by Lawry et al.[6], during the Russian Ukraine conflict, the study provided a detailed examination of Ukraine's trauma system and EMS, highlighting the challenges faced and the areas requiring improvement. Ukraine employs an emergency system integrated into its public healthcare framework, comprising medics and emergency medicine-trained physicians. However, the system's structure and functionality were critically tested during the conflict. Pre-hospital care was described as inconsistent, with limited or no services in some areas.

Another study conducted by Ekzayez et al.[7] examined the impact of armed conflict on the utilization of health services in northwest Syria, focusing on the challenges faced by health systems, pre-hospital emergency care, and medical staff. The study reports that some facilities were temporarily closed following airstrikes, further limiting access to emergency medical care. The findings emphasized the need for improved ambulance preparedness, better access to health services in conflict zones, and the establishment of robust referral and emergency medical systems to ensure continuity of care during crises.

Basnawi[8] conducted a reviewal study, which stated that although modern EMS departments encounter numerous operational challenges, several strategies could help mitigate these issues. Enhancing technological capacity, cross-training of staff, establishing contingency protocols, and forming strategic partnerships with external organizations can strengthen system's performance and support the delivery of high-quality patient care.

The ongoing military conflict in Khartoum province, which includes Khartoum, Bahri, and Omdurman cities, began on April 15, 2023, and has acutely impacted the country's already fragile healthcare system. The war has rendered 70% of the hospitals in combat zones as nonoperational, resulting in 12,000 deaths, thousands of injuries, and leaving 11 million people in urgent need of healthcare. More than 7 million individuals, half of whom are children, have been displaced and face acute healthcare challenges.[9,10] Financial losses to the health sector are estimated to exceed $700 million, further

straining an already under-resourced system.[11] The fragility of Sudan's monitoring and health information systems further makes it difficult to accurately assess the true scale of service disruption caused by the conflict. However, anecdotal evidence gathered by the authors indicates significant interruptions in critical, life-saving health services, including obstetric and neonatal care, emergency trauma management, dialysis, and cancer treatment.[12,13]

This research aims to investigate the ways in which the military conflict in Khartoum province has affected EMS. The fragility of the healthcare infrastructure has caused many deaths, as the emergency medical system is not equipped to serve its provisions. Based on the detailed case studies with specific examples where military conflicts have had a significant impact on EMS to highlight the overall issues and difficulties, this research provides recommendations to develop the existing system.

METHODOLOGY

This study employed a designed questionnaire to investigate the effect of military conflicts on the EMS system in Khartoum province. The research aimed to quantify the challenges, resource gaps, and systemic barriers faced by EMS professionals during military conflicts and to identify solutions for designing a more effective and resilient EMS system. A structured questionnaire was utilized as the primary data collection tool, allowing for a systematic and consistent approach to gather data from a diverse group of EMS professionals.

The structured questionnaire used in this study comprised 29 questions, carefully designed to address the study's objectives comprehensively. The questionnaire was divided into three main areas:

Demographic Information

This section of the questionnaire was specifically developed to gather baseline demographic and institutional data regarding study participants. The objective is to document the respondents' professional designations, categorize the hospitals by type, for example, public or private sector, and map the geographical distribution of the healthcare facilities involved in the study.

Challenges and Impact During Conflicts

This section addressed theoretical frameworks of both AAS and FGS EMS models to contextualize Sudan's EMS structure. Moreover, it explored the operational difficulties faced by EMS professionals during military conflicts. Questions focused on barriers, such as delays in reaching patients, disruptions in communication systems, accessibility issues in conflict zones, and safety concerns of EMS personnel. Respondents were also asked to evaluate the extent to which these challenges affected their ability to provide timely and effective care.

Availability of Resources and Medical Services

This section assessed the adequacy of resources available to EMS teams during conflicts, including ambulances, medical equipment, and trained personnel. Questions also examined the perceived quality of services provided under conflict conditions, evaluating whether these services met patients' needs and professional standards. Respondents were asked to rate the availability and functionality of key resources and to identify areas where shortages were most acute.

The questionnaire was reviewed by subject matter experts, including EMS professionals with expertise in working in conflict zones and a professional statistician to ensure its validity and relevance. A pilot test was conducted with approximately 10% of the sample size (two participants) to evaluate clarity, reliability, and usability of questions. Feedback from the pilot test was used to refine the questionnaire, ensuring that it was clear and comprehensive.

The target population included professionals directly involved in the EMS system, specifically medical director, medical physicians, and biomedical engineers. These groups were selected for their critical roles in EMS operations and their firsthand experiences with the challenges posed by military conflicts. The target of the questionnaire was to collect data from all operational hospitals during the conflict in Khartoum province, totaling 25 hospitals. A total of 22 responses were collected, one response from each hospital, reflecting a purposive sampling strategy designed to ensure diverse perspectives. By including various professional roles, the study captured a comprehensive

view of the EMS system, from clinical care to technical and logistic support.

Data collection was conducted electronically between November 20, 2024 and December 9, 2024, using online survey tools. The collected data were analyzed by employing a combination of descriptive and inferential statistical methods. Descriptive statistics were used to summarize key findings, such as the frequency of specific challenges and resource shortages, while inferential statistics explored relationships and differences among variables, such as professional roles and their perceived challenges. The analysis was designed to highlight patterns and correlations that could apprise the development of evidence-based recommendations for improving the EMS system.

RESULTS AND DISCUSSION

It is discovered that among the respondents shown in Table 1, medical physicians formed the majority job title category, with a proportion of 40.9%, while biomedical engineers were represented at 31.8%. In terms of hospital types, private hospitals had the highest representation with a proportion of 50.0%, whereas district or community hospitals had the least representation with a proportion of only 4.5%. Regarding location, Omdurman was the most common city of operation (45.5%), followed by Khartoum (31.8%).

TABLE 1. The frequency distribution of demographic information.

Question	Options	Frequency	Proportion
Q1: Job Title	Medical physician	9	40.9%
	Biomedical engineer	7	31.8%
	Medical director	6	27.3%
Q2: Hospital Type	General hospitals	8	36.4%
	Specialized hospitals	2	9.1%
	Private hospitals	11	50.0%
	District or community hospitals	1	4.5%
Q3: City	Khartoum	7	31.8%
	Omdurman	10	45.5%
	Bahri	5	22.7%

The data presented in Table 2 highlight that the majority of treatments were provided at hospitals with a focus on quick stabilization of patients (86.4%), while 13.6% reported treatment at the scene. Emergency response system was largely perceived as ineffective, with 68.2% indicating "No." Adults were the most commonly treated patient group in emergency departments for injuries (63.6%), while children and elderly were represented equally (18.2% each).

The most reported type of cases was common infectious diseases (31.8%), while injuries from shrapnel were the least common (13.6%). Difficulty in reaching patients because of blocked roads or insecurity was identified as the most significant barrier to pre-hospital care (50.0%), with safety risks of medical staff being the least reported challenge (18.2%). Delays in reaching patients because of war activities were frequently reported, with 45.5% stating "Always."

TABLE 2. Frequency distribution of challenges and impact during conflicts.

Question	Answer Options	Frequency	Proportion
Q4: Which is the main place that provides treatment to patients?	At the hospital, with a focus on stabilizing patients quickly for transportation.	19	86.4%
	At the scene, with detailed on-site diagnosis and treatment before transportation.	3	13.6%
Q5: Was the system implemented appropriately for the situation?	Yes	7	31.8%
	No	15	68.2%
Q6: Which patients are most commonly seen in the emergency department for injuries?	Children	4	18.2%
	Adults	14	63.6%
	Elderly	4	18.2%
Q7: The most common types of cases?	Field injuries	4	18.2%
	Chronic diseases	6	27.3%
	Common infectious diseases	7	31.8%
	Shrapnel injuries	3	13.6%
	Other	2	9.1%
Q8: What are the main challenges you face in providing pre-emergency care during conflicts?	Safety risks for medical staff	4	18.2%
	Lack of medical supplies	7	31.8%
	Difficulty in reaching patients due to blocked roads or insecurity	11	50.0%
Q9: How often do you face delays in reaching patients due to war activities?	Always	10	45.5%
	Often	7	31.8%
	Sometimes	5	22.7%
Q10: What challenges do you face in providing pre-emergency care during conflicts?	Lack of transportation	6	27.3%
	Safety/security risks	5	22.7%
	Shortage of medical supplies	11	50.0%
Q11: How do conflicts affect patient outcomes during emergencies?	Slightly worse outcomes	3	13.6%
	Significantly worse outcomes	14	63.6%
	Patients often do not survive	5	22.7%
Q12: How often does war conflict affect the availability of biomedical equipment for pre-hospital services?	Always	13	59.1%
	Never	8	36.4%
	Rarely	1	4.5%

Note: Percentages for each question were calculated based on the total number of respondents (n = 22)

Table 3 provides information about the availability of resources and medical services. It reveals that special training for working in conflict zones is relatively widespread (68.2%), but life-saving medications are only "Sometimes" available (50.0%). Availability of Ambulance and equipment is notably low, with fewer than three units often available (77.3%), and ambulance devices are particularly not working (45.6%). Although the availability of trained personnel is generally sufficient (86.4%), the questionnaire targets general types of training provided for conflict zones, such as training for disaster response and trauma medicine training. The maintenance of biomedical devices is rarely consistent (50.0% "Rarely"). Although patient monitors are the most commonly needed devices (50.0%), their poor maintenance emerges as the primary technical issue (59.2%). Lack of spares appears as the biggest maintenance challenge (59.1%), and the resulting intense effect on patient care (72.7%) highlights the gravity of resource limitations. Doctor numbers often fail to meet standards (54.5%; "No"), and maintenance engineers are also scarce (77.3%; "No"). Patient care and daily injuries after the war increased dramatically, often exceeding 15 injured cases daily (45.5%). Although more than five cases are treated daily (63.6%), the hospital failed to treat many injured patients (40.9%, > 5).

TABLE 3. Frequency distribution for the availability of resources and medical services.

Question	Answer Options	Frequency	Proportion
Q13: Do you receive any special training for working in conflict zones?	Yes	15	68.2%
	No	7	31.8%
Q14: Are life-saving medications available in emergency department?	Sometimes	11	50.0%
	Rarely	6	27.3%
	Not at all	5	22.7%
Q15: Are ambulances and medical equipment readily available during conflicts?	< 3	17	77.3%
	> 3	2	9.1%
	> 5	3	13.6%
Q16: What types of equipment are most affected during conflicts?	Ambulance devices (e.g., ventilators, defibrillators, etc.)	10	45.6%
	Communication systems	3	13.6%
	Patient monitoring systems	5	22.7%
	Diagnostic tools	3	13.6%
	Others	1	4.5%
Q17: Were the ambulances equipped with all emergency equipment?	Equipped with all necessary and lifesaving equipment	11	50.0%
	Equipped with just lifesaving equipment.	11	50.0%
Q18: Are there enough trained personnel to handle biomedical equipment in conflict zones?	No	3	13.6%
	Yes	19	86.4%
Q19: Are biomedical devices in ambulances or emergency units regularly maintained during conflicts?	yes, Always	2	9.1%
	Sometimes	5	22.7%
	Rarely	11	50.0%
	Not at all	4	18.2%
Q20: What is the most common problem with biomedical devices during conflicts?	Lack of power supply	5	22.7%
	Physical damage from attacks	2	9.1%
	Poor maintenance	13	59.2%
	Software or hardware malfunctioning	1	4.5%
	Logistical challenges in transporting devices	1	4.5%
Q21: What types of biomedical devices are most commonly needed in conflict zones?	Ventilators	7	31.8%
	Patient monitors	11	50.0%
	Defibrillators	4	18.2%
Q22: What are the biggest challenges in maintaining biomedical devices during military conflicts?	Lack of spares	13	59.1%
	No trained technicians	6	27.3%
	Limited electricity or power supply	3	13.6%
Q23: How does limited access to maintenance of biomedical devices affect patient care in conflict zones?	Minimal effect	2	9.1%
	Moderate effect	4	18.2%
	Severe effect	16	72.7%
Q24: Is the number of doctors consistent with the standard so as to cover new patients?	Yes	2	9.1%
	No	12	54.5%
	Maybe	8	36.4%
Q25: Are maintenance engineers available for emergency equipment?	Yes	3	13.6%
	No	17	77.3%
	Maybe	2	9.1%
Q26: What proportion of patients receive adequate care during conflicts?	0–25	8	36.4%
	26–50	8	36.4%
	51–75	6	27.2%
Q27: What was the average daily number of injuried patients after the war?	< 5 per day on average after the war	7	31.8%
	> 5 per day on average after the war	1	4.5%
	> 10 per day on average after the war	4	18.2%
	> 15 per day on average after the war	10	45.5%
Q28: How many patients were treated daily during the war?	< 3	6	27.3%
	> 3	2	9.1%
	> 5	14	63.6%
Q29: How many patients per day were the hospital unable to treat during the war?	< 3	2	9.1%
	> 3	3	13.6%
	> 5	9	40.9%
	> 10	8	36.4%

Note: Percentages for each question were calculated based on the total number of respondents (n = 22)

The current study aligns with global findings, emphasizing common barriers, such as shortage of equipment, delay in patient transportion, and insufficient training in conflict zones. The Sudanese EMS system has similar limitations as those observed in the studies conducted for Russia–Ukraine and Northwest Syria conflicts, including inconsistent prehospital care and inadequate infrastructure. However,

the EMS varies in its focus on infectious diseases, reflecting the unique public health challenges in Sudan.[6,7]

The comparative analysis underscores the need for a robust, context-specific EMS framework in Sudan. Results of the previous studies highlight the importance of integrating advanced on-site stabilization, improving ambulance preparedness, and addressing gaps in training and resource allocation.[8] Future interventions should focus on scalable, conflict-resilient models tailored to Sudan's unique challenges, drawing from global successful systems for operational efficiency and adaptability.

These findings offer a foundation for developing targeted interventions and recommendations to enhance the resilience and effectiveness of EMS systems in conflict-affected regions. In order to develop the current prehospital emergency system in Sudan to align with global standards, it is essential to identify key components based on global benchmarks that define emergency response protocols during both regular and conflict periods. A detailed comparability between global standards and the current status in Sudan is as follows.[5]

Number of Hospitals and Medical Personnel

During the conflict in Khartoum province, only 25 healthcare facilities—approximately 30% of the total—remained operational. Moreover, this study discovered that the number of available doctors was inconsistent with the standard in more than 54% EMS systems. This acute shortage of functioning emergency centers and physicians significantly undermined patient care and the overall delivery of medical services. To address these gaps, key improvements to be included are revising operational protocols to allow a greater number of hospitals to function during conflicts, thereby ensuring faster access to care, and expanding the healthcare network to incorporate specialized emergency medical services at both district and regional levels, such as Wadmadeni and Shendi cities, both of which are no more than 170 km from Khartoum province.

Number of Ambulances and Requirements

Conflict-affected areas face a critical shortage of ambulances, and those that remain in service are often equipped poorly. Survey findings reinforced this gap: 77.2% of respondents indicated that ambulances and medical equipment were not readily available during conflicts; 45.6% reported that essential ambulance devices, such as ventilators and defibrillators, were the most affected biomedical designs; only 50% stated that ambulances carried basic life-saving equipment; and another 50% noted that biomedical devices in ambulances or emergency units were rarely maintained during conflict. To address these deficiencies, improvements should focus on increasing the number of ambulances to meet the global standard of one ambulance per 25,000 persons, ensuring that each ambulance is fully equipped with modern medical technology, and strengthening of maintenance practices to keep the existing ambulances operational.

Emergency Response Time and Access to Healthcare Facilities

In many conflict-affected or underserved areas, emergency response period range from 30 minutes to more than 1 hour, largely because of damaged or blocked roads, insecurity, and a acute shortage of ambulances. Survey findings supported these challenges: 45.5% of respondents reported consistently facing delays in reaching patients because of war-related activities, and 50% identified road blockages and insecurity as the main obstacles to providing pre-emergency care. As a result, access to healthcare in conflict zones remains extremely limited, with many communities depending heavily on local or global support. To mitigate the current situation, it is necessary to improve road infrastructure and transportation system in remote areas, strengthen the coordination between medical facilities to accelerate patient transfer, increase the number of mobile clinics, and to enhance collaboration with non-governmental (NGOs) as well as international organizations, for example International Committee of the Red Cross (ICRC) to bolster logistical support.

Number of Staff and Training of Medical Personnel

There is a clear shortage of physicians in conflict-affected regions, and many existing staff lacks continuous training. Survey findings provide a mixed scene: capacity of medical facilities remained limited, although 68% of respondents

reported receiving some form of specialized conflict-zone training, such as disaster response and trauma care, and 86.4% indicated accessibility of trained personnel capable of handling biomedical equipment. During conflicts, 63.6% of hospitals treated more than five cases daily, yet 40.9% reported being unable to treat up to 10 cases per day because of resource and staffing constraints. To strengthen workforce readiness, sustainable training programs for emergency personnel, including paramedics and nurses, should be implemented, accompanying the development of specialized trauma-care training tailored to conflict-related injuries, for example: WHO/ICRC Basic Emergency Care (BEC) course of conflict-related injuries module, which provides a standardized approach to initial assessment and life-saving interventions in limited-resources, high-risk environments.[14]

Medical Devices and Equipment Resources

Survey findings revealed major limitations in medical equipment resources in conflict zones: only 50% of ambulances were equipped with basic life-saving devices; patient monitors were identified by 50% of respondents as the most urgently needed equipment; 59.2% reported that lack of spares was the biggest barrier to maintaining biomedical devices; and 72.7% indicated that poor access to maintenance had an acute impact on patient care. Practical solutions include establishing mobile biomedical maintenance units, creating decentralized supply hubs of spares, equipping ambulances and field facilities with strengthened essential devices, and strengthening partnerships with NGOs to support equipment donation, maintenance logistics, and technical capacity.

Injury Management Protocols and Preventive Measures

There is a clear need for updated and context-specific medical protocols for managing trauma in conflict zones, as existing guidelines and infection-control measures are often insufficient for the types of injuries encountered during conflicts. Survey findings further highlight capacity limitations, with 40% of hospitals reporting that they were unable to treat up to 10 patients per day during the conflict. To strengthen emergency care, it is essential to develop dedicated trauma-care protocols tailored to conflict-related injuries and to enhance preventive measures for infectious diseases within emergency and surgical settings.

Number of Health Centers and Mobile Clinics

Many rural and conflict-affected areas face a acute shortage of health centers, with most communities relying on mobile clinics that provide only basic emergency care. To improve access and quality of care, it is essential to develop a network of specialized mobile clinics capable of delivering both primary and emergency services, and to enhance their capacity to manage basic trauma cases effectively.

Medical Information Systems and Communication

Not only Khartoum province, EMS in many areas in Sudan lack integrated communication systems, resulting in inefficient coordination between hospitals and health centers. To address this, it is crucial to develop integrated medical information systems that improve real-time coordination between ambulances and hospitals, and to implement advanced communication technologies, such as radios, internet, and Global Positioning System (GPS). These tools can enhance EMS operations; for example, mobile applications that track medical cases and optimize ambulance routing.

CONCLUSION

The ongoing military conflict in Khartoum has seriously compromised the EMS system, revealing critical vulnerabilities in infrastructure, resource allocation, and operational capacity. Key issues include an acute shortage of hospitals, ambulances, and medical personnel, with current numbers falling significantly below global standards. Delays during emergency response period, primarily caused by blocked roads, rough terrain, and security risks, have further diminished EMS system's effectiveness.

Additionally, the inconsistent availability of life-saving medications and the poor maintenance of essential biomedical equipment have left the EMS system ill prepared to meet the needs of conflict-affected populations. To overcome these shortcomings, some recommendations are proposed

for EMS in Khartoum province, focusing on aligning the system with global standards. These recommendations include deploying mobile clinics for on-site stabilization, increasing the number of ambulances and hospitals, and addressing critical shortages of trained personnel through specialized training programs. Technological integration, such as GPS-based dispatch systems and maintaining electronic medical records (EMRs), is essential to improve coordination and efficiency. Strengthened supply chains and enhanced security measures are also crucial for ensuring the availability of medical resources and safety of healthcare workers. These tips offer a scalable and context-specific framework that addresses the unique challenges of providing prehospital emergency care in conflict-affected areas, aiming to improve patient outcomes and build resilience in the EMS system.

AUTHOR CONTRIBUTIONS

Conceptualization, R.E.E.A.; Methodology, R.E.E.A.; Validation, M.A.B.H., I.A.A.M., and A.M.A,A,; Formal Analysis, M.A.B.H, I.A.A.M., and A.M.A.A.; Investigation, M.A.B.H., I.A.A.M., and A.M.A.A.; Resources, M.A.B.H., I.A.A.M., and A.M.A.A.; Data Curation, R.E.E.A., M.A.B.H., I.A.A.M., and A.M.A.A.; Writing–Original Draft Preparation, M.A.B.H., I.A.A.M., and A.M.A.A.; Writing–Review & Editing, R.A.E.A., M.A.B.H.; Visualization, R.A.E.A.; Supervision, R.A.E.A.

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Not applicable.

CONFLICTS OF INTEREST

The authors declare they have no competing interests.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

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FURTHER DISCLOSURE

Not applicable.

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