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Dengue in Bangladesh and neighboring countries: an overview of epidemiology, transmission, control, and prevention

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Abstract

Background and Objectives: Dengue fever, caused by four serotypes of the dengue virus (DENV), is a global health threat, affecting millions of people annually, with a significant burden in Asian countries. Bangladesh, where dengue was first documented in the 1960s, has witnessed an escalation of cases in recent years. The aim of this review is to provide an overview on dengue covering dengue epidemiology in Bangladesh and neighboring countries, efficacy of available vaccines, diagnostic tests and preventive measures.

Materials and Methods: A narrative review was conducted using the keywords such as dengue in Bangladesh, dengue in South and Southeast Asia, epidemiology, genomic structure, transmission, diagnosis, vaccines and prevention. The information and data of this article were drawn from extensively reviewed scientific journals and pertinent authoritative sources. The data search was limited from year 2000 to 2023.

Results: Magnitude of dengue infection in Bangladesh and neighboring countries was assessed. The usefulness of diagnostic tests as well as the prospect of available vaccines was reviewed. Control and preventive measures to mitigate spread and transmission of the disease were also discussed.

Conclusion: Effective prevention and control of dengue needs coordinated efforts in surveillance, research, control and preventive measures. This holistic approach is necessary to mitigate detrimental consequences of dengue on public health and economies worldwide.

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Introduction

Dengue fever, a mosquito-borne viral disease, has profound global impacts, affecting millions of people each year. This disease is transmitted through the bite of virus-infected mosquitoes, with the primary vectors being female *Aedes aegypti*, followed by *Aedes albopictus*. The virus is characterized by four antigenically distinct serotypes: DENV-1, DENV-2, DENV-3, and DENV-4 [1]. However, a fifth serotype (DENV-5) was reported in Malaysia in 2013 [2].

Although most dengue cases are not fatal, dengue can lead to severe illness, known as dengue hemorrhagic fever and dengue shock syndrome, which often require hospitalization and intensive care. Dengue is a prevalent endemic illness found in more than 100 countries, primarily in tropical and subtropical regions worldwide [3].The surge in dengue cases strains healthcare resources in many countries, especially in regions where the disease is endemic.

Dengue has had a significant and concerning impact

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in Bangladesh, with frequent outbreaks causing substantial public health challenges. The country faces a recurring cycle of dengue epidemics, especially during the monsoon season when mosquito breeding sites are abundant. Most dengue cases are not fatal; however, disease outbreaks strain the healthcare system, with hospitals and clinics overwhelmed by dengue cases. The demand for medical care often exceeds the available resources, leading to difficulties in timely diagnosis and treatment. Furthermore, the economic impact of dengue in Bangladesh is noteworthy, as families often struggle to meet the healthcare costs associated with the disease [4]. In Bangladesh and other dengue endemic countries, the outbreak of dengue diverts resources away from other healthcare priorities, impacting the overall quality and accessibility of healthcare services. The burden on the healthcare system, combined with the economic costs of dengue treatment, aggravates the healthcare crisis.

The aim of this brief review is to provide an understanding on dengue epidemiology in Bangladesh and neighboring countries, efficacy of available vaccines, diagnostic tests and preventive measures.

Materials and methods

The search strategy for this narrative review included keywords such as “dengue fever”, “dengue hemorrhagic fever”, “epidemiology”, “genomic structure”, “transmission”, “diagnosis”, “serologic tests”, “molecular test”, “vaccines”, “dengue in Bangladesh”, “dengue in South and Southeast Asia”, and “epidemic”. The search engines included Google Scholar, Pubmed, Scopus, MEDLINE, CDC, and WHO websites. The data search was limited from 2000 to 2023. The inclusion criteria were: (1) articles describing the epidemiology, viral genotypes and serotypes, risk factors, and prevention. The exclusion criteria were: (1) articles published before 2000; (2) non-English articles; and (3) articles not having the full text. The researchers independently searched for articles and performed the quality appraisal for further inclusion in the review by reading the full text of the articles.

Structure of dengue virus

Dengue virus is a single-stranded positive-sense enveloped RNA virus belonging to the Flaviviridae family. The dengue virus is roughly spherical with a diameter of approximately 50 nanometers. The viral envelope is a lipid bilayer that encapsulates the nucleocapsid. The envelope contains E and M proteins across the surface. The virus can assume different conformations during the maturation and infection stages due to the flexibility of the envelop proteins. E-protein serves as the primary antigen causing antibody responses during infection and is essential for the initial attachment of the virus to the host cells. The amino acid sequence of E-protein among the different serotypes of DENV bears 60-70% similarity. The core of the virus is composed of the viral RNA and C proteins [1,5].

The genome of the dengue virus (Figure-1) comprises of a single-stranded positive-sense RNA. It is composed of ten genes, which are translated into three structural proteins: (1) capsid C – which plays a crucial role in encapsulating the viral RNA genome, (2) membrane M having a membrane precursor M (prM) – which is associated with the organization and maturation of the dengue virus, and (3) Envelope E – which is located on the viral

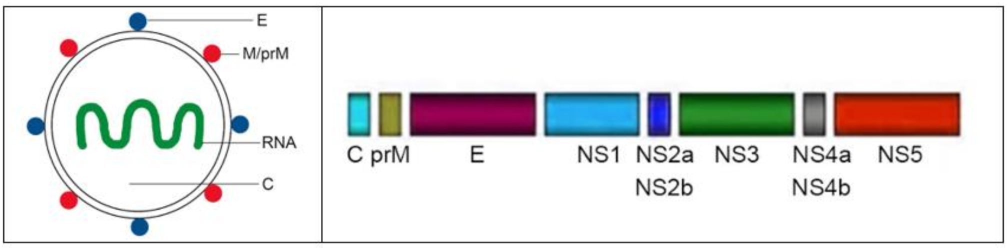

Figure-1: *Genome structure of dengue virus [1].*

surface, is essential for the initial attachment of the virus to host cells, and seven nonstructural proteins: *NS1, NS2A, NS2B, NS3, NS4A, NS4B,* and *NS5* that are involved in viral replication and assembly processes [1,5].

Epidemiology of dengue infection

Dengue is a viral infection transmitted to humans through the bites of infected mosquitoes, predominantly in tropical and subtropical regions worldwide, especially in urban and semi-urban environments. The primary vectors responsible for transmitting dengue to humans are *Aedes aegypti* mosquitoes and, to a lesser extent, *Aedes albopictus*. Dengue virus is comprised of four distinct serotypes (DENV-1, DENV-2, DENV-3, DENV-4), and individuals are susceptible to infection by any of these serotypes. Infection with a specific serotype confers lasting immunity against that serotype but does not protect from the others. Subsequent infections may increase the risk of developing severe dengue.

Dengue is a prevalent endemic illness found in more than 100 countries, primarily in tropical and subtropical regions worldwide, causing 20,000 to 25,000 deaths annually, mostly in children [3]. Approximately 390 million cases of dengue virus infections are reported annually across 128 countries, with Asian countries accounting for 70% of these infections. Out of the total 390 million cases, approximately 96 million are classified as clinical cases [3]. Age-standardized incidence rate (ASR) of dengue increased from 1990 to 2011 with a subsequent decrease per year from 2011 to 2019 [6]. The greatest risk for contracting dengue infection is in the Indian subcontinent; Southern China; Southeast Asia; Taiwan; the Pacific Islands; Mexico; Africa; the Caribbean (except for the Cayman Islands or Cuba); Central and South America, (except for Paraguay, Chile, and Argentina); Hawaii; areas along the Texas-Mexico border; and Key West, Florida.

Dengue in Bangladesh and neighboring countries

Bangladesh has a subtropical monsoon climate characterized by wide seasonal variations in rainfall. A warm and humid climate and stagnant rainwater create favorable breeding grounds for mosquitoes. This provides a suitable environment for the *Aedes* mosquitoes, the primary vectors for dengue. Furthermore, rapid urbanization in Bangladesh has led to densely populated cities, which provide ample breeding sites for *Aedes* mosquitoes in water containers, discarded tires, various other containers, and ditches that collect rainwater.

In Bangladesh, dengue was initially documented in the 1960s and was colloquially referred to as "Dacca fever" [7].The abundance of the *Aedes aegypti* mosquito vector and its urban transmission cycles has established dengue as an endemic disease in Bangladesh. According to multiple sources, several epidemics of dengue fever affected Bangladesh in recent years – two major epidemics occurred in 2019 and 2023 [7-11]. The 2019 dengue epidemic had 101,354 confirmed cases and 164 deaths, with a case-fatality rate (CFR) of 0.16%, whereas the country witnessed the most devastating epidemic in 2023, which resulted in 320,945confirmed dengue cases and 1701 deaths (CFR, 0.53%), as reported by the Bangladesh Directorate General of Health Services [11]. Table-1 shows the number of dengue cases, deaths and case fatality rate in Bangladesh from 2016 to 2023.

Table-1: *Number of dengue cases and deaths in Bangladesh from 2016 to 2023 [7-11].*

Year	Number of dengue cases	Number of dengue deaths	Case fatality rate (%)
2016	6060	14	0.23
2017	2769	8	0.29
2018	10148	26	0.26
2019	101354	164	0.16
2020	1405	3	0.21
2021	28429	105	0.37
2022	62382	281	0.45
2023	320954	1701	0.53

The dengue cases were reported from all the 64 districts of Bangladesh, with a higher number of cases in males than females (62% vs. 58%, respectively). However, the overall CFR was higher in females than in males (0.72% vs. 0.32%, respectively). Adults aged 30 years and older accounted for 38% of cases and 64% of all deaths in 2023. In contrast, a previous study of an outbreak in 2022 had a total of 62,382 cases and 281 fatalities, with a CFR of 0.45%. Dhaka and Chittagong were the hardest hit cities in the country [7-11]. An earlier cross-sectional survey of 1,176 households in 2019 reported a higher prevalence of dengue among adults aged 19 to 50 years and in females [7-9]. Although DENV3 was detected more frequently in recent past outbreaks, DENV2 was the predominant serotype isolated during this outbreak [9].The distribution of dengue cases and deaths by location in Bangladesh is shown in Figure-2 [11].

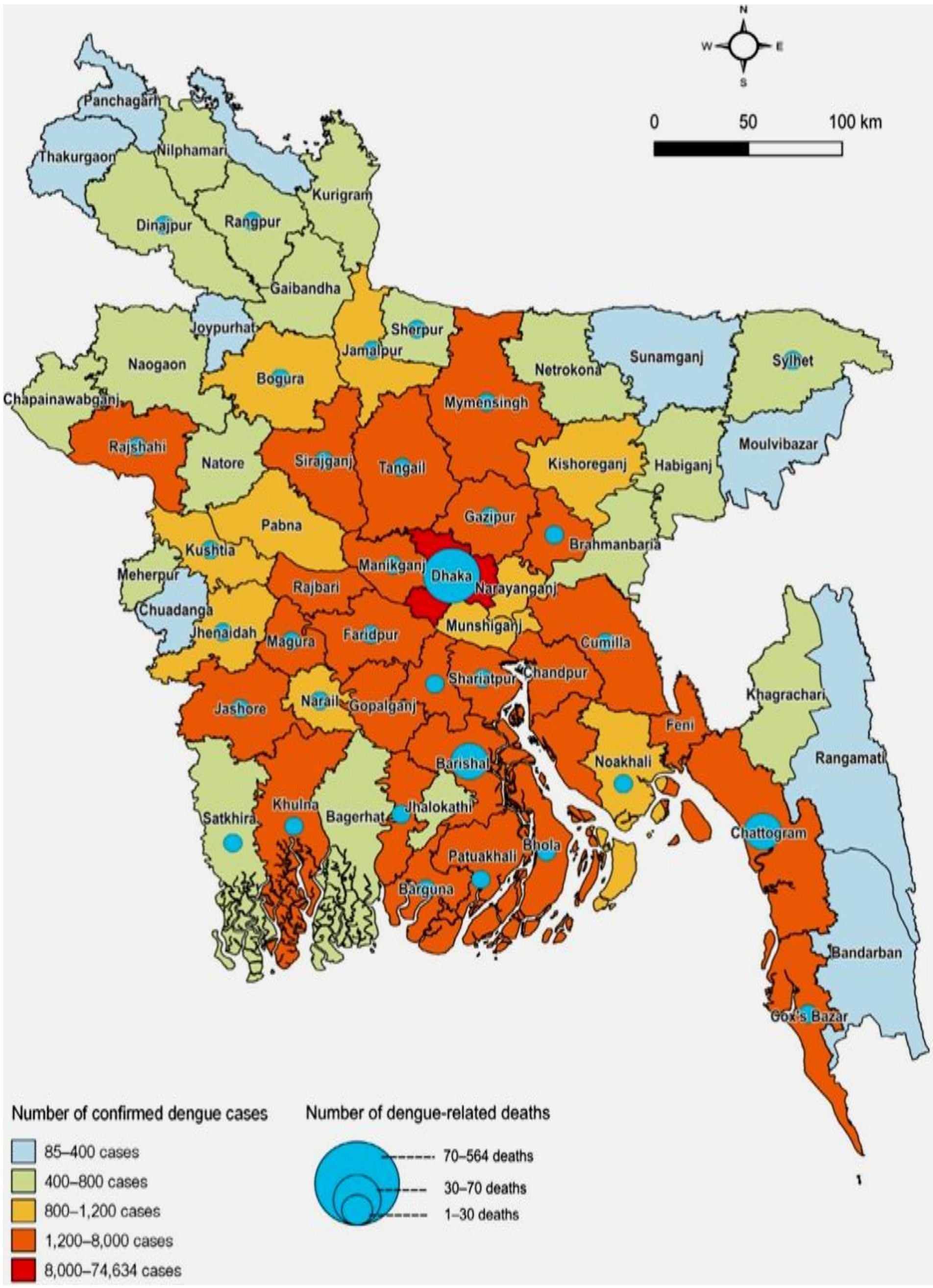

Figure-2: *Distribution of confirmed dengue cases and number of dengue-related deaths by location in Bangladesh in 2023 [11].*

According to the report compiled by National Center for Vector Borne Diseases Control in India [12], from January 2018 to September 2023, among the 28 states and 8 Union territories, the most dengue hit places (with number of dengue cases) in 2023 were: Kerala (9779), Karnataka (9185), Maharashtra (8496), Odisha (6563), Uttar Pradesh (5742), and Assam (5604). Data from West Bengal was not reported in the previously mentioned source. However, Hindustan Times (a daily newspaper in India) reported the highest number of dengue cases (over 76,000) in West Bengal as of November 1, 2023 [13].

According to World Health Organization (WHO), dengue cases in Southeast Asia regions increased by 46% (from 451,442 to 658,301) and deaths decreased by 2% (from 1,584 to 1.555) from 2015 to 2019. Tian and colleagues reviewed dengue incidence and used disability-adjusted life years (DALY) to measure the disease burden of dengue fever in the endemic countries in Southeast Asia [15]. The age-standardized rate increased by 33% from 557.15 (95% CI 243.32 to 1212.53) per 100,000 in 1990 to 740.4 (95% CI 478.2 to 1323.1) per 100,000 in 2019 in these countries. Six countries including Bangladesh, India, Indonesia, Myanmar, Sri Lanka, and Thailand are among the high-endemic countries in the world [14]. An increase of dengue mosquito vector and viruses due to increased population density, increased migration in urban areas, inadequate water supply, poor waste management systems, and global warming are among the reasons for the dengue upsurge over time.

Transmission

Dengue transmission is primarily carried out by two mosquito species, *Aedes aegypti* and *Aedes albopictus*. However, *Aedes aegypti* plays a primary role because this mosquito species can adapt to various environments. They breed in water collected in small containers, flowerpots, tires, and any stagnant water, adapting to all types of surroundings. Dengue transmission pathways involve a complex interaction involving the virus, mosquitoes (vectors), and humans (hosts). The process is outlined in Figure-3.

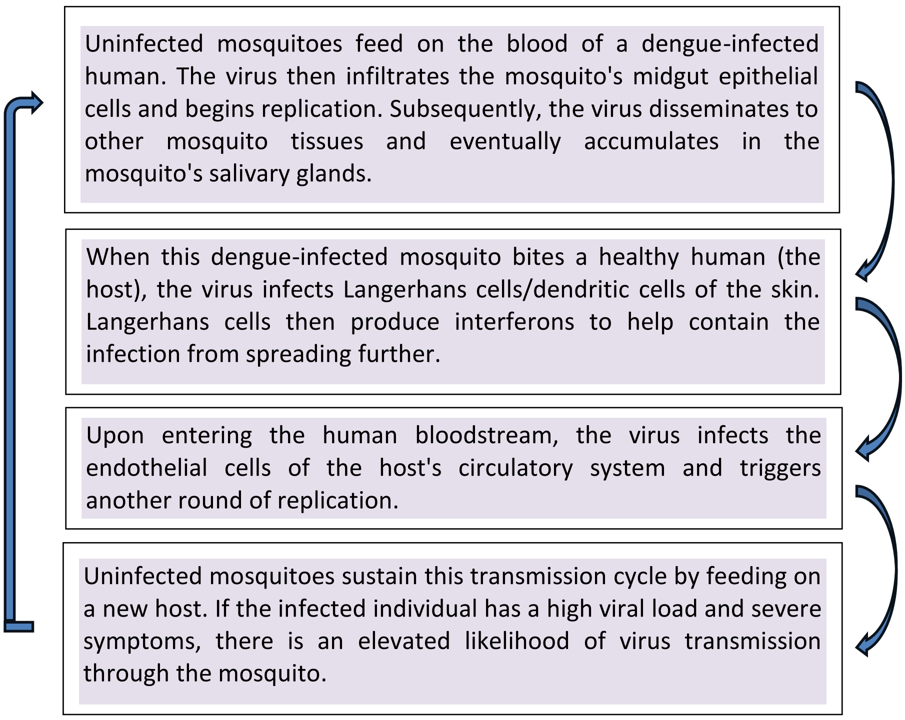

Figure-3: *The pathways involved in the transmission of dengue virus [16-18].*

Apart from symptomatic dengue cases, asymptomatic infections play a significant role in the transmission of dengue infection. Estimated overall global prevalence of asymptomatic dengue infection has been reported as 59.3% with 65.5% and 30.8% during outbreaks and non-outbreak periods respectively [19-21]. However, WHO reports that around 80% of dengue cases do not show any symptom [3]. Therefore, detection of asymptomatic dengue is crucial to prevent spread of dengue in a community.

Diagnostic tests

The primary focus in diagnosing dengue should be on the detection of the virus or the viral components. During the acute stage of the infection, diagnosis can be made by detection of the virus, or its nucleic acids or antigens. Typically, within the first 4 to 5 days of the onset of the disease, the virus can be detected in plasma, blood cells, and various tissues [22]. For patients seeking medical attention within the five days of the onset of fever, diagnostic assessment should include rRT-PCR (testing for viral RNA) or NS1 antigen test. NS1 antigen test detects the non-structural protein NS1 of dengue virus. This protein is secreted into the blood during dengue infection. NS1 has shown to produce positive results for up to 12 days after the onset of fever. In addition, Immunoglobulin M (IgM) antibodies to viral antigen also start to appear around 3-7 days following the onset of symptoms.

During the post-acute stage, serology is the method of choice for diagnosis which detects IgM or IgG antibodies. First-time (primary) dengue virus infections typically show a stronger IgM response; however, subsequent (secondary) infections show a weaker IgM response but a stronger IgG response [22]. For patients with more than one week after the onset of fever, IgM detection is the most effective diagnostic method [23]. IgM antibodies become detectable 3 to 7 days following infection and could remain detectable for 6 months or longer [23]. It takes approximately 5 to 7 days following the onset of symptoms for immunoglobulin G (IgG) antibodies to become detectable, and these levels may remain elevated for years [22].

In 2023, Luvira et al reported serum concentration by the ultrafiltration method as a simple and applicable technique to improve the diagnostic sensitivity and specificity of NS1 antigen test [24]. Dengue NS1 detection by enzyme-linked immunosorbent assay (ELISA) had the highest sensitivity of 82.4% (and 94.3% specificity), while NS1 by rapid diagnostic test (RDT) had 76.5% sensitivity, when compared with the viral detection by polymerase chain reaction (PCR). Serum concentrated three times with the ultrafiltration method using a 10 kDa molecular weight cut-off membrane increased the sensitivity of RDT-NS1 detection from 76.5% to 80.4%, with 100% specificity. Combining NS1 and IgM detection, the concentration method further increased the RDT sensitivity to 82.4% with 100% specificity.

Prevention

Mosquito control: Mosquito control efforts rely on eradicating mosquito breeding sites, as mosquitoes lay their eggs in stagnant water. Regular inspections and removal of potential breeding sites like discarded tires, flowerpots, containers, and puddles where water accumulates are essential. Furthermore, the use of larvicides can help eliminate mosquito larvae in stagnant water, while using mosquito screens or nets can prevent mosquitoes from infiltrating living spaces. In addition to various mosquito control measures, studies indicate that *Bacillus thuringiensis*, often referred to as “Bt,” can serve as a successful larvicide against mosquito larvae. The Sterile Insect Technique (SIT) has proven effective in numerous nations for managing mosquito populations, although its ecological consequences are not clearly understood [25]. Furthermore, scientists are exploring the potential of *Wolbachia*, a bacterium that naturally occurs in mosquitoes and various insects, as a means to manage mosquito populations. The concept involves releasing male mosquitoes containing *Wolbachia* into selected regions. These *Wolbachia*-infected male mosquitoes subsequently mate with indigenous wild female mosquitoes. This mating process results in unhatched eggs, consequently decreasing the population of *Aedes aegypti* mosquitoes, which are the primary carriers of the dengue virus [26].

Protective measures: Wearing long-sleeved shirts, long pants, socks, and shoes in areas where mosquito activity is high, especially during dawn and dusk, could protect from mosquito bites. Using mosquito repellent on exposed skin and clothing, seeking shelters in screened areas, and using mosquito nets could also provide protection against mosquito bites.

Community and public health initiatives: Identifying and cleaning up potential mosquito breeding sites in the community, campaigning and raising awareness about dengue prevention and control, educating students about dengue prevention through school programs, and implementing travel restrictions to and from dengue-infected areas, could play a significant role in dengue prevention.

Dengue Vaccines: There are several challenges in developing an effective dengue vaccine – simply because of the complexities of formulating a tetravalent vaccine, and in conducting an efficacy trial against all four serotypes. At least seven DENV vaccines have undergone different phases of clinical trials; they include: (1) tetravalent, live-attenuated vaccines, (2) chimeric live attenuated vaccines, (3) inactivated vaccines, (4) subunit vaccines, and (5) nucleic acid-based vaccines. However, only three of them (Dengvaxia®, Odenga or TAK-003, and TV003/005) have showed promising results in several studies [27-29]. Table-2 summarizes the three vaccines with promising efficacy against dengue infection.

Dengvaxia® is a tetravalent live-attenuated dengue vaccine (LATV), which received authorization in 2022 for use in children, aged 9 to 16 with a confirmed history of dengue infection and living in dengue-endemic regions [27]. This vaccine is only for individuals with prior dengue infections. If given to individuals without a previous infection who later contract the virus, the risk of severe dengue is high. The vaccine's effectiveness is achieved through a three-dose regimen, with each dose spaced 6 months apart. Until now, among all the available vaccines, Dengvaxia protects children from dengue illness, hospitalizations, and severe dengue 8 out of 10 times (80%) in children who had dengue before vaccination. The vaccine protects against all four dengue virus serotypes [29].

Qdenga (TAK-003), a dengue tetravalent vaccine, is recommended by the World Health Organization (WHO) for children aged 6 to 16, irrespective of their previous dengue infection history. Therefore, a laboratory-confirmed dengue infection is not a prerequisite. This vaccine is administered as a two-shot series with a 3-month interval [29].

TV003/TV005 is a tetravalent live-attenuated dengue vaccine. It is produced by the National Institute of Allergy and Infectious Diseases (NIAID) of the United States and the Butantan Institute in Brazil. Of the five LATV formulations that were evaluated, TV003 and TV005 induced the most balanced neutralizing antibody responses [29]. TV005 is an improved version of TV003; it significantly increases seroconversion and antibody titers against DENV2.

A recent clinical trial of TV005 focusing on safety and immunogenicity has been successfully carried out in Bangladesh [30]. The study demonstrated that by 180 days post vaccination, 83%, 99%, 96%, 87% vaccine recipient were found seropositive to DENV1, DENV2, DENV3 and DENV4 respectively. Antibody titers to all serotypes remained stable in 63-86% adults after 3 years of follow-up. However, the antibody titters declined in individuals without past exposure to dengue by 3 years.

However, it's essential to recognize that the dengue vaccine can have specific side effects, including soreness, itching, headaches, fatigue, and general discomfort. In rare instances, individuals may experience fainting after vaccination, and there is a minimal risk of a severe allergic reaction triggered by the vaccine [30]. It is advisable to consult with a healthcare professional before considering vaccination.

Table-2: *Comparison of available vaccines for dengue [27-29]*

Name, composition and dose of the vaccine	Immunogenicity	Efficacy	Advantages and Disadvantages
Dengvaxia (CYD-TDV). Sanofi, Pasteur, France. **Composition**: Tetravalent, live-attenuated chimeric vaccine. CYD-TDV was constructed by substituting prM and E genes from DENV1–4 into the backbone of yellow fever 17D vaccine strain (YFV-17D. Four chimeric namely CYD-DV1–CYD-DV4) compose the CYD-TDV. **Dose**: 3-dose series on a 0/6/12 month schedule.	In all age groups, combined seropositivity rates 28 days after the 3rd dose: 77.1% to 94.1% for all serotypes	60% against symptomatic dengue. Protects children from dengue illness, hospitalizations, and severe dengue 8 out of 10 times (80%) in children who had dengue before vaccination. Effective against all four dengue virus serotypes.	**Advantages**: Recommended for people who have had dengue before. Protects children against dengue for at least 6 years and reduces the chance of hospitalization and severe dengue to 20%. **Disadvantages**: Vaccine may exacerbate the risk of severe disease after infection through a mechanism called antibody-dependent enhancement.
Qdenga (TAK-003) or DENVax. Takeda Pharmaceutical Company Limited, Japan. **Composition**: Recombinant chimeric attenuated vaccine. prM and E genes of DENV1, 3 and 4, are inserted into DENV-2 PDK53 backbone. **Dose**: 2 dose series -0/3 month	Seropositivity rates : 97.3%, 98.7%, 88.0%, and 56.0% for DENV-1, -2, -3 and -4, respectively at 36 month (Phase-2 trial)	Cumulative efficacy approximately 27 months since first dose: 72.7% (CI: 67.1%,77.3%), including 67.0% (95% CI, 53.6%–76.5%) in dengue-naïve and 89.2% (95% CI, 82.4%–93.3%) against hospitalized dengue.	**Advantages**: TAK-003 targets all four serotypes of dengue virus, **Disadvantages**: Efficacy varies by serotype. Protective effect against DENV-3 and DENV-4 is lower than that of DENV-1 and DENV-2.
TV003 /TV005. NIAID, USA and the Butantan Institute in Brazil. **Composition**: Tetravalent, chimeric live-attenuated vaccine. Constructed by 30-nucleotide (Δ30) deletion into 3' UTR region of DENV-1, 3 (+additional 31 nucleotide deletion) and 4. rDENV-2 strain composed of an rDEN4Δ30 backbone with the precursor pre-membrane (prM) and E genes of DENV-2 **Dose**: Single dose	A single dose of either TV003/TV005 induces sero-conversion to 4 DENV serotypes in 74% -92% byTV003 and 90% byTV005 in sero-negative adults. Induces near-sterilizing immunity following 2nd dose of vaccine administered 6-12 months later.	TV003/TV005 showed good immune protection efficacy in single-dose immune experiments.	**Advantages**: No significant difference between TV003 and TV005 regarding the rate of adverse events. TV003/TV005 caused 75% to 77% vaccine viremia in recipient. Single dose of TV003/TV005 elicits strong sero-conversion. Compared to TV003, TV005 significantly increases seroconversion frequency and overall antibody titers against DENV2. **Disadvantages**: Vaccinees tend to develop rashes after vaccination with TV003/TV005.

Note: NIAID : National Institute of Allergy and Infectious Diseases

Discussion

Dengue is an endemic disease in many countries. While cases can crop up anywhere, they typically occur in tropical and subtropical regions where rainfall and humidity are high. Dengue fever is primarily prevalent during the rainy season. There are an estimated 400 million dengue cases that occur throughout the world each year. Of those, approximately one in four, or 96 million, results in illness [8,14]. It is considered a significant public health issue, and its impact is felt worldwide.

In Bangladesh, dengue is an endemic disease that primarily surfaces during the monsoon season. In recent years dengue infection in Bangladesh has been significantly high, creating significant pressure on the healthcare system which is not fully prepared to tackle this added stress. Since the vector carrying the virus is a mosquito, it is easily comprehendible that the eradication of mosquito breeding sites would produce significant progress in dengue prevention and control in Bangladesh. Due to the high population density and rapid urbanization, the risk of re-infection from dengue remains a formidable challenge in Bangladesh, and controlling the situation remains a concern.

The climatic conditions in Bangladesh are progressively becoming more conducive to the transmission of dengue and other vector-borne diseases such as malaria and chikungunya. This change is attributed to factors like excessive rainfall, water logging, flooding, rising temperatures, and significant alterations in the country's traditional seasonal patterns [8].

In Bangladesh, the dengue situation in 2023 is cause for serious concern, with a significant increase in both the number of dengue cases and related fatalities compared to the past five years. The dengue virus has affected all 64 districts of Bangladesh. The surge in dengue cases began in May 2023 and has persisted since then [9,10,11]. However, because of possibility of under reporting, it is assumed that the actual figures for both cases and fatalities may be considerably higher than the reported numbers.

Based on a survey run by the Directorate General of Health Services (DGHS), in the earlier part of 2022 (pre-monsoon), there was an increased concentration of *Aedes* mosquitoes in Dhaka, exceeding the levels recorded in 2021. Experts in the Communicable Disease Control (CDC) unit of the DGHS had foreseen a deteriorating dengue situation in Dhaka city for this year unless proactive measures were implemented. A follow-up survey, (monsoon) produced in September, indicated that the mosquito population in Dhaka city doubled compared to the pre-monsoon assessment [[9,10,11]. Therefore, this current outbreak could have been predicted. The reports from the CDC should have been treated with utmost seriousness, and prompt, well-targeted measures from the relevant agencies could have played a crucial role in alleviating the ongoing crisis.

The fundamental aspect of dengue prevention is safeguarding the population from dengue virus transmission. There is no alternative to individual and social awareness and governmental engagement for dengue control. Mosquito and larva eradication efforts must be undertaken at both the government and private levels. The examples of school, college, and community-based voluntary initiatives are not new in Bangladesh. Social and political organizations must take a proactive role. Additionally, using mosquito nets and mosquito repellent creams at home could provide essential avoidance from mosquitoes.

This review is limited by the fact that a literature review of similar nature is prone to bias, which could be reduced by a systematic review. Since this study did not follow a systematic review methodology, the search strategies did not warrant a comprehensive review. Further, this study included data for about 22 years, primarily using the outbreaks reported from Bangladesh. In addition, the review did not use a systematic method of reducing the risk of bias assessment by meta-analysis of the data.

Conclusions

Dengue prevention and control in Bangladesh and other dengue endemic countries of the region require a dedicated multi-pronged approach involving individual, social, and government efforts. Additionally, the global impacts of dengue also highlight the need for coordinated efforts in surveillance, research, and preventive measures to combat the spread of the disease and its detrimental consequences on public health and economies worldwide.

Competing interest

No competing interest/conflict of interest.

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