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CASE STUDY OF NOROVIRUS OUTBREAKS ON CRUISE SHIPS: ENGINEERING AND PUBLIC HEALTH RESPONSES

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Abstract
Norovirus (NoV) gastroenteritis epidemics on cruise ships can impact numerous individuals, incapacitate susceptible travelers, interrupt holidays, and result in economic detriment to the cruise industry. The objective was to identify risk variables associated with NoV epidemics on cruise ships and evaluate the efficacy of preventative and control strategies. The research performed a comprehensive literature review by searching the PubMed and Scopus files and grey literature for research articles and reports detailing NoV epidemics aboard cruise ships from 2000 to 2025. A meta-analysis of NoV incidence among travelers and flight personnel was conducted. Information from 48 epidemics across 25 cruise ships between 2000 and 2025 was sourced from 15 papers and five states, revealing a mean prevalence (assault rate) of 8% for guests and 3% for crew members. Person-to-person dissemination was the predominant method in 38 of the 46 epidemics, occurring exclusively in 15 instances and as a component of multiple transmission channels in 25 cases. The presence of an unwell cabin companion constituted the predominant risk factor. Six epidemic studies indicated inadequate cleanliness, whilst four indicated appropriate hygiene within the cruise environment. Behavioral hazards among travelers were examined in three of the thirteen studies. The results suggest a necessity for behavioral therapies to enhance personal cleanliness, illness reporting, and adherence to isolation protocols, as well as a reevaluation of existing methods of isolation that place symptom and asymptomatic persons in the same chamber.
Keywords – Norovirus, Cruise, Public Health, Outbreaks

1. INTRODUCTION

The cruise business has emerged as a significant component of the global tourism sector [1]. The Cruise Line International Association (CLIA) reports that the company has steadily gained popularity, expanding at 7.9% from 2010 to 2023 [2]. Contemporary massive cruise vessels reportedly accommodate around 5k passengers per voyage and are distinguished by features such as casinos, spas, several dining establishments, and eateries [12].

In this atmosphere, travelers from various locations predominantly remain indoors and interact for prolonged durations in semi-enclosed spaces. Frequent gatherings, coupled with the considerable duration travelers spend on board, enhance the probability of interaction among customers. This facilitates the transfer of infectious illnesses between individuals or indirectly via contamination of surfaces [11].

Infectious illnesses can be disseminated from cruise vessels to the broader community, exacerbating transmission rates and increasing the disease impact [3][19]. Infections of contagious diseases among cruise ship passengers can incur substantial economic losses to the tourist sector. Various stakeholders have collaboratively devised and executed strategies to enhance knowledge and mitigate the transmission of illnesses on cruise vessels. Behavioral treatments have been acknowledged as essential in preventing travelers from serving as vectors for transmissible diseases and safeguarding passengers against infection [18].

Noroviruses (NoVs) are universally acknowledged as the primary etiological agents of acute viral diarrhea in humans globally [4] [13]. About 25 million instances of severe diarrhea in the USA are attributed to NoV infections, according to the Centers for Disease Control (CDC) [5]. The elevated prevalence can be readily elucidated by examining the microbiological properties of the virus that causes it. The minimal infectious dosage comprises fewer than 100 virus particles, resulting in a high infection rate for NoVs. NoVs are transferred by multiple pathways, including ingesting infected food and beverages, touching infected objects, or a specific type of airborne distribution caused by aerosols from vomit [14]. NoV infection provides only transient immunity,

likely attributable to the genetic variety of this virus subtype. This virus exhibits extensive dissemination and induces epidemics, particularly in confined settings like hospitals, nursing facilities, dorms, and cruise vessels. Cruise ships are experiencing a rise in NoV epidemics, particularly due to the growing number of at-risk guests in the past few years [6].

The cruise line sector has witnessed unprecedented annual passenger numbers since the early 2000s. Cruise ships provide optimal conditions for creating new epidemics: shared food and beverages are vectors for getting sick [15]. At the same time, the semi-enclosed environment of the vessels promotes person-to-person transmissions. It is essential to recognize that one-third of those on cruises are elderly individuals, who are more susceptible to illnesses and problems from diseases [17][20].

The enhanced identification of NoV epidemics on cruise vessels and the diverse legislations enacted in different nations necessitate a reassessment of the understanding of this health challenge [7]. The research resolved to systematically examine studies released over the past two decades concerning NoV epidemics on business vessels, aiming to summarize information regarding the main infection reports, diagnostic methodologies employed for virus identification, and the proportion of people impacted [16].

2. MATERIALS

2.1 Methodology for Information Retrieval

The research adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) standards to conduct a systematic review and meta-analysis [8]. The research searched the PubMed and Scopus libraries for relevant peer-reviewed journal articles. Relevant papers' reference lists were examined, and qualifying articles were incorporated into the research. The research explored the CDC website to locate public investigations and submitted an official request for authorization to integrate these reports into the systematic evaluation. The research contacted the CDC, as it is the sole programme that has been performing specific monitoring and inquiry into outbreaks of diarrhea aboard cruise vessels since 1980, including the research period [9].

Two investigators conducted a research review regarding eligibility requirements and the data extraction process, while an additional reviewer adjudicated any discrepancies between the two investigators. The search results were first evaluated for compliance with the inclusion criterion by examining the title and description. All relevant research was acquired, and the same examiners separately evaluated the complete text to assess eligibility. PubMed was regarded as the primary reference resource for the discovered duplicates [10].

2.2 Standards for admission and removal

The papers that were deemed eligible were required to report all of the information that follows: (i) Laboratory-confirmed epidemics of NoV on cruise vessels, (ii) rates of infection among travelers and crew participants, (iii) composed in English, and (iv) reported between 2000 and 2025. Eligibility requirements about the timeframe were established to encompass the period preceding the COVID-19 epidemic. A subsequent review will examine cases of gastroenteritis following the onset of COVID-19. Articles documenting NoV epidemics on cargo vessels, sailing yachts, or failing to satisfy other eligibility requirements were omitted. Infections occurred during a cruise, with a cumulative case count exceeding the predicted norm. The criterion for reporting an outbreak was an attack rate of 3% or higher among passengers or crew members. NoV epidemics were instances in which fecal samples from at least two infected persons proved positive for NoV via reverse transcription, microscopy with electrons, or enzyme assay.

Data was gathered from each epidemic, including the time frame and cruise schedules, the agent that caused it and its strain when accessible, the amount of instances and the overall number of travelers and crew members, the case means, evidence regarding the mode of delivery, the type and specifics of the epidemiological investigation carried out, the variables that contributed to the epidemic, risk factors for behavior, and the preventative measures implemented (pre-embarkation assessment, monitoring, isolation, sanitation, disinfection, cessation of sailing, schooling). The research obtained data regarding the naming of NoV isolates as documented by the writers in the original papers, without categorizing the strains according to contemporary nomenclature and categorization systems. Outbreaks on the same vessel on successive voyages were recorded as distinct subsequent occurrences [21]. To evaluate the efficacy of control measures, in the current investigation, the researchers quantified the incidence of breakouts throughout consecutive trips on the same vessel following the implementation of the control strategy. The research determined that the control tactics were ineffective during the prior voyage when an epidemic transpired on the next cruise.

The research identified the method for spreading and the risk variables following an analysis of the epidemiologic findings from the epidemic investigations in the original publications. Factors were deemed significantly linked with illness if the p-value was less than 0.05 in a multivariable analysis. The curve of epidemics and additional risk indicators (e.g., infected cabinmate) reported in the primary research were evaluated to ascertain whether an outbreak had disseminated via contact between individuals.

2.3 Comprehensive analysis of multiple studies

The research performed an incidence meta-analysis utilizing the random-effects model, applying the logarithm transformation for those studies that reported a single percentage to derive estimated values. A continuity adjustment was implemented for the investigations exhibiting zero-cell counts. The research employed Restricted Maximum Likelihood (REML). The F-statistic was utilized to examine variation, indicating the proportion of variation in the effect's impact attributable to variability instead of sample error. The research further investigated heterogeneity by calculating the Q statistic and the 92% prediction intervals, which indicate the potential range of impact metrics for another investigation in a population analogous to that contained in the meta-analysis. The research assessed minor research impacts, whether visually by examining the proportions of the funnel plot or numerically by employing Egger's test when the analysis included more than 10 trials. Depending on the cruise route, a subgroup study was performed to address the anticipated significant variation. The research evaluates subgroups based on several risk factors identified as causative agents of infection.

The results were visually represented in forests. Each analysis used the R experimental package, employing the metaprop command from the meta module. All p-values below 0.05 were considered statistically significant. In the meta-analyses of individual dimensions, the assault rate served as the comparative measure of impact. The rate of attacks is characterized as the overall number of individuals (travelers or crew employees) who fell ill, divided by the total number of individuals at risk of the illness. The research calculated the assault rate independently for customers and crew personnel. Danger indicators uncovered in research were incorporated into the meta-analyses.

3. METHODS

3.1 Search Results And Study Decision

The preliminary database search produced 580 items, from which 460 duplicates were eliminated. Of the remaining 115 papers, 45 were eliminated during the screening of titles and abstracts for failing to address the issue of concern. The remaining 72 complete articles were assessed according to the established eligibility requirements. Sixty publications were removed owing to inappropriate demographics and results. One further paper was excluded after the methodological evaluation phase. Only nine studies were incorporated in the final evaluation.

3.2 Study attributes

Nine studies with 5.3k individuals were considered. A collaborative study was conducted between Nigeria and Britain. All studies utilized a cross-sectional approach. Five publications addressed each of the three elements, while four articles covered at least two aspects. All publications analyzed and documented knowledge.

3.3 Evaluation of the quality of contained research

In total, most studies (n = 8) responded affirmatively to six inquiries, while one study answered affirmatively to seven, and another to five. Eight investigations did not achieve scores on issues 5 and 6, which pertained to confounding variables during the research procedure.

3.4 Primary discoveries learning

Knowledge was evaluated using four sub-themes: Comprehensive information regarding the disease, its spread methods, clinical manifestations, and preventive strategies—fundamental understanding of the viral illness. Seven articles indicated that crew members possessed enough broad knowledge of the illnesses under investigation. Most of those taking part were cognizant of the severity and dissemination of the viral infection. Knowledge degrees about familiarity varied from 75% to 98%. Only one study indicated inadequate acquaintance (48%) with the condition. One article failed to provide details regarding a broad understanding of the illness in question.

3.4 Transmission method

The research indicated adequate awareness of propagation modes among most subjects, with percentages varying from 53% for Sexually Transmitted Infections (STIs) to 96 % for COVID-19. Both publications examining COVID-19 demonstrated a high level of understanding regarding routes of infection. In the Italian study, most of those surveyed (96%) comprehended that COVID-19 can be transferred through droplets emitted by an infected individual when coughing or sneezing. The bulk of articles concerning HIV/AIDS and STIs revealed analogous findings. Research in Senegal indicated that 94% of those interviewed recognized that HIV could be transmitted via genital contact. Supplementary papers from Italy (83 %), Morocco (92%), and Kiribati (71%) demonstrated analogous levels of expertise. This differed from research, which indicated that merely 34% of participants recognized unprotected intercourse as a mode of HIV transmission. Research indicated adequate understanding of dissemination methods via blood, including parent-to-child dissemination, blood transfusions using infected plasma, and the application of polluted sharp instruments such as knives and syringes.

3.5 Symptoms

Merely four of the nine studies examined provided awareness levels concerning disease signs. Three of the four investigations demonstrated sufficient levels of understanding. The Italian research study on COVID-19 revealed a high level of awareness (98%) regarding the manifestations of the virus. A study conducted in the Philippines

showed that over 72% of those surveyed recognized the signs of STIs. A study indicated that merely 54% of those surveyed possessed comprehensive knowledge regarding the symptoms associated with HIV/AIDS and other STIs.

3.6 Preventive strategies

Participants possessed enough information regarding the prevention of infection with the reported illness. This was elevated about COVID-19. The Italian research indicated that 91% of respondents acknowledged that the propagation of COVID-19 could be mitigated by wearing facial masks. In comparison, 97% believed that isolating and treating COVID-19 individuals effectively decreased the spread of the illness. The understanding of HIV/AIDS and STI preventative methods, including abstention and condom usage, exhibited variability across trials. Respondents in research have reported that condom use effectively prevents HIV/AIDS and other STIs. This contrasts with respondents in a separate study from the Philippines and Montenegro, who indicated low levels of awareness of condom use for the avoidance of HIV and STIs, at 56% and 41%, respectively. Two-thirds (68%) of participants in the Montenegro trial identified abstinence as a protective strategy, whereas more than a third (36%) stated so in the Senegal research.

3.7 Research Findings

A total of 125 cases of NoV were documented. Due to outbreaks occurring on successive excursions of the same ship, the number of boats implicated totalled 75. Most vessels were navigating North-Central American and European streams, with three exceptions: one epidemic transpired on board a ship traveling from the continent, one study detailed a breakout, and a single paper documented a NoV outbreak on an Australian vessel.

Twelve investigations of NoV outbreaks across 20 vessels utilized an ad-hoc survey delivered to a sample of travelers and crew members for data collection. Six studies independently reported the infection rates for guests and crew members, ranging from 18% to 75% and 2.1% to 32%, respectively. Three investigations indicated that the overall infection rate (including passengers and staff members) varied from less than 2% to 42%. Data for the research were acquired through consultations with the ship's medical crew and by reviewing passenger lists usually compiled by cruise companies, as reported by the CDC.

Fifteen investigations, encompassing 54 boats, examined the potential origins of infection, which were attributed solely to food consumed on board or to several sources, including food, water, and the surroundings, in most instances. The origin of the virus was intermittently "undetermined." Medical workers aboard cruise vessels gathered stool and blood samples from ill guests for testing in all investigations, except for the study that solely evaluated food. Food testing was documented in five investigations, resulting in 12 occurrences. Ambient swabs were exclusively obtained during the specified outbreaks. The results were conducted on 54 of the 72 affected vessels, with the genotype of the NoV identified in 60 of these cases. An enzyme assay methodology was employed in seven trials.

3.8 Constraints and advantages

Only four publications were eligible for consideration in the study. There was variability in the methodologies of the included publications and the critical evaluation instruments employed. The study’s trustworthiness is undermined. The diversity in study types and techniques hindered comparisons; hence, the analysis emphasized an overarching depiction of behaviors among travelers on cruise ships concerning the transmission of infectious illnesses. A notable positive aspect of the evaluation is mitigating bias throughout the procedure, as only two researchers participated in every investigation stage. In the event of disputes, the other people in the study group were contacted until an agreement was achieved.

4. CONCLUSION

Preventing and managing person-to-person epidemics of NoV on cruise ships is difficult. This is likely attributable to challenges in managing the behavioral aspects that affect the execution of restrictions among travelers. Cognitive risk factors in travelers have not been sufficiently examined. Research findings advocate for behavioral interventions to enhance personal cleanliness, prompt reporting of signs, and adherence to separation protocols, as well as reevaluating existing isolation regulations that place sick and asymptomatic cabinmates in identical quarters.

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