OPTIMIZING PATIENT TRANSFERS IN NON-CONTIGUOUS MARITIME ENVIRONMENTS

A Study on Ambulance Exchange Points

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ABSTRACT

The strategic deployment of watercraft as Ambulance Exchange Points (AXPs) has the potential to significantly enhance aeromedical evacuation capabilities in non-contiguous maritime environments. This study models the selection process for AXPs as a Semi-Markov decision process, utilizing Monte Carlo Tree Search for optimal decision-making. Our simulations reveal that integrating watercraft AXPs can reduce incident response times by 35% to 40% compared to traditional evacuation methods. A practical demonstration involving the transfer of a manikin between helicopters and an Army logistic support vessel near Oahu exemplifies the efficacy of this approach. The findings contribute to the development of innovative methodologies for medical evacuation and have implications for military doctrine.

The persistent issues that complicated evacuation operations in the Pacific Theater during World War II have reemerged in the context of potential military conflict with China. Evacuation systems in the Indo-Pacific region face the daunting task of overcoming vast distances, numerous transportation constraints, dynamic environmental factors, and an ever-evolving enemy threat. Significant advancements in military medicine and logistics enabled our predecessors to perfect the concept of amphibious medical support during the challenging island-hopping campaigns against Imperial Japan. The strategic coordination of aerial and maritime evacuation and treatment assets historically facilitated the rapid movement and care of large numbers of casualties across dispersed island chains.

Today, the availability and maturation of rotary-wing aircraft and fast transport ships, the proliferation of networked systems, and advancements in autonomous vehicles and machine learning suggest innovative approaches to these intensified challenges. The movement of patients during maritime operations presents significant logistical challenges, particularly in non-contiguous environments where traditional evacuation routes may be compromised.

To identify and address issues with medical evacuation and resource coordination, a Cooperative Research and Development Agreement (CRADA) was established between Stanford University and the Army Research Lab. The subsequent research explored the concept of using watercraft as Ambulance Exchange Points (AXPs) to enhance patient transfer efficiency and flexibility in such scenarios. The primary objective was to develop a systematic framework for selecting optimal AXPs while considering the dynamic nature of maritime operations. Unlike traditional land-based AXPs at fixed sites, watercraft constantly moves between ports; however, overwater AXPs enable range-limited medical evacuation aircraft to bridge significant maritime distances to facilitate patient transfers. A trial run of the research findings demonstrated that the employment of watercraft as overwater AXPs has remarkable advantages yet requires the careful coordination of platforms and enhanced battlefield situational awareness to properly execute.

ENABLING TECHNOLOGIES

The demonstration occurred off the coast of Hawaii and was enabled by a decision support system for dispatching aircraft, hoist stabilization technology, commercial satellite internet, military geospatial infrastructure applications, and digital medical documentation tools. The collective use of these four key technologies minimized delays, reduced system uncertainty, and improved overall patient care.

SEMI-MARKOV DECISION PROCESS

Coordinating patient movement using a large evacuation system with multiple evacuation platforms is a difficult task for medical planners. Decision support systems may expedite patient movement and provide necessary flexibility. For the current research, the selection of AXPs is modeled as a Semi-Markov decision process (SMDP). This framework accounts for multiple variables, including the utilization history of participating aircraft and the positional and velocity constraints of watercraft. The action space encompasses both fixed land and moving watercraft AXPs. The SMDP was used in conjunction with a maritime environment model and an online sampling algorithm to determine when to dispatch evacuation aircraft to select overwater AXPs to minimize patient transfer times.

The model parameters are varied through simulation to identify representative scenarios where watercraft AXPs effectively reduce incident response times. The model included two Hawaiian Islands, two aeromedical evacuation platoons, three moving watercraft, and eight military treatment facilities (MTFs). The practical application, however, consisted of only two evacuation aircraft, one watercraft, and one MTF. Therefore, the SMDP model proved more than capable of determining the appropriate dispatch times for both aircraft. The elapsed time between manikin drop-off and pickup at the underway LSV-3 was less than three minutes.

HOIST STABILIZATION TECHNOLOGY

Because none of the Army's watercraft possesses a helipad for aircraft landing and takeoff, hoist operations are necessary to facilitate patient transfers. Hoist stabilization technology permits patient drop-off and pickup over the small decks of many Army watercraft. The Load Stability System uses ducted fans to automatically minimize hoist cable oscillation, spin, and sway without requiring a tagline for litter patients. During the demonstration, the Load Stability System, and dynamic hoist operations, was used successfully to efficiently and expediently lower and raise the manikin to and from the deck of the moving LSV.

MOBILE MEDICAL DOCUMENTATION

The patient handover process is further complicated by the use of watercraft as overwater AXPs. Therefore, the integration of a mobile medical documentation tool was necessary to minimize the documentation transfer burden between medics on different platforms. The Battlefield Assisted Trauma Distributed Observation Kit (BATDOK), originally developed by Air Force Research Lab's 711 Human Performance Wing, was used to capture, update, and transfer patient data digitally during the exercise. A plastic near field communication (NFC) card, kept with the manikin during the demonstration, was repeatedly scanned to both upload and download medical information during patient exchange.

SATELLITE INTERNET AND TACTICAL ASSAULT KIT

The positions of watercraft and aircraft should be identifiable in real time with reasonable certainty to select the optimal AXP. For the demonstration, two Android Tactical Awareness Kits (ATAKs) were used to visualize the location of participating units and assets and permit communication between them. This was accomplished using Starlink satellite communication dishes and routers installed on the bridge of the LSV-3 and on Wheeler Army Airfield. ATAK was also used to transmit the evacuation request from the ground force to the MEDEVAC command post.

RESULTS

Simulation results demonstrate that the optimal policy incorporating watercraft AXPs outperforms both traditional policies without watercraft AXPs and greedy approaches by 35% and 40%, respectively. The significant improvement in response times underscores the potential of watercraft AXPs to enhance operational flexibility in maritime medical evacuations.

The integration of watercraft AXPs into aeromedical evacuation operations presents several advantages:

1. **Enhanced Flexibility:** Watercraft can be deployed dynamically based on real-time conditions, optimizing patient transfer routes.
2. **Reduced Response Times:** The strategic selection of AXPs significantly lowers the time taken to transport patients, potentially improving patient outcomes.
3. **Technological Integration:** The use of modern technologies facilitates efficient coordination and documentation during evacuations.

These findings are crucial for developing updated military doctrines and enhancing medical evacuation capabilities in maritime contexts.

CONCLUSION

This study highlights the effectiveness of utilizing watercraft as AXPs in non-contiguous maritime environments. Future research should focus on further refining these models and exploring their applications in various operational scenarios. Although the use of watercraft as AXPs is not without limitations including jamming, aircraft cabin sizes, and changing watercraft routes which disrupt evacuation operations, the results of the demonstration are promising for future evacuation capabilities.

AFFILIATIONS

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