Exploring the integration of artificial intelligence (AI) and augmented reality (AR) in maritime medicine: A narrative literature review

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Abstract

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Exploring the integration of artificial intelligence (AI) and augmented reality (AR) in maritime medicine: A narrative literature review

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Abstract

This narrative literature review explores the integration of artificial intelligence (AI) and augmented reality (AR) in the field of maritime medicine. A comprehensive search was conducted in academic databases using relevant search terms, resulting in the identification of 257 records. After screening for relevance and quality, a final review was conducted on 17 papers. The review highlights the potential applications and benefits of AI and AR in enhancing medical practices and safety measures for seafarers. The integration of AI and AR technologies in maritime medicine shows promise in providing real-time medical assistance, remote consultations, augmented training, and improved diagnostic capabilities. Additionally, AI-driven predictive models can aid in early detection of health issues and support proactive health management onboard ships. Challenges related to data privacy, connectivity at sea, and the need for regulatory frameworks are also discussed. The data analysis reported in this review contributes to a better understanding of the current state and future potential of AI and AR in maritime medicine and provide insights into opportunities for further research and implementation in the maritime industry.

Keywords: Artificial intelligence, Virtual reality, Maritime medicine, Seafarers, Medical practices, Diagnostic capabilities, and Predictive models

1. Introduction

Seafarers play an instrumental role in the shipping industry by providing skilled labour that is necessary to safely transport goods and people around the world. They are responsible for maintaining ships, navigation, and other operations related to sea transportation. The captain is responsible for the health of the crew, for providing basic medical assistance and for overseeing the day-to-day hygiene and general health of the crew [1]. The Maritime Labour Convention

(MLC) 2006 requires that seafarers should have equal access to the medical care and health protection that workers ashore, which includes timely access to medicines, medical equipment, facilities for diagnosis and treatment, as well as medical expertise and information [2]. As a result, the quality of care and attention given to those in need of onboard medical assistance may vary significantly from ship to ship.

The healthcare sector has been undergoing significant transformations, driven primarily by the need for better healthcare outcomes and more effective management of resources [3], [4]. Healthcare innovation has been transformed by the emergence of artificial intelligence (AI), and augmented reality (AR) [5], [6]. AI-powered technology has been successfully applied to a range of healthcare areas, from drug discovery and medical diagnosis to advanced personalized care. In this scenario, maritime medicine holds enormous potential for AI-based technologies. Maritime medicine is a branch of medicine that deals with illnesses and injuries occurring at sea [7]. It includes medical assistance at sea as well as the prevention of diseases and injuries that can occur on ships. This field also deals with the promotion of the health and safety of the crew and passengers onboard [7], [8]. With the advent of new technologies, such as AI, AR, and machine learning (ML), various innovations are possible, including more precise remote diagnosis and treatment, predictive analytics, and real-time monitoring. These innovations may enhance the standard of care and reducing risks to human health at sea [9].

The potentialities of medical assistance at sea cannot be overstated. The ocean is a vast and unpredictable environment, and a medical emergency onboard a ship has the potential to become life-threatening [10], [11]. Moreover, the isolation of being ill at sea often means that medical assistance is not readily available, making it important for crew members to have reliable means of accessing medical care [12]. Since the earliest days of radio communication, medical assistance at sea has been a critical component of seafarer’s safety. Despite being located in remote locations, it can provide medical treatment of reasonable quality for those aboard ships. Since international shipping demand is increasing and ships need to communicate with shores clearly and effectively, this topic is of particular relevance. The adoption of AI technologies in maritime medicine has improved healthcare practices. One of the significant areas where AI has been implemented is in diagnostic processes using ML algorithms that enhance the accuracy of diagnoses [13].

AI can also be used for remote monitoring and surveillance in the maritime setting, allowing early detection of medical issues and prompt intervention [14]. Additionally, AI robots can be deployed in maritime environments that are hazardous to human health, reducing the risks of injury or exposure to toxic substances [15]. The use of AI can lower costs, improve healthcare outcomes, and increase efficiency. As seafarers demand more healthcare services and ships face the challenge of providing timely and effective medical care, AI can transform maritime

medicine. The integration of AI into maritime medicine requires careful consideration, appropriate regulations, and ethical considerations. The potential impact and benefits of AI technology in maritime medicine are relevant, with promising prospects for enhancing health services and safety in the marine environment [9], [13], [15]. With the use of AI innovations, maritime medicine can improve the safety, healthcare outcomes, and well-being of seafarers.

As far as we know, no review studies had been conducted on the integration of AI, AR and other technologies in maritime medicine. Systematic reviews of seafarers have been presented in some works on telemedicine technologies [16], [17]. Despite their valuable insights into the effectiveness and challenges of remote medical care, these studies did not present standardized outcomes. While these reviews are essential, it is important to be aware of potential limitations when interpreting them. Additionally, they must be considered alongside other types of evidence, such as qualitative research and real-world experiences from practitioners and seafarers [18]. This paper is a narrative review of the opportunities and innovations that AI and AR can bring to maritime medicine. We also provide a comprehensive overview of the topic that can help readers to be informed about the breadth of existing literature, including both empirical studies and theoretical perspectives. Moreover, in this work we aim to raise the key issues and challenges of AI in maritime medicine to make it more appealing to a broader audience, including policymakers, practitioners, and the general public.

To provide an overview of current research, applications, and potential benefits of AI and AR in maritime medicine, the following research questions (RQ) were put to provide a comprehensive analysis of the issues covered in this narrative review.

RQ1: What is the current state of research on the role of AI and AR in maritime medicine?

RQ2: How are these technologies being used to enhance healthcare delivery and training for maritime workers and seafarers?

RQ3: What are the challenges that may arise when installing AI and AR on shipping environment?

2. Methods

2.1. Document search

The document search was conducted using the scientific libraries Google Scholar, Scopus, and Web of Science along with medical libraries like PubMed/MEDLINE, Cumulative Index to Nursing and Allied Health Literature (CINAHL), and BioMed Central (BMC). A snowballing technique was also employed to check the reference lists of relevant articles to locate additional sources that

may not have been included in the initial database search. The search keywords used were ‘Artificial Intelligence in Maritime Medicine’, ‘Augmented Reality Applications in Maritime Healthcare’, ‘AI and AR in Maritime Medical Training’, ‘Maritime Healthcare Technologies’, ‘AI-driven Diagnostics in Maritime Medicine’, ‘AR-based Medical Visualization in Maritime Settings’, ‘ML in Maritime Healthcare’, ‘AI and AR for Crew Health Management’, ‘Human-Machine Interaction in Maritime Medicine’, ‘AI-assisted Medical Decision Support at Sea’, ‘Augmented Reality Simulation for Maritime Medical Training’ and ‘AI-based Remote Health Monitoring for Seafarers’. For the research question being developed, these relevant keywords were selected and represent the primary concepts or themes of the narrative review. To combine keywords logically, Boolean operators (AND, OR, NOT) are employed. This enabled us to create comprehensive search strings that contain diverse combinations of search terms.

2.2. Inclusion and Exclusion Criteria

Our analysis included only papers that were peer-reviewed all over the world and published in English between 2000 and July 2023. Focusing on articles published from 2020 to the present ensures that the presented review included the most current developments and research with the studies related to AI and AR in seafarers' healthcare. The importance of this relevant in rapidly evolving fields like AI. Works presented included experimental or observational studies related to AI and AR in seafarers' healthcare. All articles that explored AI and AR subjects and issues related to maritime medicine were included as well to gain a holistic understanding.

The present review excluded papers not in English, not conducted in a maritime health care setting, and not focused on clinical decision support at sea, AR, and AI simulation among seafarers. Studies that did not explicitly link clinical diagnosis, medical training, or improvement initiatives to medical practice at sea were not considered.

2.3. Screening and selection

The screening process of article selection involved various phases. At first, authors conducted search with the above mentioned strategy, and recorded the number in spreadsheet. Each article was screened carefully by reading the title and abstracts of the retrieved articles to identify potentially relevance [19]. In a second phase, a full-text review of the selected articles based on the inclusion and exclusion criteria was made. Subsequently, we extracted relevant information from the selected articles and organized the extracted data in a tabular or thematic format for easier synthesis. This included study design, methodology, key findings, limitations, and any other pertinent information. Ultimately, summarization of the main findings of each selected study in a coherent and narrative manner to identify common themes, patterns, and trends across the studies was made.

3. Results

3.1. Search outcomes

Figure 1 summarizes the study selection flow chart. The search identified 257 items with given search strategy and 17 potential papers were included in this review. These papers were reviewed and topics covered were extracted and presented for further analysis. The topics identified were improved diagnostic accuracy with ML, enhancing medical diagnosis, AI powered digital assistants like ChatGPT in patient monitoring and care, virtual reality and telemedicine for remote consultations, and AI based streamline work flow in maritime medicine [20].

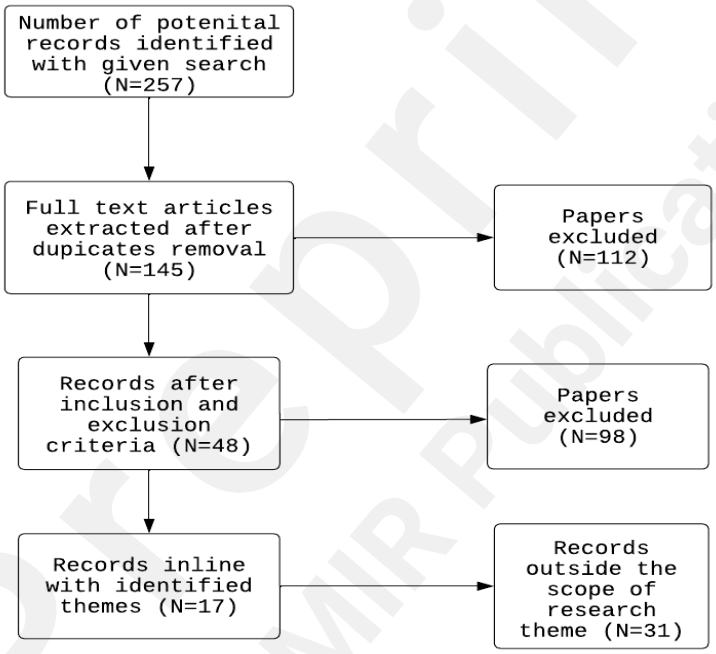

Figure 1. Paper selection flowchart

3.2. Extracted AI and AR topics in maritime medicine

Technological advancements in the field of maritime medicine have led to the AI utilization to transform the approach how medical care is delivered on ships. AI and AR bring about a revolutionary change in the shipping industry by improving the accuracy and speed of medical diagnosis and treatment. With the help of AI-powered sensors and wearable devices, medical professionals can monitor the health of seafarers remotely and provide timely medical attention in case of need AI algorithms can analyse big amounts of medical data, such as medical history, vital signs, and diagnostic test results, to identify patterns and predict potential health risks.

This provides a proactive approach to medical care, allowing for early detection and treatment of illnesses before they pose a threat to the health and safety of seafarers. By considering all these factors, we have categorized selected works based on five topics that were discussed below and presented in Table 1.

N	Topic	Technology	Outcomes	Benefits	Ref
1	Improved diagnostic accuracy	ICT	Symptom sequences automatically collected	Doctors make better-informed decisions with medical advice that reduces complications due to misdiagnosis.	[21]
		ICT	Using AI and predictive analytics, cloud-based technology can be used to proactively manage seafarers' psychiatric concerns onshore.	New ways to track and manage individual's COVID-19 responses by using seafarer's safety technology	[22]
		Independent component analysis (ICA)	Examine the effect of sailing on the brain's functional connectivity. Investigated the stress response in the brain of seafarers.	Health, well-being, and performance of seafarers may be improved through improved working conditions.	[23]
		Two-fold support vector machines	In comparing fMRI data between mentally healthy and mentally sub-healthy seafarers, certain brain regions and networks are differentially activated, revealing mental sub-health mechanisms	A timely intervention prevents the escalation of mental health issues and promotes well-being for seafarers	[24]
2	Enhancing medical decision making	ML classification	A model successfully identified anxiety and depression among seafarers with 82.6% accuracy and 84.1% precision	It was possible to develop a computer-based automated analysis technique with sufficient accuracy for screening.	[25]
		Text mining	Through word clouds, symptomatic information was visualized and 96% of medical problems were correlated with diagnosis outcomes.	Onshore doctors can make quick decisions by extracting clinical symptoms of seafarers and assessing patient feedback through sentiment analysis	[26]
		LASSO regression ML model	A 93.8% accuracy rate was achieved when classifying seafarer's medical text documents. Each disease's symptom frequency visualized	Provides healthcare providers with valuable insights and information hidden in unstructured text. Seafarers benefit from this enhanced clinical decision-making.	[13]
		Bayesian network and a ‘symmetric method’	Record any noticeable changes in performance of the seafarer during regular working hours,	Subjective experiences can be revealed through self-reports to ensure the	[27]

			especially during critical tasks.	safety and well-being of seafarers.	
		Deep learning	The feasibility of detecting mental health conditions in real-time using the deep learning method, enabling immediate intervention.	It advances mental health research and intelligent detection methods for seafarers' mental health conditions.	[28]
3	Safety perception and risk assessment	ML based classification model	Proposed ML model proved to be more efficient and can achieve an average improvement of 73.72% in detained ship identification	Maintain marine safety, protect the marine environment, and provide decent working and living conditions.	[29]
		Data driven ML method	Analyse psychophysiological activities and predict operator qualifications.	Managing seafarers' performance and eliminating subjective bias	[30]
		Automated ML (AutoML)	Automated maritime student training by using AutoML tools to select relevant features	The early identification of at-risk maritime students can greatly improve student support systems, resulting in better academic outcomes and helping maritime students succeed	[31]
		ML	A non-linear relationship between predictor variables and safety perception is captured.	Predicting safety perception can help identify seafarers who may need additional training, support, or interventions to improve safety awareness and behaviour.	[32]
		AI modelling	This study identifies specific ship driving habits associated with safety risks. Maritime accidents can be attributed to a variety of factors.	Ship operators can improve compliance with safety standards by implementing the AI model's safety recommendations.	[33]
4	Streamlining administrative tasks	AI based genetic algorithm	A celestial navigation fix involves finding the position that best matches the observed celestial bodies.	Rather than sticking to local optima, genetic algorithms can find the global optimum rather than getting stuck in local ones	[34]
		iForest model	Identification of anomalous patterns in port state control inspections. Shared characteristics reveal different clusters of ship detentions.	By updating the predictive model with new information over time, port state control inspections continue to improve.	[35]
5	Remote consultations	Virtual reality (VR)	Reveal specific eye tracking patterns and	Understanding eye tracking patterns allows	[36]

	gaze behaviour during maritime safety training in the metaverse or VR environment.	for the optimization of training content and presentation. By knowing where trainees focus their attention, instructional designers can highlight critical safety elements and improve information retention.

3.2.1. Improved diagnostic accuracy

An important aspect of wearable technology and Information and Communication Technology (ICT) devices in maritime medicine is to have the ability to enhance telemedicine. Telemedicine involves utilizing ICT devices like marine doctor can provide healthcare services over a distance between land-based healthcare providers and remote seafarers' onboard ships [21]. The use of ICT devices can improve the accuracy and efficiency of medical consultations by providing real-time monitoring of key physiological parameters such as heart rate, blood pressure, and oxygen saturation levels [22]. These data can be transmitted to healthcare providers onshore to be used to diagnose and treat medical conditions, including emergencies. Wearable devices can also enable remote consultations between seafarers and onshore healthcare providers, facilitating early diagnosis and treatment of medical conditions, and reducing the need for expensive and time-consuming travel to port-based medical facilities. The integration of wearable technology and ICT devices in maritime medicine can change healthcare delivery in the maritime domain, enhancing patient outcomes, and improving the mental health of seafarers [22], [23].

ML has shown great potential in improving diagnostic accuracy in various medical fields, including maritime medicine. A study incorporated two-fold SVM to provide timely intervention that prevents the escalation of mental health issues and enhances the well-being of seafarers [24]. By analysing and learning from large sets of data, ML algorithms can accurately diagnose and predict the onset of illnesses, even before symptoms are present. In maritime medicine, this technology can be used to diagnose and predict illnesses that are common among seafarers. By using ML algorithms, medical professionals can make more accurate diagnoses and provide more effective treatments, which can improve the health outcomes of seafarers.

3.2.2. Enhancing medical decision-making through ML

Three studies mentioned ML based predictive analytics to enhance medical decision-making and help medical professionals to identify patterns and trends that can be used to predict a seafarers health status [25], [27], [28]. These studies were used to identify seafarers who are at risk of developing mental health issues such as depression, anxiety, and loneliness. Physicians can use

this information to plan targeted prevention plans to help reduce the risk of developing these diseases. Two studies supported incorporation of text mining knowledge to help doctors to identify seafarers who are most likely to expose from certain diseases along with required treatments or medications [26], [13]. These studies incorporated sentimental analysis allowing onshore doctors to make more informed decisions. Overall, the potential benefits of predictive analytics in enhancing medical decision-making are relevant and this technology will play a significant role in transforming maritime medicine and improving patient outcomes.

3.2.3. AI based seafarers safety and risk assessment

AI modelling plays a significant role in safety perception and risk assessment for seafarers. Three studies presented ML based approaches in seafarers safety risks that can be identified and mitigated before they escalate into serious incidents [29], [31], [32]. It is mentioned that ML can be used to predict equipment failures and maintenance needs. By analysing data from ship sensors and systems, algorithms can anticipate potential breakdowns, allowing for proactive maintenance and reducing the risk of accidents caused by malfunctioning equipment. One study highlighted that data from wearable devices or sensors can be useful in assessing safety risks [31]. These models can identify patterns of behaviour that may indicate fatigue, stress, or other factors affecting performance and safety. By addressing these issues promptly, the risk of accidents due to human factors can be reduced. Historical data on maritime incidents can be used to build predictive models that assess the likelihood of specific types of accidents occurring. These models can help shipping companies and authorities identify high-risk areas and take preventive measures to avoid potential accidents [33].

3.2.4. Streamlining administrative tasks and enhancing workflow

The application of AI in streamlining administrative tasks and enhancing workflow in maritime medicine has the potential to bring significant improvements in efficiency, safety, and quality of care. Automation of administrative tasks, such as scheduling appointments, updating medical records, and filing insurance claims, can help minimize paperwork, reduce errors, and free up valuable time for healthcare providers to focus on patient care [34]. AI-powered electronic health records (EHRs) can improve the accuracy and completeness of patient information, facilitate information sharing among multiple healthcare providers, and enable real-time monitoring and analysis of patient data to identify potential health risks and optimize treatment plans. Moreover, AI-powered chatbots can provide quick and personalized responses to patients' queries, offer health education, and provide support to patients with chronic conditions, increasing patient engagement and satisfaction. Similarly, in case of maritime medical emergencies occurring in remote locations where specialized medical attention is not available, ML-models can help to improve the quality of medical care by providing faster and more

accurate diagnosis, treatment, and monitoring of patients [35]. For example, ML algorithms can analyse medical images and detect anomalies, assisting healthcare professionals in making accurate and timely diagnoses.

3.2.5 Virtual reality and telemedicine for remote consultations

One of the most promising technological advancements in the field of maritime medicine is the integration of virtual reality and telemedicine for remote consultations. These technologies have the potential to greatly improve the quality of healthcare services available to seafarers who are often isolated at sea for long times, far away from medical facilities. One study, highlighted with help of virtual reality, that medical professionals can conduct examinations and procedures on seafarers without physically being in the same location [36]. These virtual consultations allow patients to be treated from ships without the physical presence of a doctor on board.

A shortage of medical knowledge among ship captains, which are the persons with the duty of providing medical assistance on board ships, affects seafarers' personal health more than that of normal workers [10], [12], [37]. It has historically been difficult for remote workers to receive healthcare because of commute requirements. Advanced AR equipment enables marine industries and their workers to receive care. Depending on the clinician's schedule, a person may not even have to take leave time from work when using virtual visits [38], [39]. It may be advantageous for some specialty practitioners to provide telemedicine to their patients because they can see them at home. As technology continues to advance, these opportunities will be even more readily available, making healthcare on the high seas a reality that is more efficient and effective than ever before.

3.3. Addressing challenges of implementing AI in maritime medicine

Despite the promising potential of AI in revolutionizing maritime medicine, significant challenges and obstacles remain in implementing AI in this field. The first challenge is the lack of availability and accessibility of reliable data sources, which are necessary to train and test AI models. Additionally, the standardization of data formats across different hospitals and nations is a crucial issue that needs to be addressed. Another significant challenge is the lack of trust in AI technology by healthcare providers, especially considering the high stakes associated with saving lives at sea. Furthermore, the high cost of implementing AI systems and acquiring the necessary hardware and software can also be a barrier to adoption. Finally, regulatory approvals and policies on the use of AI in healthcare need to be developed and implemented to ensure ethical and responsible use of the technology. Addressing these challenges is essential for the successful implementation of AI in maritime medicine and the provision of effective and efficient healthcare services for seafarers.

3.3.1. Infrastructure

It is necessary to have appropriate hardware and software components for AI and AR platforms. Health professionals and patients can use videoconferencing equipment, devices for remote monitoring, secure data storage servers, and user-friendly software interfaces [40]. Developing virtual medical platforms requires hardware and software components equipped with videoconferencing devices, remote monitoring devices, and secure data storage servers [40], [41]. The development of user-friendly software interfaces can enhance the experience of healthcare professionals and seafarers. As smartphones and tablets become more prevalent, virtual medical platforms should be compatible with mobile devices to improve accessibility and convenience for seafarers. In order to protect the integrity and confidentiality of seafarers' patient data as it is transmitted over networks, strong network security measures are needed, such as firewalls, encryption protocols and intrusion detection systems.

3.3.2. Ethical and legal considerations

Ethical and legal considerations are critical to ensuring the responsible development and deployment of these new technologies [42], [43]. One ethical challenge is the potential for AI systems to perpetuate biases and discrimination, which can have serious implications for patient care. For example, if a system is trained on a dataset that primarily includes data from a certain demographic group, it may not be as accurate or effective for patients from other specific groups like seafarers. Additionally, there are legal considerations related to patient privacy, data security, and liability. AI systems must comply with regulations such as the General Data Protection Regulation (GDPR) and the Health Insurance Portability and Accountability Act (HIPAA) to ensure patient data is protected. Furthermore, the liability for any harm caused by AI systems is still unclear. It is crucial that developers and stakeholders in the marine industry carefully consider these ethical and legal considerations to ensure that AI-powered maritime medicine is used to promote patient safety and well-being [44]. Moreover, the implementation of AI in maritime medicine requires a high degree of coordination among stakeholders, including ship owners, medical professionals, and technology providers, to ensure its effective deployment and integration.

4. Discussion

This narrative review has highlighted the opportunities, innovations, and future perspectives of transforming maritime medicine with latest technologies like AI and AR. Based available literature we have identified five themes that have discussed the potential benefits of implementing AI in the maritime health sector, including improved diagnosis, prevention, and treatment of maritime-related illnesses. The current trends and innovations in AI technology and their potential applications in maritime medicine have been discussed. Furthermore, this study has explored the challenges that may arise with the implementation of AI and AR technologies in the maritime health sector, including ethical concerns and education of medical personnel.

In the field of maritime medicine, AI innovations are rapidly developing. First, AI-powered medical devices are being designed to meet the unique requirements of maritime medicine. They can diagnose and treat various diseases, while providing rapid and accurate diagnostics. Second, AI-based predictive modeling software, often based on ML algorithms, is being increasingly employed. By analysing a vast amount of historical data on maritime health emergencies and safety data, these models can identify potential risks, predict patterns, and provide targeted interventions designed to mitigate them. Third, AI has transformed the field of telemedicine, making it easier for maritime medical professionals to communicate effectively with offshore personnel [45], [46]. This has improved the quality of healthcare available onboard vessels, creating a more connected and responsive maritime medicine system. As AI technologies continue to develop, they offer promising opportunities for transforming maritime medicine into a more efficient, responsive, and effective healthcare system.

The integration of AI in maritime medicine is a promising area that has a relevant potential to impact the future of healthcare in the maritime industry [47]. With the increasing demand for medical expertise at sea, AI-based solutions can address the challenges and ethical issues associated with providing healthcare in remote and hazardous environments. AI can support informed decision-making and improve the accuracy of diagnosis, treatment, and follow-up care, ultimately leading to better health outcomes for seafarers. Moreover, AI can facilitate data-driven research and innovation in maritime medicine, leading to the development of advanced medical technologies and protocols that can be shared across the industry [48]. However, realizing the full potential of AI in maritime medicine will require effective collaborations between maritime stakeholders, medical experts, data specialists, and AI developers. It will also require careful consideration of ethical, safety, and regulatory concerns to ensure that AI is deployed in a manner that benefits all stakeholders.

The development of intelligent imaging for diagnostic imaging is a significant advancement in medical research. It involves the AI integration into diagnostic imaging systems to enable medical professionals to access precise, real-time analysis of patient data. Furthermore, medical practitioners can utilize AI-powered diagnostic imaging to monitor patients remotely, making healthcare more accessible and affordable. As such, the integration of intelligent imaging with traditional diagnostic systems can improve modern healthcare by providing faster and more accurate diagnoses while improving patient outcomes.

4.1. Opportunities in transforming maritime medicine with AI

The transformative potential of AI in maritime medicine is relevant and it will enable numerous benefits to the maritime industry. AI and AR have provided real-time solutions to complex medical situations and have introduced innovative healthcare delivery systems, which have led to improved healthcare outcomes for a larger number of individuals [49], [50]. Moreover, the incorporation of AI-powered medical devices and virtual teleconferencing software in maritime medicine has resulted in cost-effective healthcare provision and has led to reduced healthcare

costs for shipping companies. Although there are concerns about AI replacing human healthcare workers, the potential benefits of AI integration in maritime medicine should be viewed as a complementary measure rather than a replacement. With further innovation and development of AI in maritime medicine, it will continue to contribute significantly to the improvement of healthcare delivery at sea and ensure safer movement of goods around the world. It is, therefore, important for stakeholders in the maritime industry to continue embracing AI in the healthcare sector to improve overall industry performance.

Another opportunity for the application of AI in transforming maritime medicine lies in the ability to provide timely and proactive intervention to prevent medical emergencies. With predictive analytics, AI can analyze data collected from various sources such as sensors, wearables, medical records, and environmental factors to identify patterns and predict potential health risks before they occur [50]–[52]. This can enable maritime healthcare providers to take preventive measures such as adjusting crew schedules, providing targeted interventions, and implementing safety protocols to avert potential health crises. Moreover, AI-powered virtual assistants and chatbots can enhance crew members' access to medical information and advice, enabling them to self-diagnose and manage minor health concerns without requiring the intervention of medical personnel [53], [54]. This can reduce the workload of maritime medical providers while empowering crew members to take more proactive measures toward their health and well-being. As AI technology continues to evolve, the potential for enhancing maritime medicine with data-driven insights and proactive interventions is limitless.

4.2. Future perspectives

The rise of AI-based applications in maritime medicine brings a new era of opportunities and innovative approaches to enhance the safety of seafarers. It is necessary to improve technology training for seafarers, but not as compensation for equipment that was not designed with the user in mind [55]. With the ability to analyse vast amounts of data, predict outcomes, and recognize patterns, AI systems can assist in decision-making, reduce human errors, and provide early warnings to prevent or mitigate accidents. Moreover, AI can assist in the optimization of treatment, improve medical diagnoses, and offer telemedicine services to seafarers. However, there are also potential challenges to overcome, such as ethical considerations and the need for proper training and regulation [56], [57]. Therefore, a collaborative effort is necessary among academic institutions, maritime stakeholders, developers, and policymakers to advance the use of AI in maritime medicine, ensure proper implementation, and avoid potential misuse. Overall, the future of maritime medicine is promising with the incorporation of AI, and ongoing research and development will further explore its potential to transform the industry.

Medical data analytics and prediction models can help TMAS doctors make informed decisions

on how to proceed with medical treatment. AI-powered diagnostic algorithms can accurately identify medical conditions and initiate treatment recommendations, reducing human error and improving patient outcomes [58], [59]. Additionally, AI technology can help maritime organizations to better manage their health and safety protocols, leading to a safer and more efficient shipping sector. As technology continues to advance, the possibilities for the application of AI in maritime medicine are endless, and the industry is poised for a revolutionary transformation in the years ahead.

Another significant potential application of AI in maritime medicine is the prediction and prevention of disease outbreaks. Populations in confined spaces create a fertile ground for the spread of infectious diseases [60], [61]. While various monitoring systems are available to detect outbreaks, AI presents an opportunity to predict and prevent outbreaks before they occur. AI can analyse big data from different sources such as electronic health records, shipping schedules, meteorological data, and social media feeds to predict the likelihood of the outbreak and identify the most vulnerable groups. AI can also inform decision-makers and stakeholders on the necessary intervention measures to prevent or contain the outbreak, including screening, quarantines, and vaccination. The prediction and prevention of outbreaks can save lives, protect public health, and minimize disruptions to maritime operations. However, AI's effectiveness in disease prediction and prevention depends on data quality, data access, and the development of robust algorithms. Therefore, stakeholders must ensure that AI is used to promote ethical and responsible practices while respecting individual rights and privacy.

The increased adoption of AI in maritime medicine has the potential to significantly change healthcare provision in this domain, making it more efficient, cost-effective, and better targeted. This is particularly relevant in the context of the maritime industry, where healthcare provision can be limited and difficult to access. AI can help to address these challenges by supporting more accurate diagnoses and providing personalized treatment plans based on the specific needs of individual patients. The use of AI in maritime medicine can also facilitate remote consultations, enabling medical professionals to provide care to seafarers in real-time, regardless of their location. Overall, the increased adoption of AI in maritime medicine represents an exciting opportunity to improve healthcare provision and support the wellbeing of seafarers around the world.

4.3. Study limitations

Despite its value for providing a comprehensive overview of a topic and providing insight into the existing literature, narrative reviews also have certain limitations. As far as the given themes are concerned, this study does not follow a systematic search and selection process like systematic reviews. As a result, some relevant studies might be missed, resulting in selection bias. There is a great deal of reliance on the judgment and personal bias of the author in narrative reviews. A review's comprehensiveness can be affected by this subjectivity. It can be challenging for others to replicate or verify the findings of a narrative review without a

predefined protocol and transparent methods. Despite these limitations, this review study is probably a contribution to the literature having provided a comprehensive and accessible summary of research on AI and AR in maritime medicine.

5. Conclusions

This narrative review has identified and discussed the various opportunities and innovations brought about by the integration of AI in maritime medicine. Increasing evidence indicates that AI systems enhance the diagnostic accuracy and treatment of ship crew members, with innovations such as chatbots, wearables and diagnosis platforms playing a crucial role in this process. Moreover, AI tools have been shown to facilitate the optimization of medical services in remote areas through the utilization of predictive analytics and risk assessment algorithms. Moreover, the integration of AI and AR technologies has the potential to modify significantly medical training and education for maritime healthcare professionals. Overall, these opportunities and innovations have the potential to improve the quality of healthcare services for seafarers, reduce costs, and ultimately enhance the safety and well-being of crew members at sea. However, more work is needed to fully harness the benefits of AI in medical assistance at sea and address the ethical implications of these digital tools.

The future of maritime medicine is poised to bring significant changes in the sector. The integration of AI and other emerging technologies is creating a transformative era in the practice of maritime medicine. The implications of these changes for the future of maritime medicine include the potential to enhance access to quality healthcare services, improve patient outcomes, reduce healthcare costs, and increase efficiency in medical decision making. Moreover, these innovations will help in addressing unique healthcare challenges faced in maritime environments, including limited resources, remote locations, and extreme weather conditions, among others. Overall, the future of maritime medicine is exciting, and it is expected that the integration of AI and AR technologies will significantly impact the sector's growth and development.

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