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The epidemiology of 32 selected communicable diseases in Iraq, 2004–2016

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ABSTRACT

Background: The 2003 invasion of Iraq significantly undermined population health. However, there is a lack of understanding of how it undermined communicable disease control. This study was performed to assess the incidence trends of 32 communicable diseases in post-conflict Iraq.
Methods: Reported incidence data for 32 communicable diseases (2004–2016) were collected from routine reports sent to the Iraqi Ministry of Health by primary health centers, and general and tertiary hospitals. Incidence (per 100 000) was defined as the number of reported incident cases divided by the population size. Joinpoint regression was used to examine the incidence trends and average annual percentage change (AAPC) for each disease, and the overall incidence rate across the period.
Results: Communicable diseases increased significantly during the peak years of the war, especially during the US troop surge period (2007–2009). As US troops withdrew (after 2011), overall communicable diseases decreased. The incidence rate of nearly half of the 32 diseases decreased significantly, while the incidence rate of five increased significantly (hepatitis A, varicella, viral meningitis, cutaneous leishmaniasis, extrapulmonary tuberculosis).
Conclusions: The early foundational strength of Iraq's health system may help explain why infectious disease failed to overwhelm the population following the invasion. Iraq's federal government could exercise its legal authority to manage threats to public health security by expanding the disease surveillance system.

Introduction

Communicable diseases thrive in conflict settings. Outbreaks can spread rapidly because of deteriorating nutrition, overcrowding and unsanitary conditions in displaced person's camps, and deteriorating health care infrastructure. Vaccine-preventable diseases can spread rapidly when vaccination routines are interrupted, infectious disease surveillance deteriorates, treatment capacity declines, and outbreak responses are curtailed (Nnadi et al., 2017).

Iraq is a middle-income country among the 22 nations in the Arab world. Iraqi health care and medical education were among the best in the Arab region in the 1970s and 1980s. The system maintained some of this momentum even during the Iran–Iraq War in the 1980s, and multiple conflicts afterwards, in part because medical graduates were barred from leaving the country until 2004 (Al Hilfi et al., 2013). A near-total financial and trade embargo (known as 'sanctions') was imposed on Iraq by the United Nations Security Council in August 1990 (when Iraq invaded Kuwait) and through the invasion in early 2003. These sanctions served to significantly undermine Iraq's health system infrastructure, resulting in non-functional equipment, insufficient human resources (especially nurses), and inadequate drugs and other supplies (Al Hilfi et al., 2013). At the time of the 2003 invasion, Iraq's heavily hospital-oriented and capital-intensive model was not agile in response to communicable disease outbreaks (WHO Regional Health Systems Observatory, 2006).

Morbidity and mortality associated with infectious diseases increased in Iraq during the 1990s sanctions, which served to increase food insecurity and infant mortality, while reducing

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access to vaccines and compromising the quality of drinking water (Valenciano et al., 2003). Communicable disease outbreaks in Iraq in the 1990s and through the 2000s were reported to be attributable to the environmental and infrastructure damage caused by the 1991 Gulf War and subsequent sanctions, followed by the 2003 invasion (Al Hilfi et al., 2013).

The Institute for Health Metrics and Evaluation's Global Burden of Disease project ranked 'conflict and terror' as the top cause of disability-adjusted life years (DALYs) lost in 2017. No infectious diseases ranked among Iraq's top 10 causes of mortality, other than 'neonatal sepsis' and 'lower respiratory infection,' which ranked 8 and 10, respectively, in 2017 (IHME, 2017). Only two communicable diseases were ranked as contributing to the top causes of death in the whole Arab region between 1990 and 2010, tuberculosis (TB) and measles. Both declined in their rank between 1990 and 2010, with TB falling from 15th to 19th, and measles falling from 23rd to 85th (Mokdad et al., 2014).

Children living in war and conflict settings are at risk of vaccine-preventable and other infectious diseases, even several years after wars are settled. Vaccine campaigns can sometimes be conducted even in war conditions (Garges et al., 2016), but the environment remains fertile for epidemic spread of infectious disease. War creates shortages of vaccines, problems with the cold chain for vaccine fidelity, and difficulty in finding and vaccinating children (especially those no longer in their original families or who have been wounded) (Obradovic et al., 2014). After controlling for demographic characteristics, children exposed to the 2003 Iraq War were found to be 21.5 percentage points less likely to have received neonatal polio immunization (Cetorelli, 2015).

Vaccination remains one of the most cost-effective disease prevention strategies, averting millions of childhood illnesses and deaths every year. The most acute gaps observed in vaccination coverage are observed among children living in fragile states affected by conflict. In 2015, Syria's vaccine coverage for diphtheria, pertussis and tetanus (DPT) declined by half (from 81% to 41%). Wild poliovirus has thrived in conflict and post-conflict settings, resulting in special attention to vaccination campaigns in such settings. In Ukraine, coverage fell from 80% in 2012 to 20% following 2 years of violent conflict. In 2015, two-thirds of the 20 million unvaccinated infants were living in an armed conflict country (Nnadi et al., 2017).

Iraqi population movements changed in character and volume over the course of the long war, increasing the population risk for communicable diseases, especially TB, hepatitis B, cholera, and measles (Lischer, 2008; Karasapan and Kulaksiz, 2001; Eiset and Wejse, 2017).

This study was performed using routine data collected from Iraq's Center for Disease Control, operated by the Ministry of Health, to assess the specific reported incidence trends of 32 communicable diseases in post-conflict Iraq, from 2004 to 2016.

Methods

Study design, setting, and participants

Monthly data for 32 communicable diseases in Iraq were collected for the period 2004 to 2016. Cases were reported by all public-sector hospitals and primary health centers to the Preventive Health Department in the Directorate General of Health of each province, except for the Kurdistan region. Each province then reported to the Center for Disease Control/the Communicable Disease Control Unit of the Ministry of Health in Iraq. The case definitions of the diseases are determined according to the International Classification of Diseases Tenth Revision (ICD-10), usually based on clinical examination and microbiological and/or radiological tests as needed; the case is then classified either as definite, probable, or possible, and only definite cases are usually reported.

Ethical approval was obtained from the College of Medicine, Mustansiriya University, and the Department of Statistics, Iraqi Ministry of Health.

Statistical analyses

The reported incidence trends for 32 communicable diseases in Iraq, 2004–2016, are described here. Incidence (per 100 000) was defined as the number of annual reported incident cases divided by the population size. The population size was extracted from the Iraqi Central Statistical Organization. The diseases were grouped into four categories: (1) vaccine-preventable (poliomyelitis, measles, diphtheria, mumps, tetanus, neonatal tetanus, pertussis, rubella), (2) other World Health Organization (WHO) surveillance diseases (anthrax, malaria, meningococcal meningitis, rabies, typhoid fever, visceral leishmaniasis (kala azar), bacillary dysentery, cholera, hemorrhagic fever, hepatitis A, hepatitis B, hepatitis C), (3) other vector-borne and zoonotic diseases (brucellosis, schistosomiasis, hydatidosis, toxoplasmosis, typhus), and (4) other reemerging diseases (TB, extrapulmonary TB, pneumonia, leprosy, cutaneous leishmaniasis, varicella, viral meningitis). We included in the 'vaccine-preventable category' those diseases for which Iraq routinely vaccinates — therefore, cholera and varicella were excluded.

The average annual percentage change (AAPC) was calculated and the Z test was used to assess whether the year-over-year change in each disease reported incidence rate was significantly different from zero. The trend was described as increasing or decreasing when the annual percentage change was significant ($p < 0.05$), or else the trend was termed stable.

Joinpoint regression was used to examine the overall reported incidence and the incidence trends and changes for each disease, using both annual data and monthly data. Joinpoint regression is a statistical modeling technique that explains the relationship between two variables using segmented linear regression (Kim et al., 2000). We allowed a maximum of three joinpoints, as suggested by program developers, and used the Bayesian information criterion to select the best fit model (Yang et al., 2017). We allowed the minimum number of observations from a joinpoint at either end of the data (excluding the first or last joinpoint if it falls on an observation), and between two joinpoints, to be 1 for annual data and 9 for monthly data (to account for seasonality). For mathematical integrity, when it was noted that the reported incidence trend data contained some values of zero, we substituted the value with 0.01% of the smallest incidence (0.00002 per 100 000) for the zeros (Yang et al., 2017). This happened in 9.8% of all cases. Following the joinpoint regression, the trend in overall annual reported incidence and overall monthly incidence were analyzed, and also the degree of aggregation for the individual disease joinpoints.

Stata (version 13.0) was used for the data extraction, cleaning, and analysis, and joinpoint (version 4.6.0) was used for further data analysis.

Results

Figure 1 illustrates the annual reported incidence trend for each of the four major types of communicable disease. Between 2004 and 2016, a total of 2 679 481 cases of the 32 communicable diseases were reported (average yearly reported incidence rate 634.73 per 100 000). The overall annual reported incidence displayed a hump-shaped curve; it started at 639.79 cases per 100 000 in 2004, reached its peak in 2009 at 822.10 per 100 000, and decreased to 523.00 per 100 000 in 2016. The AAPC in reported

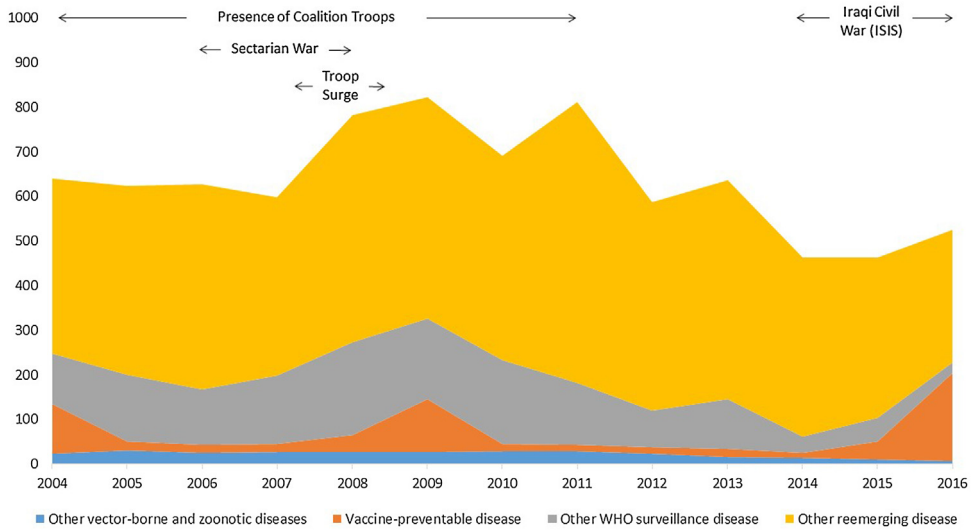


Figure 1. Temporal trends in annual reported incidence rates (per 100 000 population) of four types of infectious disease in Iraq.
Note: Values are per 100 000 population per year.
Source: Data from the Center for Disease Control/the Communicable Disease Control Unit of the Ministry of Health in Iraq.

incidence of communicable disease between 2009 and 2016 (−7.2%) was significantly lower than that between 2004 and 2009 (5.9%). Out of the four categories of disease, the seven conditions in the 'other re-emerging disease' category contributed nearly 70% of all reported incidence rates over the period.

Table 1 describes the reported incidence rate and annual percentage change for each of the 32 individual diseases. The sparkline graphs show the annual trend for each disease. Of the 32 diseases, 14 decreased significantly over the 13 years, including diphtheria (AAPC −18.5%), neonatal tetanus (AAPC −11.0%), pertussis (AAPC −12.5%), rubella (AAPC −42.6%), anthrax (AAPC −47.5%), malaria (AAPC −38.7%), meningococcal meningitis (AAPC −13.7%), rabies (AAPC −11.8%), typhoid fever (AAPC −27.8%), visceral leishmaniasis (AAPC −18.3%), brucellosis (AAPC −13.2%), schistosomiasis (AAPC −64.1%), TB (AAPC −3.0%), and pneumonia (AAPC −6.6%). Five diseases increased significantly, including hepatitis A (AAPC 15.3%), cutaneous leishmaniasis (AAPC 13.8%), extrapulmonary TB (AAPC 2.9%), varicella (AAPC 5.7%), and viral meningitis (AAPC 8.1%).

Figure 2 further illustrates the trend of each individual disease, but disaggregated by month. This allows the relative burden of each disease, disease outbreaks, and seasonal patterns to be seen. Typhoid fever, pneumonia, and varicella had relatively high reported incidence rates. Several diseases showed significant seasonal patterns, including but not limited to typhoid fever, visceral leishmaniasis, bacillary dysentery, brucellosis, pneumonia, and varicella. There was a measles outbreak in 2009, two mumps outbreaks in 2004 and 2016, and a rubella outbreak in 2004.

Figure 3 shows the results of the joinpoint regression and plots the overall reported incidence of the 32 diseases by year (Figure 3a) and by month (Figure 3b). For the annual incidence regression, a rise in reported incidence rate was found between 2003 and 2009, followed by a relatively steep decline. For monthly reported incidence regression, it was found that the reported incidence trend from January 2004 to March 2011 indicated an increase, while after April 2011, the monthly reported incidence trend indicated a decrease. Joinpoint regression was also conducted for each of the 32 diseases by year and by month, and the location of the joinpoints was documented and plotted over time (see **Supplementary Material**). This allowed us to see when most joinpoints aggregated, as an indication of when the disease incidence trend changed. The majority of annual incidence joinpoints gathered during the 2010–2014 period.

Discussion

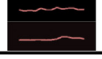
Using routine incidence data collected from the Iraq Center for Disease Control, the reported incidence trends of 32 communicable diseases in post-invasion Iraq were analyzed. Communicable diseases increased significantly during the peak years of the war, especially during the US troop surge period (2007–2009). As US troops withdrew (after 2011), overall communicable diseases decreased (with other reemerging diseases like pneumonia and varicella contributing the most to incidence rates). Nearly half (n = 14) of the 32 diseases decreased significantly in incidence rate, while five increased significantly (i.e., hepatitis A, cutaneous leishmaniasis, extrapulmonary TB, varicella, and viral meningitis).

This study is novel in providing the year-specific reported incidence of 32 communicable diseases in Iraq for the years 2004–2016. Iraq's remarkable Ministry of Health surveillance system allowed us to determine trends in the country's communicable disease patterns, with clear implications for the assessment of prevention and control efforts over the decade. All disease incident reports were made available by month, and the longer time series allowed joinpoint analysis.

Vaccine-preventable diseases

Out of eight vaccine-preventable diseases, four (diphtheria, neonatal tetanus, pertussis, and rubella) were decreasing over the study period, while the other four (measles, mumps, poliomyelitis, and tetanus) were stable. Although statistics for vaccine coverage were not available, the results suggest that most vaccine-preventable diseases were under reasonable vaccine control post-invasion, despite several small outbreaks. A 2017 publication suggests that Iraq's vaccination coverage rate was better than that of several other countries in Eastern Mediterranean conflict-affected countries (Syria, Yemen, and South Sudan) (Raslan et al., 2017). Our findings underscore this conclusion, with zero poliomyelitis cases for all years, except for two in 2014, likely imported from Syria (Raslan et al., 2017). We also confirmed that poliomyelitis was under control through the affiliated dataset of

Table 1
Reported incidence rate and average annual percentage change in infectious diseases in Iraq, 2004–2016.

Disease	Sparkline	Annual percentage change	95% CI	*p* value
Vaccine-preventable disease				
Diphtheria		-18.5%	(-26.5, -9.5)	<0.05
Neonatal tetanus		-11%	(-17.1, -4.5)	<0.05
Pertussis		-12.5%	(-20.4, -3.9)	<0.05
Rubella		-42.6%	(-57, -23.5)	<0.05
Measles		-19.0%	(-37.5, 5.1)	0.10
Mumps		6.1%	(-12.7, 29)	0.50
Poliomyelitis		12.5%	(-11.6, 43.1)	0.30
Tetanus		1.3%	(-6.4, 9.6)	0.70
Other WHO surveillance disease				
Anthrax		-47.5%	(-60.6, -30.1)	<0.05
Malaria		-38.7%	(-55.6, -15.2)	<0.05
Meningococcal meningitis		-13.7%	(-20.5, -6.2)	<0.05
Rabies		-11.8%	(-18.4, -4.6)	<0.05
Typhoid fever		-27.8%	(-39.4, -13.9)	<0.05
Visceral leishmaniasis (kala azar)		-18.3%	(-23.6, -12.5)	<0.05
Bacillary dysentery		-6.9%	(-15.4, 2.5)	0.10
Cholera		-29.7%	(-64.8, 40.6)	0.30
Hemorrhagic fever		-19.8%	(-48.4, 24.8)	0.30
Hepatitis B		3.5%	(-0.9, 8.0)	0.10
Hepatitis C		-0.1%	(-3.4, 3.4)	1
Hepatitis A		15.3%	(4.8, 26.8)	<0.05
Other vector-borne and zoonotic disease				
Brucellosis		-13.2%	(-18.2, -7.8)	<0.05
Schistosomiasis		-64.1%	(-73, -52.3)	<0.05
Hydatidosis		-1.9%	(-7.6, 4.2)	0.50
Toxoplasmosis		3.3%	(-2.1, 9.1)	0.20
Typhus		-8.1%	(-48.1, 63)	0.80
Other reemerging disease				
Tuberculosis		-3.0%	(-5.2, -0.7)	<0.05
Pneumonia		-6.6%	(-11.2, -1.8)	<0.05
Leprosy		9.6%	(-27.1, 64.8)	0.60
Cutaneous leishmaniasis		13.8%	(0.7, 28.6)	<0.05
Extra pulmonary tuberculosis		2.9%	(0.6, 5.3)	<0.05
Varicella		5.7%	(0.2, 11.4)	<0.05
Viral meningitis		8.1%	(3.5, 12.9)	<0.05

CI, confidence interval; WHO, World Health Organization.
Note: The sparkline graphs show the annual trend in each disease. Graphs in green indicate a 'decrease', those in black indicate 'stable', and those in red indicate an 'increase' over the years.
Source: Data from the Center for Disease Control/the Communicable Disease Control Unit of the Ministry of Health in Iraq.

acute flaccid paralysis (AFP) incidence (not shown in the analysis), which showed that the reported incidence of AFP was stable between 0.91 per 100 000 population and 1.57 per 100 000. This is also in agreement with the results of another study of AFP in Iraq from 1997 to 2011 (Jasem et al., 2014).

However, it should also be noted that Iraq experienced four vaccine-preventable disease outbreaks: measles in 2009, mumps in 2004 and 2016, and rubella in 2004. It was not possible to investigate the causes behind these outbreaks, but potential explanations include a lower vaccine coverage rate and higher vaccine failure rate. According to Jasem et al., the measles vaccine failure rate for Iraq was as high as 66% due to inappropriate vaccine handling, failure to maintain the cold chain, improper administrative procedures, and other host- and vaccine-related factors (Jasem et al., 2012). Many of these factors could be attributed to the deteriorating infrastructure during the conflict.

Other WHO surveillance diseases

Of the other WHO surveillance diseases, the incidence was decreasing for half (anthrax, malaria, meningococcal meningitis, rabies, typhoid fever, visceral leishmaniasis), while the others were stable (bacillary dysentery, cholera, hemorrhagic fever, hepatitis B and C) or were increasing (hepatitis A). It was possible to confirm the trend in rabies with one study (Horton et al., 2013), and the outbreak of cholera in 2008 with one WHO news report (WHO, 2018).

Typhoid fever was found to be decreasing during the study period, with an annual percentage change of −27.8%. The reported incidence rate dropped from its highest point of 182.61 per 100 000 in 2008, to 1.28 per 100 000 in 2016. This could be attributed to improved water supply, or more likely problems in case finding and reporting. Until recently, the diagnosis of typhoid fever still

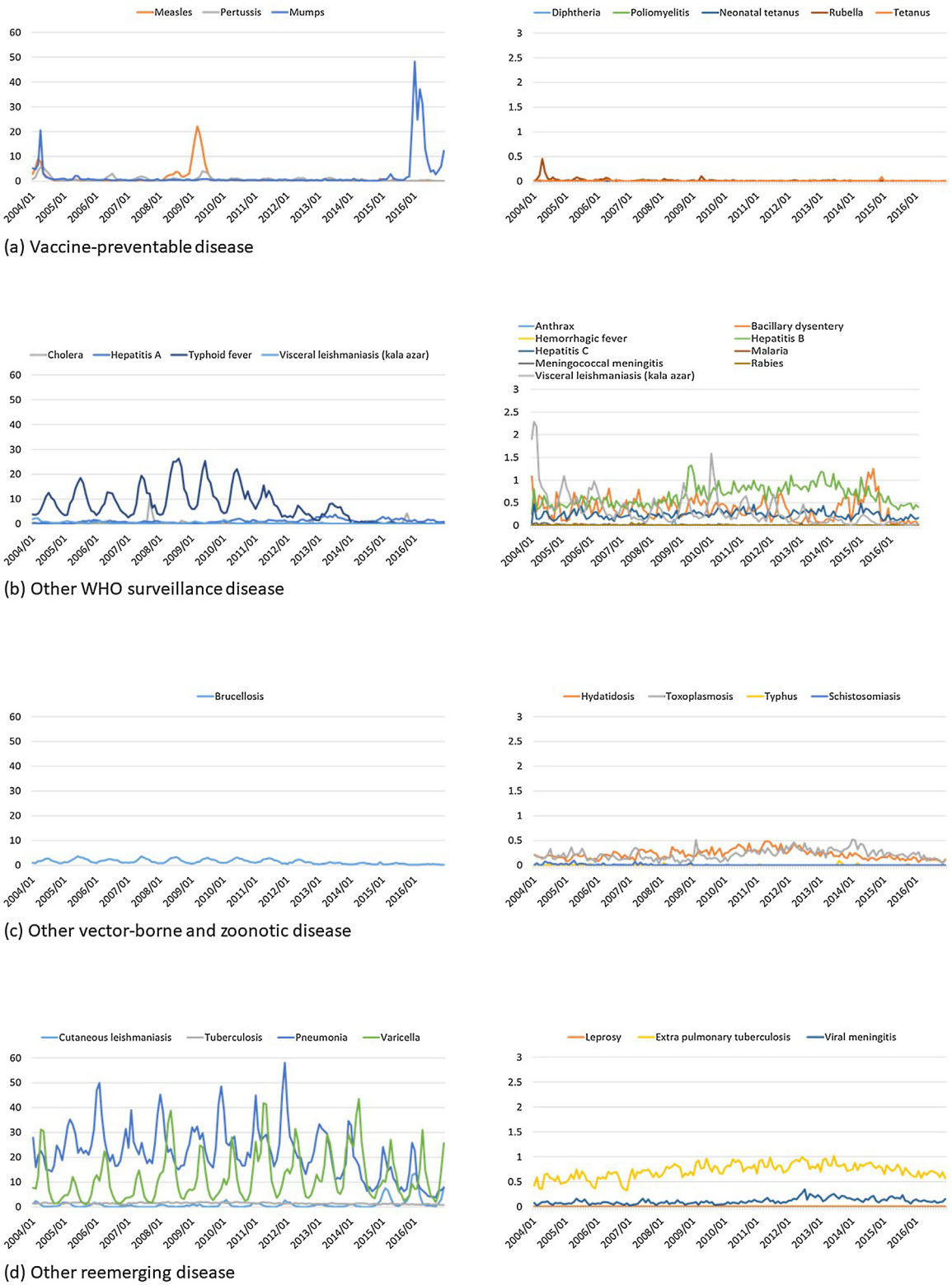


Figure 2. Monthly reported incidence rates (per 100 000 population) of infectious diseases by category in Iraq, 2004–2016.
Note: Values are per 100 000 population per month; for graphs on the left, the *y*-axis ranges from 0 to 60; for graphs on the right, the *y*-axis ranges from 0 to 3.
Source: Data from the Center for Disease Control/the Communicable Disease Control Unit of the Ministry of Health in Iraq.

depended on the Widal test. In the last few years, clinical symptoms, leukocyte number, and the isolation of *Salmonella* Typhi were used for diagnosis, which may have led to a classification bias and may explain the decrease in reported incidence.

As shown in Figure 4, there was a small outbreak of cholera in 2008. To prevent and control cholera outbreaks, a robust surveillance and laboratory system, combined with water and sanitation infrastructure, are essential. However, the war-related deterioration of water quality and sanitation apparently facilitated

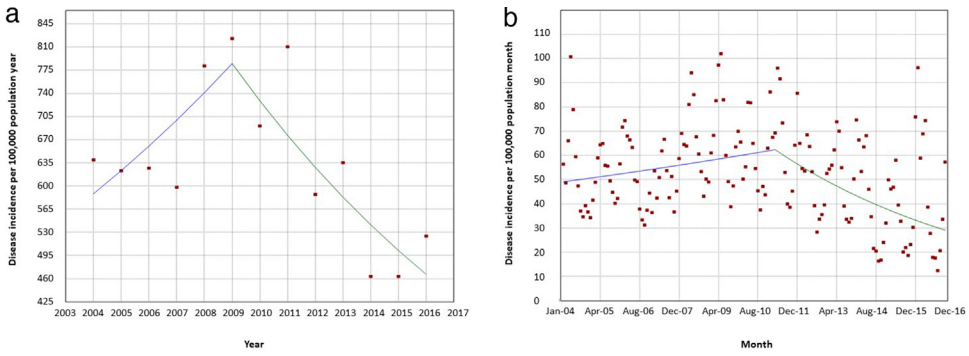


Figure 3. Joinpoint regression showing trends in the overall reported incidence of the 32 infectious diseases by year (a) and by month (b).
Note: Each red point indicates the incidence per 100 000 population per year (a) or month (b). The regression model fit trends for the incidence rates and calculated joinpoint where the trend changes.
Source: Results from the joinpoint analysis of data from the Center for Disease Control/the Communicable Disease Control Unit of the Ministry of Health in Iraq.

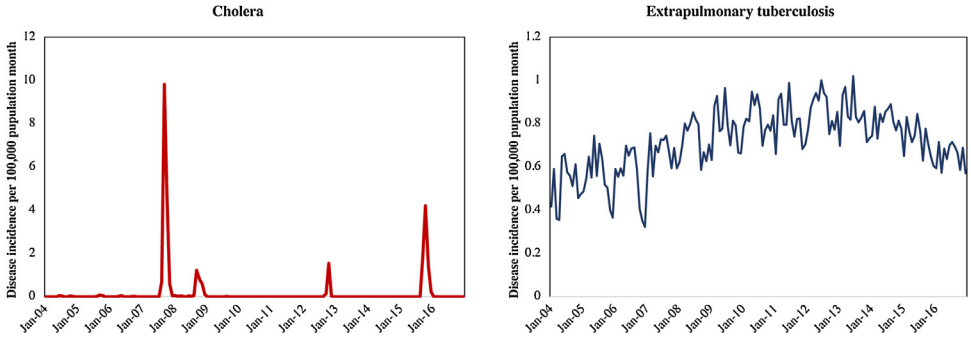


Figure 4. Monthly reported incidence rates (per 100 000 population) of cholera and extrapulmonary tuberculosis in Iraq, 2004–2016.
Note: Values are per 100 000 population per month.
Source: Data from the Center for Disease Control/the Communicable Disease Control Unit of the Ministry of Health in Iraq.

cholera contamination. While cholera is vaccine-preventable, vaccinations are not routinely administered worldwide, including in Iraq, except for one round of oral cholera vaccination in 2015 (WHO, 2018). This one-time vaccination campaign successfully controlled the epidemic, as reported by the US Centers for Disease Control and Prevention (Lam et al., 2015). Such measures, along with immediate water treatment and case management, are priorities in times of outbreak (Lam et al., 2015).

Hepatitis A rates increased significantly over the 13 years, with an annual percentage change of 15.3%. Hepatitis A is endemic in Middle Eastern countries, and Iraq has a higher prevalence than Somalia and Palestine, but lower than Afghanistan (Safiabadi et al., 2017). The increased incidence of hepatitis A could be attributable to poor primary hygiene practices, interrupted water supplies, and population displacement, all common in conflict settings (Turky et al., 2011).

Other vector-borne and zoonotic diseases

Vector-borne and zoonotic diseases contributed the smallest number of incidents to the overall burden of communicable diseases. Two diseases decreased over the period (brucellosis and schistosomiasis) or three were stable (hydatidosis, toxoplasmosis, and typhus). This could be attributed to the restoration of veterinary services post-war (FAO, 2009), as well as enhanced vector-focused control programs.

As an example, schistosomiasis had a reported incidence of 0 in 2011 and afterwards, and was the only communicable disease to remain consistently at zero for the past five years of the study period. The successful control of schistosomiasis likely resulted from extensive snail control. Through extensive testing and treatment of infected school children and applying molluscicides to snail habitats in the 1970s, the prevalence rate dropped significantly to just 0.1% in 2010 (Jone, 2015).

Other reemerging diseases

Despite the successful control of most of the communicable diseases mentioned above, several reemerging diseases in Iraq present cause for concern. Although decreasing TB and pneumonia rates were seen and leprosy remained stable, four other diseases (cutaneous leishmaniasis, extrapulmonary TB, varicella, and viral meningitis) were increasing. We were able to confirm the trend in TB (Huseynova et al., 2013) and cutaneous leishmaniasis (Salam et al., 2014; Alsamarai et al., 2016) in the literature.

Pneumonia and varicella both had high reported incidence rates, with a clear seasonal trend. The rise in varicella was likely associated with the internal displacement of people from war areas to internal displaced person's camps—locations not optimal for disease control (Khaleel and Khistawi, 2018). Also, although varicella is now a vaccine-preventable disease, the use of this vaccine is not covered by the Iraq national health system. Pneumonia has posed a long-term problem for Iraq, and outbreaks among the US army were also reported in 2003 (Sanchez et al., 2015; Gottlieb, 2003).

Although TB has been decreasing, small increases in extrapulmonary TB were observed in 2004–2012, with a seasonal pattern (Figure 4). Extrapulmonary TB requires expanded health system capacity, and health workers must conduct adjunctive diagnosis, which is usually difficult to achieve in times of conflict (Hassanain et al., 2018). Considering that extrapulmonary TB is generally not associated with person-to-person spread, the early diagnosis and

treatment of active TB to stop infection, the prevention of active disease in latently infected individuals, and vaccination are strategies recommended to stop its transmission (Ayed et al., 2018).

Other diseases were also worth investigating. For example, cutaneous leishmaniasis has re-emerged since 2015, with a clear seasonal pattern. The increase may be attributed to non-immune population movement and/or a lack of the WHO-recommended first-line drug (Alsamarai et al., 2016), but may also be due to a lack of proper diagnostic facilities in past decades (Salam et al., 2014). Viral meningitis also increased, with an 8.1% annual percentage change. No documentation regarding the trends in these diseases and their control strategies could be found; clearly more research is needed.

Limitations of this study

Although this analysis of trends in communicable diseases in Iraq provides new insights into infectious disease rates in Iraq since the 2003 invasion, it is not without limitations. First, we have no reports from before 2004, so no comparison could be made to the pre-war period. Further, the disease dataset did not include reports from the private sector, including private clinics, or information from Kurdistan, a nearly separated northern region. Also the disease dataset did not include several important diseases including HIV/AIDS. Finally, the incidence numbers are reported case numbers obtained from routine reports, and there was likely underreporting of the disease cases, especially when record-keeping was interrupted by chaotic conditions created by the conflict. The war certainly undermined case reporting, collecting, and various aspects of the health information system. We recognize this specific limitation and present our findings as the reported incidence. We also did not disaggregate the data in this report by region, age, or sex (a review of these data is underway). Nonetheless, it is believed that this is the best-available evidence for communicable disease trends in Iraq during the various phases after the 2003 invasion. It should also allow comparison to other countries in the region.

Conclusions

Communicable diseases increased significantly during the peak years of the war (by 5.9%), especially during the US troop surge period (2007–2009). Nonetheless, overall communicable diseases decreased after US troop withdrawal in 2011, and infectious diseases are not primary contributors to Iraq's mortality burden. The early foundational strength of Iraq's health system may help explain why infectious disease failed to overwhelm the population following the 2003 invasion. Of the 32 infectious diseases studied, most were stable or on the decline by 2016. Reemerging diseases like pneumonia and varicella contributed the most to infectious disease incidence rates. An increase in hepatitis A (a WHO surveillance disease), along with four reemerging diseases (leishmaniasis, extrapulmonary TB, varicella, and viral meningitis) was observed. However, half of the vaccine-preventable diseases in this study were on the decline, and the remaining four were stable. The most recent infectious disease outbreaks were attributable to measles (2009) and mumps (2016).

The Ministry of Health set plans to expand health service delivery as it recovered from decades of war and sanctions, while also reorienting the public sector towards primary care; remarkably, it has delivered. Despite Iraq's rapid population growth since 2003 (2.6% per annum on average), the number of primary health centers per 100 000 population grew from 5.5 to 7.4 (Cetorelli and Shabila, 2014). Disease surveillance systems and screening programs have gradually been restored (WHO EMRO, 2017). Individuals now carry 'smart cards' with their registration and health records, and receive prompts for required immunizations and clinic visits. A recent study indicated that more than 90% of child immunizations were complete (Al Hilfi et al., 2013).

We recommend that Iraq's federal government exercises its legal authority to manage threats to public health security by expanding the disease surveillance system to include more types of facilities and the private sector (Wilson et al., 2009).

Author contributions

R. Lafta provided the original dataset. Y. Zhao conducted the statistical analysis and created the figures and tables. Y. Zhao and A. Hagopian wrote the first draft of the manuscript, A. Flaxman and R. Lafta provided critical feedback on the first draft of the manuscript, figures, and tables. All authors read and approved the final manuscript.

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Ethical approval

Ethical approval was obtained from the College of Medicine, Mustansiriya University, and the Department of Statistics, Iraqi Ministry of Health.

Conflict of interest

The authors declare no conflicts of interest.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ijid.2019.09.018.

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