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تفشى السعال الديكي في أجدابيا بين الرضع اللذين تقل اعمارهم عن سنة: دراسة حالة التطعيم ووبائية وشدة المرض

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Outbreak of Pertussis in Ajdabiya among infants under one year old: Epidemiology, vaccination status and disease severity

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Abstract:

Pertussis, commonly known as whooping cough, remains a significant global public health challenge, with infants under one year old facing the highest risk of severe complications and mortality. This retrospective descriptive study aimed to analyze the epidemiology, vaccination status, and disease severity during a pertussis outbreak in Ajdabiya, Libya, from October 2025 to April 2026. The study included 65 infants diagnosed with pertussis at the Central Hospital of Ajdabiya. Data were collected from medical records and laboratory results and analyzed using SPSS. The results revealed that infants under three months old were the most affected (70.8%). A substantial immunity gap was identified, as 100% of the infants' mothers had not received the Tdap vaccine during pregnancy, and 69.2% of the infants were unvaccinated. Clinical analysis showed that 87.7% of infants exhibited paroxysmal coughing, while 60% experienced life-threatening apnea and cyanosis. Malignant pertussis occurred in 20% of cases, with mortality reaching 10.8%. Statistical analysis indicated a strong correlation between the quality of supportive care and survival outcomes (p=0.000, Spearman correlation=0.815). The findings underscore the critical vulnerability of newborns due to the absence of maternal antibodies and delayed primary vaccination. The study strongly recommends incorporating the Tdap vaccine into the national immunization program for pregnant women, alongside strict adherence to vaccination schedules and the implementation of standardized supportive care protocols to reduce morbidity and mortality in resource-limited settings.

Keywords: Pertussis, Outbreak, Infants, Disease Severity, Vaccination, Ajdabiya.

الملخص

لا يزال السعال الديكي يشكل تحدياً كبيراً للصحة العامة على مستوى العالم، حيث يواجه الرضع دون سن السنة أعلى مخاطر الإصابة بالمضاعفات الشديدة والوفاة. تهدف هذه الدراسة الوصفية الاستعادية إلى تحليل الوبائيات، وحالة التطعيم، وشدة المرض خلال تفشي السعال الديكي في مدينة أجدابيا، ليبيا، في الفترة من أكتوبر 2025 إلى أبريل 2026. شملت الدراسة 65 رضيعاً تم تشخيص إصابتهم بالسعال الديكي في مستشفى أجدابيا المركزي. تم جمع البيانات من السجلات الطبية ونتائج المختبر وتحليلها باستخدام برنامج .SPSS أظهرت النتائج أن الرضع دون سن ثلاثة أشهر كانوا الأكثر تضرراً (70.8%). كما تم تحديد فجوة مناعية كبيرة، حيث لم تتلق 100% من أمهات الأطفال لقاح Tdap أثناء الحمل، وكان 69.2% من الرضع غير ملقحين. وأظهر التحليل السريري أن 87.7% من الرضع عانوا من سعال نوبي، بينما عانى 60% من توقف التنفس والزرقة المهددة للحياة. حدث السعال الديكي الخبيث في 20% من الحالات، وبلغت نسبة الوفيات 10.8%. وأشار التحليل الإحصائي إلى وجود ارتباط قوي بين جودة الرعاية الداعمة ونتائج البقاء على قيد الحياة($p=0.000$) ، ارتباط سبيرمان=0.815 .(تؤكد النتائج على الضعف الشديد لحديثي الولادة بسبب غياب الأجسام المضادة للأم وتأخر التطعيم الأولي. توصي الدراسة بشدة بإدراج لقاح Tdap في برنامج التحصين الوطني للحوامل، إلى جانب الالتزام الصارم بجداول التطعيم، وتنفيذ بروتوكولات رعاية داعمة موحدة لتقليل معدلات المراضة والوفيات في البيئات محدودة الموارد.

الكلمات المفتاحية: السعال الديكي، تفشي، رضع، شدة المرض، تطعيم، أجدابيا.

1.Introduction

Pertussis, commonly known as whooping cough, is a highly contagious acute respiratory infection that has posed a significant threat to human health for centuries. Historically, the disease was associated with millions of infections and hundreds of thousands of deaths annually. Although widespread vaccination programs in the 1940s and 1950s led to a dramatic decline in cases, a sudden resurgence has been observed recently, with the disease re-emerging as a significant public health threat over the past two decades (Pertussis, 2024). While pertussis affects individuals of all ages, it is of greater clinical significance in infants—particularly those under six months of age who have not completed their primary vaccination series—as they suffer from the highest rates of severe complications and mortality (Chatterjee & Sungjun, 2018; Heininger et al., 2010).

1.1. Pertussis Overview

The primary causative agent of pertussis is Bordetella pertussis, a small, aerobic, Gram-negative coccobacillus that exclusively infects humans. Transmission occurs via respiratory droplets expelled during coughing or sneezing, making it one of the most contagious diseases, with attack rates reaching 80% to 100% in high-risk groups (Skowronski et al., 2012). Once inhaled, the bacteria colonize the ciliated epithelial cells of the upper respiratory tract using adhesive substances, such as filamentous hemagglutinin (FHA) and pertactin (PRN).

The bacteria secrete potent toxins, which serve as the primary virulence factors. In severe cases, Pertussis toxin (PT), an AB5 exotoxin, enters the bloodstream and disrupts host cell signaling by inhibiting the *Gi* protein and increasing intracellular cAMP levels. This leads to systemic effects, such as lymphocytosis and the inhibition of phagocytic cell depolarization, allowing the pathogen to evade the initial immune response. This progression can result in malignant pertussis, characterized by pulmonary hypertension, respiratory failure, and cardiac arrest (Chatterjee & Sungjun, 2018; CDC, 2024).

Clinical presentation typically follows three stages. The catarrhal stage (one to two weeks) is characterized by high bacterial shedding, making patients most infectious during this phase. This is followed by the spasmodic stage (two to six weeks), marked by violent coughing fits often terminating in a "whoop"—a sharp noise produced by forced inspiration through a

narrowed airway, caused by the buildup of mucus and cellular debris due to tracheal cytotoxin-induced cilia paralysis (Chatterjee & Sungjun, 2018).

Symptoms vary by age. Infants under six months often lack the characteristic paroxysmal cough, presenting instead with apnea, cyanosis, and bradycardia. Conversely, adolescents and adults frequently experience a chronic, non-specific cough. Because these older groups often present with milder symptoms, they are frequently misdiagnosed, acting as "silent" reservoirs that transmit the bacteria to vulnerable newborns (Chatterjee & Sungjun, 2018; Heininger et al., 2010; CDC, 2024). Severe complications include nutritional deficiencies, seizures, and physical injuries like subconjunctival hemorrhages or rib fractures; in rare instances, systemic hypoxia or internal trauma during convulsions may cause altered consciousness (Chatterjee & Sungjun, 2018).

Malignant pertussis, which is life-threatening, occurs primarily in unvaccinated infants under three months of age. It presents with extreme leukocytosis (often exceeding 50–100x10^9 cells/L), pulmonary hypertension, and multi-organ failure, leading to a mortality rate of approximately 50% (CDC, 2024).

Diagnosis in infants often relies on clinical signs and routine blood counts, termed a "clinical diagnosis." However, a "laboratory-confirmed" diagnosis requires direct etiological evidence, such as PCR or bacterial culture (CDC, 2024). PCR is the preferred international method due to high sensitivity (90%), though it decreases as symptoms persist, often becoming unreliable after three to four weeks. Bacterial culture remains the "gold standard" but is limited by long processing times and potential interference from prior antibiotic use. Serological testing is valuable for patients symptomatic for two to four weeks; measuring anti-PT IgA is particularly specific as it is less influenced by vaccination than IgG (Chatterjee & Sungjun, 2018; CDC, 2024).According to 2024 expert consensus, a formal clinical diagnosis in children can be established with a peripheral white blood cell count ≥ 20x10^9 L and a lymphocyte count ≥ 10 x10^9 L, combined with characteristic symptoms or a clear epidemiological link (CDC, 2024). In resource-limited settings, clinical suspicion remains vital, supported by indicators such as intermittent respiratory distress and post-tussive vomiting (Chatterjee & Sungjun, 2018; Skowronski et al., 2012; Heininger et al., 2010).

Effective treatment requires early initiation—ideally during the catarrhal stage—to reduce symptom severity and transmission. Macrolide antibiotics, such as azithromycin, are the preferred first-line choice. For infants under two months or severe cases, intravenous beta-lactams are often utilized (Chatterjee & Sungjun, 2018; CDC, 2024). Intensive supportive care, including mechanical ventilation and techniques to reduce white blood cell counts, is critical for malignant pertussis, whereas conventional treatments like steroids and bronchodilators have not proven effective (CDC, 2024).

1.2. Vaccination Coverage

Pertussis vaccines are available in two primary forms: whole-cell vaccines (wP), which utilize inactivated whole bacteria to stimulate broad, durable immunity; and acellular vaccines (aP), which contain purified bacterial antigens—such as pertussis toxin (PT) and filamentous hemagglutinin (FHA)—to elicit a targeted immune response. The globally adopted immunization schedule comprises a primary three-dose series in infancy, with specific Tdap booster doses recommended for adolescents and pregnant women (World Health Organization [WHO], 2019).

Whole-cell pertussis vaccines (DTP3) have been utilized extensively since their development in the mid-20th century and remain integral to national immunization programs in many developing regions. According to the WHO (2019), approximately 85% of children globally receive the initial pertussis vaccine dose, predominantly in the wP formulation due to cost-effectiveness and vaccine availability. While developed nations frequently achieve coverage rates exceeding 90%, the vaccine formulation varies by jurisdiction. Countries such as the

United States, Canada, and several European nations have transitioned to aP vaccines to leverage their superior safety profiles (WHO, 2019).

Conversely, in many developing nations across Africa, Asia, and Latin America, the wP vaccine remains the primary choice, valued for its lower cost and robust immunogenicity, notwithstanding its higher reactogenicity (WHO, 2019). Developed nations, including the United Kingdom and Australia, transitioned to aP vaccines in the late 1990s and early 2000s to reduce common adverse effects, such as pyrexia and injection-site reactions; however, these transitions have prompted ongoing discourse regarding the duration of vaccine-induced immunity (WHO, 2019).

Libya's transition to acellular vaccines reflects broader regional and global efforts to prioritize safety and enhance public trust in immunization programs (WHO, 2019). Historically, Libya maintained high childhood coverage (exceeding 95%) for the wP formulation. The 2013 shift to the aP formulation was intended to minimize mild side effects, such as fever and irritability, and to align with contemporary international standards. Although associations between wP vaccines and permanent neurological damage have been refuted, they have been linked to rare adverse events, including febrile seizures and hypotonic-hyporesponsive episodes (HHE), occurring in approximately 1 out of 1,500–2,000 doses (WHO, 2019).

Libya's current infant immunization schedule includes a primary series of three doses at 2, 4, and 6 months using a hexavalent vaccine (DTaP-HB-IPV-Hib), followed by a pentavalent booster (DTaP-IPV-Hib) at 18 months (WHO, 2019). Despite high childhood coverage, Libya does not currently incorporate the Tdap vaccine for pregnant women or adults. Local research (2023–2024) has identified a critical "absolute immunity gap," observing that 98.5% of pregnant women in Libya were seronegative for pertussis antibodies at delivery (Abusrewil et al., 2025a, 2025b). Consequently, newborns frequently lack passive transplacental immunity, rendering them highly susceptible to pertussis during the initial two months of life prior to receiving their first dose (Abusrewil et al., 2025a, 2025b).

1.3. Epidemiology

Pertussis remains a significant global health challenge, characterized by a notable resurgence since the 1980s despite high vaccination coverage in many nations. Historically, the disease was associated with millions of infections and hundreds of thousands of deaths annually. Although incidence declined following the introduction of mass vaccination in the 1940s and 1950s, a sudden increase has been observed recently. In 2024, global reports indicated a 476% rise in cases compared to 2023, with over 941,565 recorded cases, driven primarily by outbreaks in the Western Pacific and European regions (Pertussis, 2024).

The global epidemiological pattern has shifted; the peak incidence has transitioned from children under five to include adolescents and adults. This demographic serves as a primary reservoir, often exhibiting mild or atypical symptoms, such as the "hundred-day cough," which frequently goes undiagnosed. This results in the "silent" transmission of *Bordetella pertussis* to vulnerable, unvaccinated infants (Pertussis, 2024). While infants under one year remain at the highest risk for severe complications, such as malignant pertussis, the rising incidence among school-aged children highlights a growing immunity gap (Heininger et al., 2010).

Several factors contribute to this resurgence, including waning vaccine-induced immunity and the global transition from whole-cell (wP) to acellular (aP) vaccines in high-income countries. Although aP vaccines offer an improved safety profile, they are associated with a shorter duration of protection and are less effective at preventing nasal colonization, thereby facilitating asymptomatic transmission (Chatterjee & Sungjun, 2018). Furthermore, immunity from aP vaccines wanes significantly within 4 to 10 years post-vaccination, leaving adolescents and adults susceptible (Chatterjee & Sungjun, 2018).

Pathogen evolution also plays a critical role. *B. pertussis* has mutated to evade vaccine-induced immunity, leading to the emergence of "vaccine-escape" strains, particularly the ptxP3 lineage.

This genotype, which overproduces pertussis toxin (PT), has largely replaced the ancestral ptxP1 genotype worldwide and is linked to higher rates of hospitalization and mortality (Chatterjee & Sungjun, 2018; Pertussis, 2024). Many circulating strains also lack the pertactin (PRN) protein—the specific antigen targeted by most aP vaccines—further facilitating immune evasion (Chatterjee & Sungjun, 2018). Additionally, in regions like mainland China, the emergence of macrolide-resistant ptxP3 strains has further complicated outbreak management (Pertussis, 2024).

The COVID-19 pandemic exacerbated this situation by creating a temporary "immunity gap." Lockdowns and social distancing led to a 33% global decline in routine vaccination rates and prevented natural boosting through community exposure (Pertussis, 2024). With the relaxation of these measures in 2023 and 2024, populations with low baseline immunity experienced significant surges, such as in China, where cases in the first half of 2024 were 54 times higher than the previous year (Pertussis, 2024).

1.4. Local Context in Libya

The epidemiological landscape in Libya presents a paradox: high vaccine coverage rates contrasted with a rapid loss of protective immunity during early childhood. While Libya has maintained DTP3 coverage exceeding 95% for over 25 years, official case reports are believed to significantly underestimate the true burden due to limited diagnostic capacity and surveillance (World Health Organization [WHO], 2019). A 2015 study in Tripoli revealed that 76.1% of children aged 5 to 7 years had undetectable levels of IgG antibodies against pertussis toxins despite having received four infant doses, indicating widespread circulation among vaccinated children (WHO, 2019). Furthermore, a multi-center study (2023–2024) identified a critical vulnerability: 98.5% of pregnant Libyan women were seronegative at delivery. Given the lack of a routine maternal Tdap program, newborns remain unprotected during their first two months of life (Abusrewil et al., 2025a, 2025b).

1.5. Seasonality

Pertussis seasonality is highly variable and does not follow a uniform pattern. While infections occur year-round, peaks are often observed in summer and autumn, influenced by climate and social factors like school attendance (Chatterjee & Sungjun, 2018; Heininger et al., 2010; Pertussis, 2024). North American studies have noted autumn/winter concentrations, whereas British Columbia and the Netherlands reported peaks in August and September. England has shifted toward a bimodal distribution with spikes in September and February, a pattern also observed in Senegal (Chatterjee & Sungjun, 2018). The COVID-19 pandemic further disrupted these trends, resulting in irregular growth patterns and winter surges, particularly in China, where the lack of prior exposure fueled these anomalies (Pertussis, 2024).

1.6. Study Objectives

Given the recent outbreaks in several Libyan cities, pertussis has emerged as a significant public health concern. Consequently, the primary aim of this study is to assess the severity of this recurring epidemic in the city of Ajdabiya. This research seeks to evaluate vaccination status, investigate transmission dynamics, identify immunity gaps in infants under one year of age, and provide evidence-based recommendations for effective management and preventive strategies.

2.Method

2.1. Study design

The researchers conducted retrospective descriptive case series at the central hospital of Ajdabyia city, Eastern Libya, which was the only facility responsible for admitting all hospitalized infants in the city. The study sample included every infant under 12 months who was diagnosed with pertussis. The data collection period during outbreak of pertussis from

October 1st 2025 until end of April 2026. The data source was the existing medical records and blood count data that pediatricians had already collected.

2.2. Data Collection; A questionnaire was designed focusing on the following, Clinical signs: Immunity gap , Markers of disease severity and Administrative interventions

2.2.1. Clinical signs ;The data collected by the researchers aligns with the 2024 experts' agreement on diagnosis and includes: The presence of hallmark signs as paroxysmal coughing and post-tussive vomiting, the presence of apnea, cyanosis (skin turning blue), or slow heart rate. These are among the most reliable indicators of severity in infants who often lack the typical cough. Laboratory indicators were the highest white blood cell count. It's important to monitor high WBC (WBC > 50×10^9/L) to identify cases at risk of 'Malignant pertussis' and death

2.2.2. Immunity Gap:

2.2.2.1. Mother's Status: Researchers recorded whether the infants' mothers had received a Tdap vaccine between weeks 27 and 36 of pregnancy. (The maternal vaccine is 91% effective in preventing the disease in kids under 3 months old)

2.2.2.2.Infant's Status:

the researchers recorded the number of DTaP or hexavalent vaccine doses the infant received? (Full protection is only achieved after 3 doses) And they recorded the exact number of weeks since the last vaccine to assess active immunity or waning immunity.

2.2.3. Markers of disease Severity

The researchers recorded life-threatening signs like breathing stopping (Apnea), bluish skin (Cyanosis), or slow heartbeats (bradycardia). They also noted complications like Encephalopathy, Pulmonary hypertension, pneumonia, and signs of Malignancy like elevation of white blood cell counts over 50×10^9/L, which is one of the strongest indicators of death, and resistant Pulmonary Hypertension

2.2.4. Administrative interventions:

One of the researchers is the head of the Pediatrics and Neonatology Department at the hospital that received the infants. He, along with her colleagues, set up a protocol to treat the disease and prevent its complications, which was followed during the pertussis outbreak in Ajdabiya in 2025. Most patients arrived at the hospital with severe symptoms, and all of them needed to be hospitalized. The protocol focused on supportive care, and the researchers recorded the levels of supportive care, which included basic and advanced care. They recorded the first-line antibiotic treatment given (azithromycin, once daily for five days), the second-line antibiotic (like cephalosporins for pneumonia), taking of Luminal syrup (to reduce seizures), oxygen therapy (oxygen mask), receiving of IV fluids, and bronchodilators. For advanced supportive care when white blood cell levels rise above 50×10^3 (malignant pertussis), the patient received double the amount of IV fluids from usual amount , and some were given hydroxyurea 20 mg/kg of the infant's weight for 3-5 days, up to a maximum of 7 days, with monitoring of white blood cell levels, or therapeutic plasma exchange, or mechanical ventilation, or continuous positive airway pressure (CPAP) depending on the patient's condition, and all of this was recorded by the researchers. Condition status was recoreded if the case cured upon discharge from the hospital, or did the infant die?

2.2.5.Statistical analysis

The researchers used SPSS program to analyzed processed data and chose descriptive statistics to give a clear picture of the outbreak: Percentages: .They determined the median age of affected infants and the median white blood cell count at diagnosis. The results were divided by age to show that younger children had higher severity.\, percentage of threaded life signs and complications to give a clear picture of the severity : They also looked at the study months to see the seasonality of the disease. The researchers used the chi-square test (χ^2) , Mann Whitney and Fisher tests at significant level ($P < 0,05$) to study the relations between variables

3.Results

3.1. Demographic Characteristics

The study included 65 infants, detailed below by age group, month, and gender: showed the highest number of cases in the youngest age group, with a sharp decline in frequency as age increased. Most Vulnerable Group: Infants aged less than 3 months were the most affected, representing (70.8%) of all case

Table 1- Age distribution of pertussis patients

Age Groups	Frequency (Cases)	Percentage	Descriptive	
(< 1 - 3) Months	46	70.8	Mean	3.1692
(4-7) Months	14	21.5	Meadian	2.0000
(8-11) Months	5	7.7	Mode	2.00
Total	65	100.0	Std. Deviation	2.49104

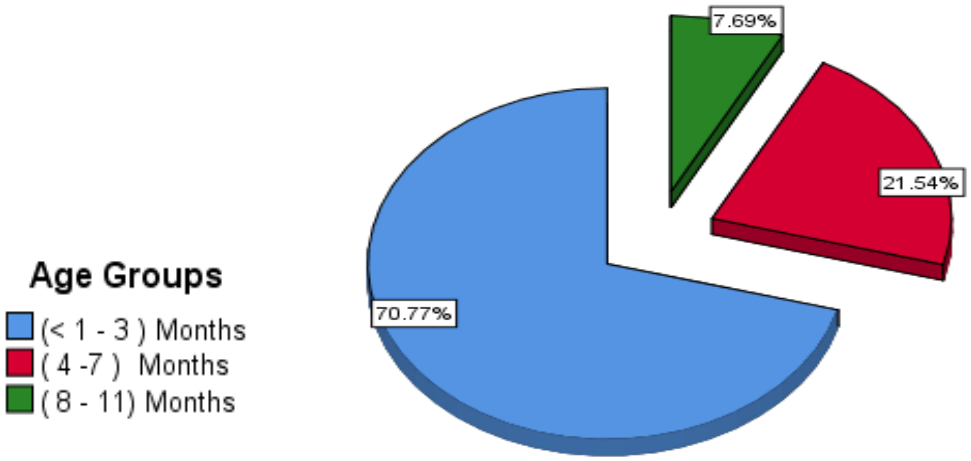

Fig 1.- Age distribution of pertussis patients

There wasn't a significant difference in infection rates between genders, with males making up 50.8% and females 49.2%.

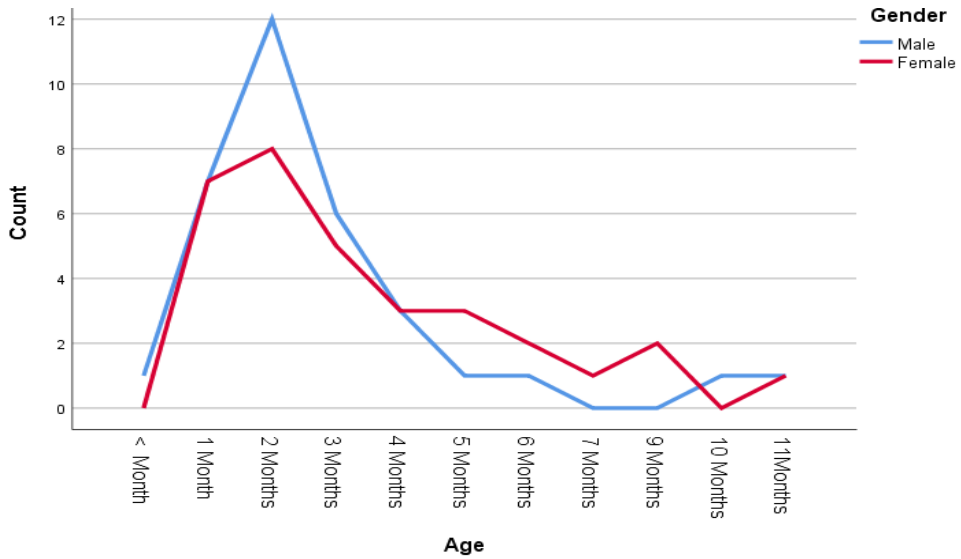

Fig. 2 . Incidence of pertussis according to Gender

3.2. Seasonality of Pertussis

The outbreak peaked in February 2026, (36.9%) accounting for more than a third of the total cases during the study period. Followed by March 2026 (24.6%).

Table 2-Incidence of pertussis according to Months of the study

	Months of the study	Frequency (Cases)	Percentage %
	October 2025	4	6.2
	November 2025	1	1.5
	December 2025	10	15.4
	January 2026	10	15.4
	February 2026	24	36.9
	March 2026	16	24.6
	Total	65	100.0

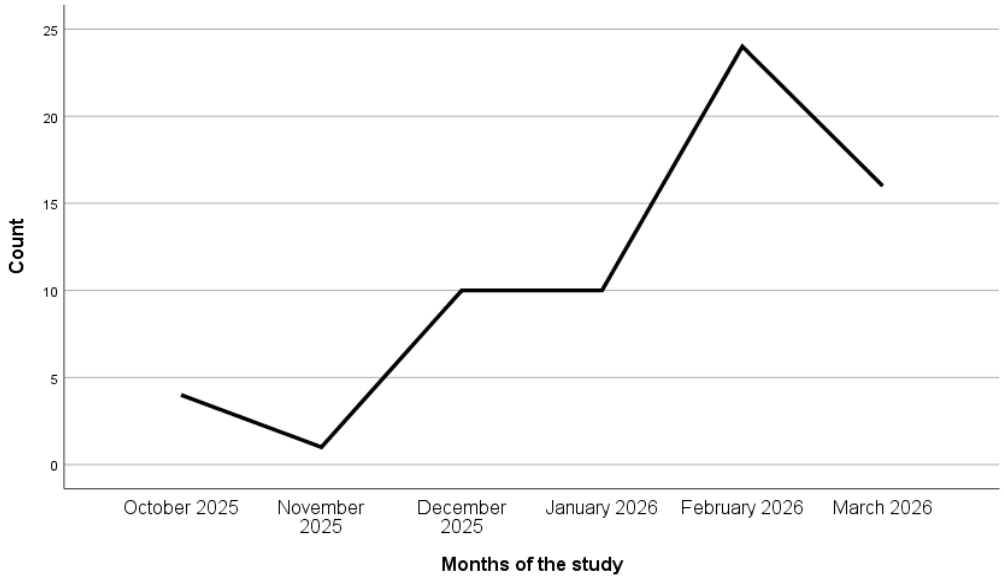

Fig.3.-Incidence of pertussis according to Months of the study

3.3. Vaccination status

Among the 65 infants studied, their vaccination distribution was as follows: 45 infants (69.2%) had not received any dose of TD aP vaccine , 13 infants (20.0%) had received the first dose, 4 infants (6.2%) had received the second dose and 3 infants (4.6%) had received the third dose The data shows a strong correlation between age and vaccination status, with the youngest infants being the least protected. In the age group that was most affected (<1–3 months), 84.8% (39 out of 46) hadn't received any vaccinations at all. No child in this group got the third dose, which is considered necessary for full protection. While the number of unvaccinated infants decline to zero in the 8–11 months group, only 40% (2 out of 5) of these infants had completed the three-dose series. Regarding mothers' vaccination, all 65 participating mothers (100%) were reported as not having received vaccination during their pregnancy.

Table 3. Vaccination coverage of study population

		Vaccination Status of Infants				Total
		Unvaccinated	**First dose**	**Second dose**	**Third dose**	
Age Groups	(< 1 - 3) Months	39	6	1	0	46
	(4-7) Months	6	4	3	1	14
	(8-11) Months	0	3	0	2	5
Total		45	13	4	3	65

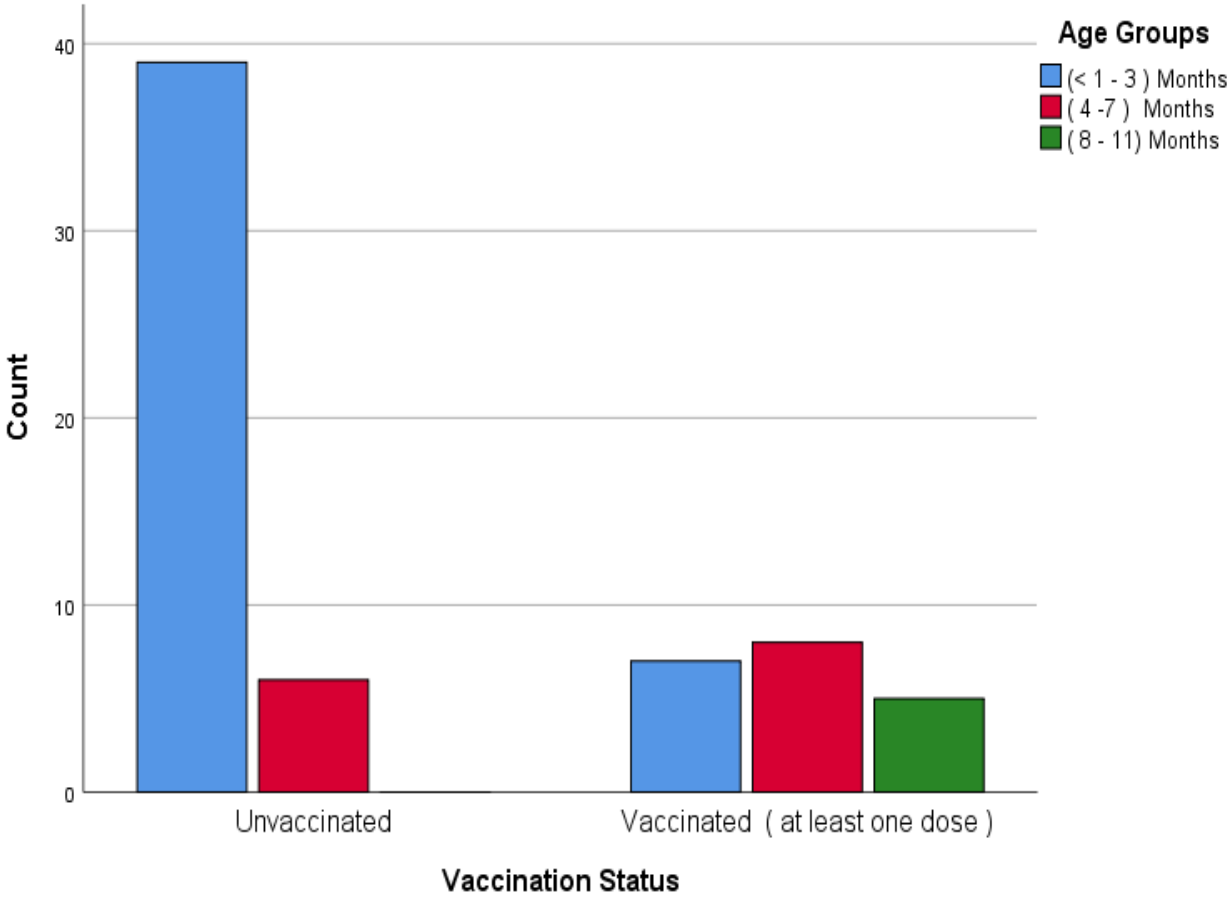

Fig.4. Vaccination coverage of study population

3.4.Clinical Presentation

3.4.1.Cough Characteristcs ; cough characteristics among 65 participants are summarized as follows: participants (87.7%) exhibit paroxysmal coughing High-pitched inspiratory "whoop" and post-tussive vomiting, , 4 participants (6.2%) exhibit same signs except vomiting after coughing: and 4 participants (6.2%) exhibit mild signs

3.4.2.Life-threatening signs: The combination of Apnea and Cynosis was the most common severe symptom, occurring in 60% (39 cases). Cynosis alone was observed in 30.8% (20 cases). Apnea alone was the least common severe sign, seen in 3.1% (2 cases). Only 6.2% (4 cases) didn't show any of these life-threatening signs.

Table .4.frequency of life threatening signs in the study population

Life-Threatening Signs:					
		Frequency	Percent	Descriptive Statistics	
	Non	4	6.2	Mean	2.4462
	Apnea (Stopped breathing).	2	3.1	Median	3.0000
	Cyanosis (Turning blue/purple).	20	30.8	Mode	3.00
	Apnea and Cyonsis	39	60.0	Std. Deviation	.82974
	Total	65	100.0		

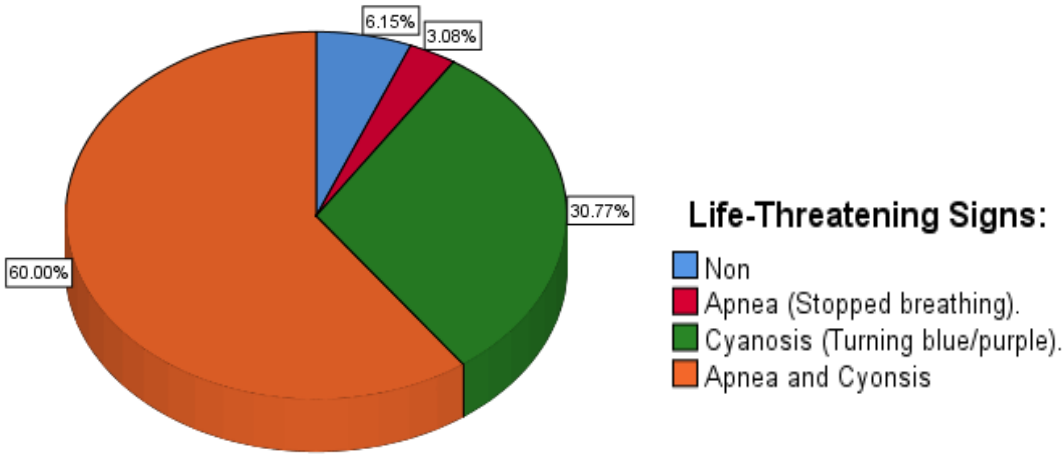

Fig.5 Percentages of life-threatening signs in the study population

3.4.3. Complications

The clinical outcomes for 65 patients were as follows: 32 patients (49.2%) didn't experience any complications. The most common complications were bronchopneumonia, affecting 40% (26 patients) without other complications. Similarly, 1.5% (one patient) suffered from encephalopathy, in addition , 7.7% (5 patients) had a combination of encephalopathy, pulmonary hypertension, and pneumonia at the same time.

Table.5. Percentages of Pertussis 's complications in the study population

Complications	Percentage %
No	49.2
Encephalopathy	1.5
Bronchopneumonia	40.0
Pulmonary hypertension	1.5
Encephalopathy, Bronchopnemonia & Pulmonary hypertension	7.7
Total	100.0

3.4.3.1-Malignant disease incidence

Cases were classified based on the level of white blood cell count as follows: Non-Malignant cases (WBC 16–50 × 10^9/L) Malignant pertussis (WBC > 50 × 10^9/L) The statistical analysis of 65 pertussis cases revealed the following: 80% (52 cases) were non-malignant, while 20% (13 cases) were classified as malignant.

3.4.3.1.1. Impact of Vaccination on Malignant Disease incidence

Unvaccinated infants (45), 8 of them (17.8%) developed a malignancy. Among those who received the first dose (13 infants), 5 of them (38.5%) developed a malignancy, which is the highest percentage among the groups. Among those who received two doses (4 infants), no malignant cases were recorded (0%). Among those who received three doses (3 infants), no malignant cases were recorded (0%). The Fisher's exact test showed a two-tailed significance (p-value) of 0.517 when the researchers compared infants who had at least one dose with unvaccinated infants. The researchers found this value much higher than the standard threshold of 0.05, so they did not reject the null hypothesis—that is, vaccination status and Incidence of Malignant pertussis are independent of each other.

Table .6. Incidence of Malignant Pertussis Among Vaccinated and Unvaccinated infants

		Non-Malignant Cases (WBC s ≥ 16-50×109/L	**Malignant Pertussis** (WBCs > 50- 120 ×109/L)	**Total**
Unvaccinated Cases		37	8	45
Vaccinated Cases (at least one dose)	First dose	8	5	13
	Second dose	4	0	4
	Third dose	3	0	3
	Total	52	13	65
	Percent	80%	20%	100%

3.5.Administrative Care

55 patients received basic supportive care, and 10 patients received advanced supportive care , about 58.2% (32 out of 55) of those who needed primary care did not have pneumonia while 23 patients did. In contrast, 90% (9 out of 10) of those who reached advanced care were already diagnosed with pneumonia.

3.5.1. Relationship Between Malignancy and Supportive Care

Statistical analysis showed a close link between Malignant pertussis and the level of care needed: The Mann-Whitney U test showed a highly significant difference (p = .000) in the level of supportive care provided between malignant and non-malignant cases. Malignant cases had a much higher mean rank (53.00) compared to non-malignant cases (28.00), meaning infants with malignancy used therapeutic resources (oxygen, IV fluids, close monitoring) more frequently and in a more complex manner. Life-threatening signs: 60% (39 infants) experienced episodes of apnea and cyanosis, which required immediate oxygen and respiratory support, and most of these were in the malignant group.

3.5.2. Impact of Supportive Care on health outcome

58 people recovered, making up 89.2% of the total sample. There were 7 deaths, accounting for 10.8%. the Chi-Square test conducted to assess the relationship between the level of supportive care and health outcomes, Pearson Chi-Square value: 43.147 with 1 degree of freedom (df). The statistical significance (Asymptotic Significance) was 0.000, which is much lower than the usual significance level (0.05), indicating a strong and statistically significant relationship between the level of care and recovery. Fisher's Exact Test was also used, and its result (0.000) confirmed a significant relationship. Spearman Correlation) also showed a very high value of .815. The results confirm that the vast majority of cases recovered (89.2%) and that there is a solid and strong statistical link between the quality and level of care provided and achieving a recovery outcome, as the tests proved that these results are not due to chance.

Table. 6.. Frequency of Supportive cares' s outcomes

Level of Supportive Care	Condition Status		Total
	Recovery	Death	
Initial Supportive Care	55	0	55
Advanced Supportive Care	3	7	10
Total	58	7	65

4. Discussion

The results of the pertussis outbreak in Ajdabiya, involving 65 infants, reveal critical patterns related to age, seasonal variation, and gender distribution. A primary finding is that 70.8% of all cases (46 infants) occurred in the age group of 1 to 3 months, highlighting a significant "immunity gap" in very young infants. Given that full protection typically requires a three-dose primary series starting at two months, newborns remain highly vulnerable. This high percentage suggests that the bacteria spread primarily among those who are too young for vaccination or have only received a single dose, underscoring the critical importance of maternal Tdap vaccination, which is 91% effective in protecting infants (Chatterjee & Sungjun, 2018).

The outbreak data demonstrates notable adherence to the "classic" clinical presentation, coupled with a high rate of serious complications. Notably, 87.7% of infants in the Ajdabiya sample exhibited the characteristic "whoop." This rate is significantly higher than those reported in other studies; for instance, Tozzi et al. (2005) noted that many children under six months do not develop the typical coughing fit. Similarly, general clinical tables indicate that while whooping cough occurs in 69% to 92% of children aged 6 days to 9 years, it is often absent in the youngest newborns. This high rate in Ajdabiya may reflect a complete lack of passive immunity in the Libyan population, as 98.5% of pregnant women in Libya are seronegative at birth, potentially leading to increased symptomatic episodes even in the youngest infants.

Observations regarding apnea and cyanosis are also significant, with 60% of infants experiencing both symptoms—a finding that aligns with risk indicators identified in previous research for this age group. The high frequency of these life-threatening signs matches findings from the United States (2005–2010), where infants aged two to three months faced the highest prevalence and risk of severe complications requiring hospitalization. Furthermore, the high incidence of cyanosis (over 90% when combined with apnea) points to a significant risk of "Malignant Pertussis." Research from French Guiana (Lubuno et al., 2026) defines this condition by acute apnea and cyanosis, noting a 50% death rate among unvaccinated infants. In the 2025 Ajdabiya outbreak, 20.0% of cases (13 infants) developed Malignant Pertussis, characterized by a white blood cell count exceeding $50x10^9$ L.

A significant finding was the protective threshold after "two doses," as no infants who received two or three doses of the vaccine developed malignant pertussis. In contrast, the highest rate of this severe disease was recorded in the single-dose group (38.5%), which was even higher than that in completely unvaccinated infants (17.8%). Statistically, Fisher's exact test ($p = 0.517$) indicates that a single dose does not provide substantial protection against malignancy in this age group, likely due to these infants remaining within the "high-risk window" under three months or due to vaccination delays. This susceptibility is exacerbated by the immunity gap in Libya, where 98.5% of pregnant women lack antibodies at birth, depriving infants of passive protection. These findings strongly support the implementation of maternal Tdap vaccination to protect newborns until they complete their routine series.

The malignancy rate in Ajdabiya (20%) exactly matches the findings from the French Guiana study (2026), which also recorded 4 malignant cases out of 20. Our results are consistent with the "Chinese Expert Consensus" (2024), which posits that severe and malignant cases are concentrated in infants under 3 months who have not completed their initial vaccinations. Furthermore, our findings align with Lubuno et al. (2026), showing that deaths and malignancies occur exclusively in unvaccinated or partially vaccinated infants.

Regarding supportive care, Fisher and Chi-Square tests indicate that changes in the level of care lead to tangible changes in recovery chances. A Spearman correlation of 0.815 reveals a very strong positive correlation, confirming that the quality of supportive care is a critical factor in patient survival. The study protocol, utilizing oxygen, azithromycin, and IV fluids, achieved a recovery rate of 89.2% and limited mortality to 10.8%, despite 20% of cases being "malignant" and 60% experiencing respiratory arrest and cyanosis. This field evidence demonstrates that a survival rate of nearly 90% is achievable in resource-limited settings through focused supportive care, even without complex interventions such as extracorporeal membrane oxygenation (ECMO).

5.Conclusions and Recommendations:

The study showed that infants under three months old are the most at risk due to a severe 'immune gap.' Contrary to common belief, the majority of infants in this outbreak showed the classic "hiccup" symptom, with the majority experiencing life-threatening pauses in apnea and cyanosis. This situation calls for immediate respiratory intervention, especially oxygen supply, and training medical staff to recognize these signs, which can overshadow the typical cough at this young age. Receiving just a single dose of vaccine during this outbreak didn't provide enough protection against 'Pertussis,' so, the main recommendation is to make sure the three doses of the vaccine are completed quickly without delay to reduce the risk of death and serious complications. Basic supportive care has played a big role in survival chances, reducing deaths. So, it's suggested to unify and improve basic care protocols in resource-limited hospitals as a practical and effective way to save lives until advanced technology becomes available. Researchers strongly recommend that the National Immunization Technical Advisory Group (NITAG) in Libya give the Tdap vaccine to mothers during the third trimester of pregnancy. It is recommended to give booster doses to children when they start school and to teenagers and adults every 10 years to compensate for waning immunity and prevent them from being a source of infection for infants. Researchers also recommend to healthcare providers (doctors and nurses): early intervention using supportive protocols and implementing respiratory disease isolation protocols for patients and their contacts for no less than 5 days from the start of effective treatment. They also recommend following the 'trench strategy' by vaccinating all close contacts of the child (father, grandparents, siblings) to create a protective shield around them, and emphasizing to families the importance of not delaying the second and third doses, as they represent the child's 'lifeline' in the absence of immunity passed from the mother. Additionally, raising awareness about life-threatening symptoms by teaching parents signs

such as 'paleness or bluish skin and stopping breathing' and the need to go to the hospital immediately if they appear, since these symptoms were present in most outbreak cases. Finally, researchers are recommended to conduct future scientific studies, such as investigating genetic mutations by performing whole genome sequencing (WGS) to find out whether the currently circulating strain is one of the international variants (like ptxP3 or pertactin-deficient strains). Also, to assess macrolide resistance, local studies on bacterial susceptibility should be carried out to check how effective azithromycin is against the prevalent local strains.

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