Challenges facing measles elimination: the Lebanese experience

Talal El Zarif
Universite Libanaise

Mohamed Faisal Kassir (mgk21@mail.aub.edu)
American University of Beirut Medical Center https://orcid.org/0000-0003-3501-1802

Nazih Bizri
University of Balamand Faculty of Medicine and Medical Sciences

Ghida Kassir
American University of Beirut Medical Center

Umayya Musharrafieh
American University of Beirut Medical Center

Abdul Rahman Bizri
American University of Beirut Medical Center

Research article

Keywords: Measles, mumps, eradication, vaccine, Lebanon

Posted Date: July 15th, 2019

DOI: https://doi.org/10.21203/rs.2.11386/v1

Version of Record: A version of this preprint was published at BMC Infectious Diseases on March 26th, 2020. See the published version at https://doi.org/10.1186/s12879-020-04956-1.

Abstract

Background Despite achieving a high vaccine coverage of measles, Lebanon, like many other countries, is still far away from achieving measles eradication. In this article, the trend of measles outbreaks in Lebanon was studied in an attempt to outline the factors that explain why the eradication plan has failed and provided potential solutions to overcome them. The relationship between the incidence of measles and mumps outbreaks in Lebanon was explored and delineated Methods In this observational study, cases of measles and mumps in Lebanon recorded between 2002 and 2018 were collected from the Lebanese Ministry of Public Health Epidemiological Surveillance Unit public database. The data was plotted on graphs taking into consideration the dates of the cases, age groups affected, and vaccination status. Results The average number of measles cases in the 1-4 years age group was the highest and was equal to 189.9 cases/year. This value declined in individuals aging less than 14 years but was followed by an increase to 82.7 cases/year in individuals older than 14 years. Following every spike in measles cases during the period between 2002 and 2018, a parallel increase in mumps cases was seen on multiple occasions. Strikingly, an average of 27.1% of the recorded measles cases belonged to vaccinated individuals, while 32.1% were unvaccinated and 40.74% had an unspecified vaccination status. Conclusions Although measles is a disease that mainly targets children, it seems essential that booster immunization programs must be held to protect young adults. The close relationship between measles and mumps incidence in Lebanon might aid in anticipating future outbreaks in order to take action before their occurrence. Finally, vaccine handling and storage in Lebanon must be re-assessed in lights of the occurrence of measles outbreaks to ensure implementing best appropriate vaccine handling till administration. Eradication plans must be tailored to hone and fit the Lebanese context.

Background

Measles is a vaccine preventable disease that despite the introduction of a vaccine is still capable of producing major outbreaks worldwide [1]. Several countries have set target dates for the eradication of the disease, only to revise them later. Countries in the Eastern Mediterranean Region had initially chosen 2010 as the target date for measles eradication but that date has been twice revised and the current target is 2020 [2]. Measles has the highest herd immunity threshold, ranging between 89% and 94%, making it more challenging for several countries to vaccinate enough individuals to reach disease eradication potential [3-5]. Lebanon is no exception to this multi-national challenge, and the recent numbers issued by the national surveillance system serve to show that the country is on par with its neighboring nations in their plight to eradicate measles [6].

Achieving a high level of population immunity to protect against the spread of measles can only be reached via administering two doses of the current measles vaccine. Measles antigen-containing vaccine 1 (MCV1), the first measles vaccine, is usually administered as part of routine vaccination services, while MCV2 can be received through the same services or through mass vaccination campaigns [6]. The estimated global coverage with the MCV1 has seen a significant rise from 72% in 2000 to 85% in 2010 [7], and Lebanon is actually amongst the 119 countries with >90% coverage with MCV1 [6]. However, the ease

of transmission of the disease, its free circulation through travelers, and the mass displacement of refugees from conflict areas to Lebanon have all made the goal of eradication more challenging [6, 8, 9].

The fact that the measles vaccine is widely available in the form of a combination vaccine with mumps and rubella implies that while attempting at eradicating measles, countries would be indirectly fighting mumps and rubella as well. A mathematical model for measles and rubella transmission has shown that in the endeavor to meet the goal of measles eradication, countries would inadvertently eliminate rubella which has significantly lower transmissibility [3]. A similar association between measles and mumps has not been referred to in the literature.

Data from the Lebanese Ministry of Public Health (LMPH) Epidemiological Surveillance Unit (ESU) reveal that measles outbreaks are still occurring in Lebanon [10]. This requires a careful approach that starts by evaluating the cause of falling behind the target of eradication despite the success in achieving >90% of first dose vaccine coverage [6]. This article will delineate the trend of measles outbreaks in Lebanon in the period between 2002 and 2018 in an attempt to understand the level at which the eradication plan is not working [11]. It will also briefly address the issue of mumps outbreaks in Lebanon, in the context of the close relationship between the two diseases given the combination vaccine which they share. Several custom recommendations will be proposed that aim at pushing the Lebanese experience towards true measles eradication.

Methods

Measles and Mumps Data Collection:

Data on documented measles and mumps cases in Lebanon were collected from the LMPH-ESU public database, which anonymously keeps track and reports these cases. The reported cases, their dates, age of the affected, and their vaccination status were collected starting 2002 till 2018.

Working Definitions:

The measles cases reported by the LMPH are classified as being either of two categories: (1) laboratory-confirmed cases based on positive measles IgM titers and/or positive RT-PCR results or (2) epidemiologically-confirmed cases that lacked laboratory confirmation at the time of documentation but have been in direct contact with lab-confirmed cases within the last 28 days and fulfill the clinical criteria of measles diagnosis. Any case that does not belong to either of these two categories was discarded. As for mumps, the cases were also confirmed using laboratory testing which included isolation of the mumps virus from a clinical specimen or serological testing showing a significant rise in the anti-mumps IgG or positive IgM in the absence of recent vaccination.

Statistical Analysis:

Collected data on the incidence of measles and mumps cases were plotted and analyzed using several techniques. The reported measles cases were categorized by age to identify the age group most

susceptible to develop the disease (Figure 1). The measles cases were also divided according to vaccination status from years 2012 to 2019, in attempt to assess the effectiveness of the vaccine (Figure 3). Finally, the measles cases from year 2002 to 2018 were plotted in the same graph as the mumps cases during the same time period (Figure 2) in order to demonstrate the temporal relationship in the outbreaks of each disease amongst the Lebanese population.

Results

The average number of measles cases occurring in Lebanon between 2012 and 2018 was calculated and distributed over 7 age groups as shown in Figure 1. The average number of cases in the < 1-year age group is equal to 70.9 cases/year comprising 15.7% of the total cases. This number increases to a maximum of 189.9 cases/year in the 1-4 years age group which comprises 42% of the cases. Beyond this group, there is a decline in the number of cases with increasing age reaching 13.57 cases/year in the 10-14 years age group; however, this number gradually increases again reaching 57 cases/year at ≥25 year age. Combining these results with those of the 15-24 year age group, the average number of measles cases in individuals older than 14 years is equal to 82.7 cases/year, accounting for 18.3% of all cases among the studied group.

In Figure 2, the number of cases of measles and mumps occurring in Lebanon were compared head to head between the years of 2002 and 2018. The number of measles cases increased from 37 in 2002 to 527 cases in 2003 which was followed by an increase in the number of mumps cases from 28 in 2003 to 54 in 2004. The number of measles cases dropped by half in 2004 and later resurged in 2005 and 2006 to 644 and 905 cases respectively. This was once again concomitant with a rise in mumps cases in 2007 and 2008 to 233 and 229 respectively. Beyond that, the number of both mumps and measles cases was almost negligible until an alerting peak in measles cases took place in 2013 recording a staggering 1760 cases which was once again followed by a surge of mumps cases in 2015 to 1496 cases. Finally, both measles and mumps cases decreased dramatically in the following years until another rise in measles cases to 938 cases occurred in 2018 with only 121 mumps cases in the same year.

Figure 3 shows the distribution of individuals who contracted measles into two groups based on their vaccination status: Group A comprises a combination of the unvaccinated individuals and those whose vaccination status was unspecified while Group B includes all the vaccinated individuals. The average percentages of these groups were then calculated and plotted on the graph. The results show that among those who contracted measles during 2012 and 2018, the percentage of individuals vaccinated against the virus averaged at 27.1% ranging from 6.4% to 51.3% across the years. An average of 40.74% (range: 33.3% – 54.5%) of the measles cases had an unspecified vaccination status while an average of 32.1% (range: 12.8% - 48.8%) of the cases were confirmed to be non-vaccinated.

Discussion

The above data clearly portray that measles is still far from the goal of eradication in Lebanon. Lebanon has witnessed several measles outbreaks in the past 20 years with a case fatality rate of 2 per 1000 reported cases. During 1997 and 1998 a first major outbreak took place in the North reporting 980 cases of measles out of which 3 cases were fatal and was followed by annual epidemic waves occurring between 2003 and 2007. In 2013, a second major national outbreak lasting for 31 weeks was recorded with a total of 2025 suspected cases being reported. Following thorough case investigation, 1760 cases were classified as measles, 27 as rubella, and 238 were discarded as non-measles and non-rubella. [10]

In Figure 1, children aging between 1 and 4 years are the most susceptible individuals to contract measles. Early in life, children usually acquire passively transferred maternal antibodies providing them with immunity against the virus. These antibodies are usually cleared within 6 months from the baby's serum and as a result, children become more susceptible to infection. Although immunized mothers of the post-vaccine era are expected to provide their children with these antibodies, a variety of factors influence their serum levels. Declining maternal immunity is one factor and is best explained by the decreased exposure to wild-type viruses. [12] Another important factor is prematurity which has been established as one of the causes of decreased antibody titers compared to term infants. [12, 13]

The Center for Disease Control (CDC) recommends routine vaccination of children with the measles-mumps-rubella (MMR) vaccine in a 2-dose series scheduled at 12-15 months and 4-6 years with the possibility of giving the 2nd dose as early as 4 weeks after the 1st one. [14] Regarding the MCV vaccine, the WHO recommends that the first dose be given at 9 months where attack rates are high and risk of serious disease among infants exists and at 12-15 months where risk of infant infection is low. Although the second dose is generally administered at school age (4-6 years), it may be given as early as one month following the 1st dose, depending on the measles status in the country. [15] In Lebanon, the Ministry of Public Health adopted a vaccination strategy where which children will receive a zero dose of MCV at 9 months followed by a first dose of MMR at 12 months and a second dose of MMR at 18 months. [16] This appears to be well warranted given the significant number of measles cases in the younger ages as seen in Figure 1.

It is clear that measles is a disease of the pediatric population; however, adult cases must not be overlooked (Figure 1). A deeper investigation that goes beyond surveillance data must be implemented to understand the loopholes in the current vaccination program ranging from parental attitude towards the vaccine to insufficient supplies of the vaccine. A recent study by the WHO revealed that almost 77% of the potentially preventable cases of measles were among children aging less than 15 years who are at the heart of immunization programs. Although the average number of measles cases in individuals older than 14 years in Lebanon (Figure 1) is much less than the 45% reported by the European CDC database in 2017 among individuals older than 14 years, it remains a significant percentage that should not be ignored. [17] A study implemented in China revealed that the seropositivity rate of measles antibodies was significantly lower in subjects aged 15-19 years than those aged 5-9 years. This result was attributed

to the waning antibody titers especially that there are no circulating wild-type viruses to confer natural immunity. It is rather challenging to implement a vaccination campaign to target adults as they will be most probably scattered among the population and unreachable taking into consideration the different circumstances and conditions. It would be more feasible to conduct an immunization program that involves high school students when they are still in mandatory education. Not only will it protect these teenagers from future measles infection, but also will contribute to the protection of future babies via increasing the measles maternal antibody levels and reducing the incidence of measles among infants without risking vaccinating pregnant women. A combination measles-rubella vaccine should be encouraged in the revaccination program in an attempt to adopt a cost-effective strategy that will aid in prevention of the Congenital Rubella Syndrome on one hand and measles elimination on the other increasing the chance of a combined eradication program. Revaccination of secondary school students regardless of previous measles vaccination or diseases status resulted in complete protection, raising seropositivity from 91% to 100% making it a very promising initiative. [18]

It appears from Figure 2 that there is a close relationship between measles and mumps incidence in Lebanon, and a clear pattern can be noticed when examining the outbreaks of each of these diseases. One or two years after every increase in measles cases among the Lebanese population over the past 20 years, a parallel increase – although less intense – in mumps cases can be observed. This trend has not been established elsewhere in the literature, yet it might be expected as the two diseases share a common vaccine. Should the rise in measles cases reflect a shortfall in the vaccination strategy, it would be logical to expect a deficiency in the immunity against mumps as well, and thus mumps outbreaks paralleling the measles outbreaks. Taking into consideration that the mumps vaccine is less immunogenic than that of measles [19], this might be of immense importance for public health strategies, as it might help anticipate any mumps epidemic before it occurs. For example, Israel has witnessed an outbreak of 262 mumps cases between January and August 2017 although vaccination levels reached ≥ 96% [20]. This was concomitant with a measles outbreak during the summer of the same year. [21]. While we are still far from defeating measles, we can use the measles epidemics to review our vaccination strategies, reassess the level of herd immunity against the disease, and prepare our healthcare systems for an imminent mumps epidemic as per the established pattern. National catch-up vaccination campaigns using the MMR vaccine after a measles outbreak might also be useful, as it might help curb the expected incoming mumps outbreak.

Figure 3 shows that most of the measles cases were either unvaccinated or had an unspecified immunization status in all the studied years except for 2015. Multiple factors might affect the accuracy of these figures and numbers. One factor that must be taken into consideration in assessing the overall vaccine effectiveness is the number of vaccine doses administered; many of those who claimed they contracted measles despite vaccination might have received an insufficient dose of the vaccine that does not confer immunity. This misunderstanding might thus skew the percentages and falsely elevate the percentage of those contracting measles despite vaccination. Another factor is the high proportion of cases whose vaccination status is unknown (40.74%, Figure 3). This means that only 59.26% of the cases had a documented vaccination status, which still lags behind the target set by the WHO at a minimum of 80%, indicating a failing surveillance system [11]. The proportion of non-vaccinated persons

among those individuals might be higher than those who are vaccinated within the same group, obscuring the true estimate of vaccination coverage. Finally, one should take into consideration that there is a high chance that non-vaccinated persons are in fact clustered together and that the estimated vaccination coverage does not reflect the general population but rather represents that of a higher risk subpopulation [22].

Upon examining Figure 3, one cannot ignore the striking number of vaccinated people who contracted measles, as this might jeopardize the integrity of the vaccine in the eyes of the community. The current used vaccine in Lebanon is an-attenuated live measles vaccine that belongs to the Schwartz strain according to the WHO [10]. As mentioned earlier, individuals in Lebanon get a total of 3 vaccines that confer immunity against measles. Moreover, national catch-up campaigns against measles are conducted in case of any outbreaks as was the case in 2001, 2008 and 2013 in an attempt to enhance vaccination coverage and reduce the number of susceptible individuals. In one American study that discussed one of the largest measles outbreaks among highly vaccinated students – whose source case had coincidentally contracted the virus from Lebanon – it was revealed that students who have received both doses of the vaccine outside the United States were more susceptible to the infection than those who received both doses in the United states.[23] This was partly attributed to the quality of storage of the vaccine (the cold chain). Measles vaccine should be stored at 2-8°C and improperly stored vaccine may fail to provide protection against the disease. It has been revealed that new strains like the B3 strain, which is a more transmissible genotype, are becoming increasingly widespread leading to new epidemics worldwide. The quality of vaccine storage should be reviewed in Lebanon in lights of the observed ineffectiveness of vaccination in a significant number of people. Immunological and genetic research is also recommended to evaluate vaccine effectiveness against the aforementioned strains and identify any new strain that might not be covered by the available vaccines. This is to be bolstered by routine re-vaccination of high-risk individuals like health-care workers and contacts of measles cases in a strategy similar to the ring vaccination adopted in eradicating other viruses like Pox virus; this would help limit the dissemination of the virus and eventual eradication [24].

This high number of measles cases in vaccinated individuals might also be attributed to the fact that routine vaccination timeliness and completeness are still public health challenges, and currently timeliness is not routinely used as an indicator to evaluate immunization programs in Lebanon. A recent study by Mansour et al, found several factors that hinder vaccination, and these include socio-demographics, knowledge, beliefs and practices associated with age-appropriate vaccination. Interestingly, erroneously believing that children's vaccination is up-to-date for their age was negatively associated with the administration of timely vaccines [25]. Mothers may perceive that the vulnerability to disease lessens with older age in the already sensitized child who has completed the primary vaccination series providing them with a sense of safety and subsequent non-compliance to booster shots [26].

The presented data should serve as a guide for the strategies that must be set in the current fight against measles. The WHO has published a strategy which can serve as the base upon which we build one of our own that suits the Lebanese experience [2]. While the Lebanese Ministry of Public Health has already instituted a successful surveillance program and achieved a sufficient percentage of measles

vaccination, a clear outbreak plan remains to be set [6]. This plan can mimic the experience in Gabon which showed the importance of continuous surveillance, as well as molecular investigation in the fight against measles. Besides, active surveillance of measles contacts should also be implemented in case national vaccination campaigns are not possible, regardless of the vaccination status; in fact, secondary measles contraction in vaccinated individuals can present itself with symptoms dissimilar to those typical of the disease, allowing viral circulation in the absence of active monitoring [21]. This has been the case during the Israeli outbreak where the primary case presented with only fever and rash which was quite challenging to suspect measles [21]. The surveillance system must also improve in tracking vaccination records through encouraging families to hold onto home-based records [11].

Several infectious diseases outbreaks were noted in Lebanon in correlation with the huge influx of Syrian refugees into the country [8, 27]. No available data are present to describe the levels of measles vaccination in the migrant Syrian community in Lebanon. Data from Syria have shown subpar levels of first dose coverage of the measles vaccine ranging between 50-79% among their population [6]. The Italian experience showed that the migrant communities are not necessarily representative of their source population when it comes to measles vaccine coverage rates [28]. The discrepancy between migrants and their source population reflects the need for special screening and vaccination campaigns in migrants in Lebanon. This would be essential for the policy makers and the Ministry of Public Health to be able to contain ongoing outbreaks and curb future epidemics.

One of the cornerstones in the strategy to eliminate measles will be building public trust in the measles vaccine. Ever since the spread the later-falsified MMR-Autism theory, measles vaccination rates witnessed a hefty drop in some regions in the Western world. For example, the UK was declared endemic for measles in 2008, with some areas of London and Ireland reaching a vaccination level of only 60%. The United States also witnessed several outbreaks in the current decade with vaccination levels as low as 50% – far from the 95% herd immunity threshold [29]. However, the advocates of this theory are decreasing, yet some parents are still exhibiting a general anti-immunization approach [30]. Effective communication teams should be created and invested in to target different audiences and inform them on the importance of vaccination and the dangers of remaining unvaccinated [2]. This is highlighted in a recent study by Hoffman et al, which warned that social media outlets may facilitate anti-vaccination connections and organization by enabling the diffusion of century old arguments and techniques and facilitating anti-vaccination behaviour [31]. Although the subgroups arguing against vaccinations remain limited, such influences need to be combated and counteracted. Health professionals should leverage social networks to deliver more effective, targeted messages to different constituencies.

Last but not least, investing in local capacity building and research projects to understand the epidemiology and behaviour of the measles virus in relation to the population dynamics in Lebanon is of immense importance to establish national strategy and guidelines. This, in addition to the recommendations mentioned above, shall hopefully put the Lebanese community on the right path for true measles elimination.

Conclusion

In addition to ensuring compliance with a full course of vaccination of young children, booster immunization programs should be implemented to help protect young adults too. In addition, potential mumps outbreaks must be considered once measles outbreaks take place as there seems to be a close relationship between the two. Finally, eradication plans must be re-assessed ranging from adequate vaccine storage and transport to meticulous surveillance of potential measles cases to ensure minimal spread among the Lebanese population. The limitations of this study include lack of data on primary cases, secondary spread, and management that would have allowed to reproduce a better understanding of the present genotypes of measles strains among the population, identified the population at risk, and provided a closer picture to as how the Lebanese healthcare system is dealing with the diagnosis and treatment of measles cases.

Abbreviations

- LMPH = Lebanese Ministry of Public Health
- ESU = Epidemiological Surveillance Unit
- MCV = Measles antigen-containing vaccines
- MMR = Measles-Mumps-Rubella
- CDC = Center for Disease Control

Declarations

Ethics approval and consent to participate:

not applicable

Consent for publication:

not applicable

Availability of Data and Material:

The datasets generated and analysed in this study are available in the Lebanese Ministry of Public Health Epidemiological Surveillance Unit public records. These can be accessed at: https://www.moph.gov.lb/en/Pages/2/193/esu.

Competing Interests:

The authors declare that they have no competing interests.

Funding:

This research received no specific grant from any funding agency, commercial or not-for-profit sectors.

Author's contribution:

TEZ and MFK collected, cleaned, and analyzed the data and undertook the writing of the manuscript. TEZ and MFK also contributed to the proofreading and editing of the manuscript. NB and GK took part in the planning and manuscript revision. UM and ARB undertook the conceptualization and planning of this project, as well as manuscript revision and editing.

Acknowledgements:

We are grateful to colleagues at the Lebanese Ministry of Public Health for their help throughout this project. Their contribution during data collection was essential for this project.

References

1. Goodson, J.L. and J.F. Seward, *Measles 50 Years After Use of Measles Vaccine.* Infect Dis Clin North Am, 2015. **29**(4): p. 725-43.
2. Orenstein, W.A., et al., *Measles and Rubella Global Strategic Plan 2012-2020 midterm review report: Background and summary.* Vaccine, 2018. **36 Suppl 1**: p. A35-A42.
3. Thompson, K.M., *Evolution and Use of Dynamic Transmission Models for Measles and Rubella Risk and Policy Analysis.* Risk Anal, 2016. **36**(7): p. 1383-403.
4. World Health, O., *Measles vaccines: WHO position paper, April 2017 - Recommendations.* Vaccine, 2019. **37**(2): p. 219-222.
5. Dbaibo, G., V. Tatochenko, and P. Wutzler, *Issues in pediatric vaccine-preventable diseases in low- to middle-income countries.* Hum Vaccin Immunother, 2016. **12**(9): p. 2365-77.
6. Moss, W.J., *Measles.* Lancet, 2017. **390**(10111): p. 2490-2502.
7. Patel, M.K., et al., *Progress Toward Regional Measles Elimination - Worldwide, 2000-2015.* MMWR Morb Mortal Wkly Rep, 2016. **65**(44): p. 1228-1233.
8. Ozaras, R., et al., *The Syrian conflict and infectious diseases.* Expert Rev Anti Infect Ther, 2016. **14**(6): p. 547-55.
9. Raslan, R., et al., *Re-Emerging Vaccine-Preventable Diseases in War-Affected Peoples of the Eastern Mediterranean Region-An Update.* Front Public Health, 2017. **5**: p. 283.
10. *Measles Surveillance Guideline*. 2015, Epidemiology Surveillance Program - Ministry of Public Health: Lebanon.

11. Patel, M.K. and W.A. Orenstein, *Classification of global measles cases in 2013–17 as due to policy or vaccination failure: a retrospective review of global surveillance data.* The Lancet Global Health, 2019. **7**(3): p. e313-e320.
12. Manikkavasagan, G. and M. Ramsay, *Protecting infants against measles in England and Wales: a review.* Archives of Disease in Childhood, 2009. **94**(9): p. 681-685.
13. *Centers for Disease Control and Prevention.Recommended Child and Adolescent Immunization Schedulefor ages 18 years or younger UNITED STATES 2019 . Accessed 23 February 2019.*; Available from: https://www.cdc.gov/vaccines/schedules/downloads/child/0-18yrs-child-combined-schedule.pdf.
14. Özbek, S., et al., *Passive immunity of premature infants against measles during early infancy.* Acta Paediatrica, 1999. **88**(11): p. 1254-1257.
15. *What is the optimal age to give MCV2? Recommendations on timing. Accessed on 23 February 2019.*; Available from: https://www.who.int/immunization/sage/8_Optimal_age_MCV2_GOODMAN.pdf?ua=1.
16. *National Immunization Calender. Accessed on 23 February 2019*. Available from: https://www.moph.gov.lb/en/Pages/17/1153/national-immunization-calendar.
17. *Measles affects all age groups. Accessed on 23 February 2019.*; Available from: https://ecdc.europa.eu/sites/portal/files/images/Measles_2018.png.
18. He, H., et al., *Waning immunity to measles in young adults and booster effects of revaccination in secondary school students.* Vaccine, 2013. **31**(3): p. 533-537.
19. Kennedy, R.B., et al., *Differential durability of immune responses to measles and mumps following MMR vaccination.* Vaccine, 2019. **37**(13): p. 1775-1784.
20. Indenbaum, V., et al., *Ongoing mumps outbreak in Israel, January to August 2017.* Euro surveillance : bulletin Europeen sur les maladies transmissibles = European communicable disease bulletin, 2017. **22**(35): p. 30605.
21. Avramovich, E., et al., *Measles Outbreak in a Highly Vaccinated Population - Israel, July-August 2017.* MMWR Morb Mortal Wkly Rep, 2018. **67**(42): p. 1186-1188.
22. Althaus, C.L. and M. Salathé, *Measles Vaccination Coverage and Cases among Vaccinated Persons.* Emerging infectious diseases, 2015. **21**(8): p. 1480-1481.
23. Yeung, L.F., et al., *A Limited Measles Outbreak in a Highly Vaccinated US Boarding School.* Pediatrics, 2005. **116**(6): p. 1287-1291.
24. Melenotte, C., et al., *Measles: is a new vaccine approach needed?* The Lancet Infectious Diseases, 2018. **18**(10): p. 1060-1061.
25. Mansour, Z., et al., *Factors affecting age-appropriate timeliness of vaccination coverage among children in Lebanon.* Gates Open Res, 2018. **2**: p. 71.
26. Sinno, D.D., et al., *Prevalence and predictors of immunization in a health insurance plan in a developing country.* Pediatr Int, 2009. **51**(4): p. 520-5.

27. Kassir, M.F., et al., *Human rabies control in Lebanon: a call for action.* Epidemiology and Infection, 2018. **147**: p. e46.
28. Ceccarelli, G., et al., *Susceptibility to measles in migrant population: implication for policy makers.* J Travel Med, 2018. **25**(1).
29. Hussain, A., et al., *The Anti-vaccination Movement: A Regression in Modern Medicine.* Cureus, 2018. **10**(7): p. e2919-e2919.
30. Brown, K.F., et al., *UK parents' decision-making about measles–mumps–rubella (MMR) vaccine 10 years after the MMR-autism controversy: A qualitative analysis.* Vaccine, 2012. **30**(10): p. 1855-1864.
31. Hoffman, B.L., et al., *It's not all about autism: The emerging landscape of anti-vaccination sentiment on Facebook.* Vaccine, 2019.

Figures

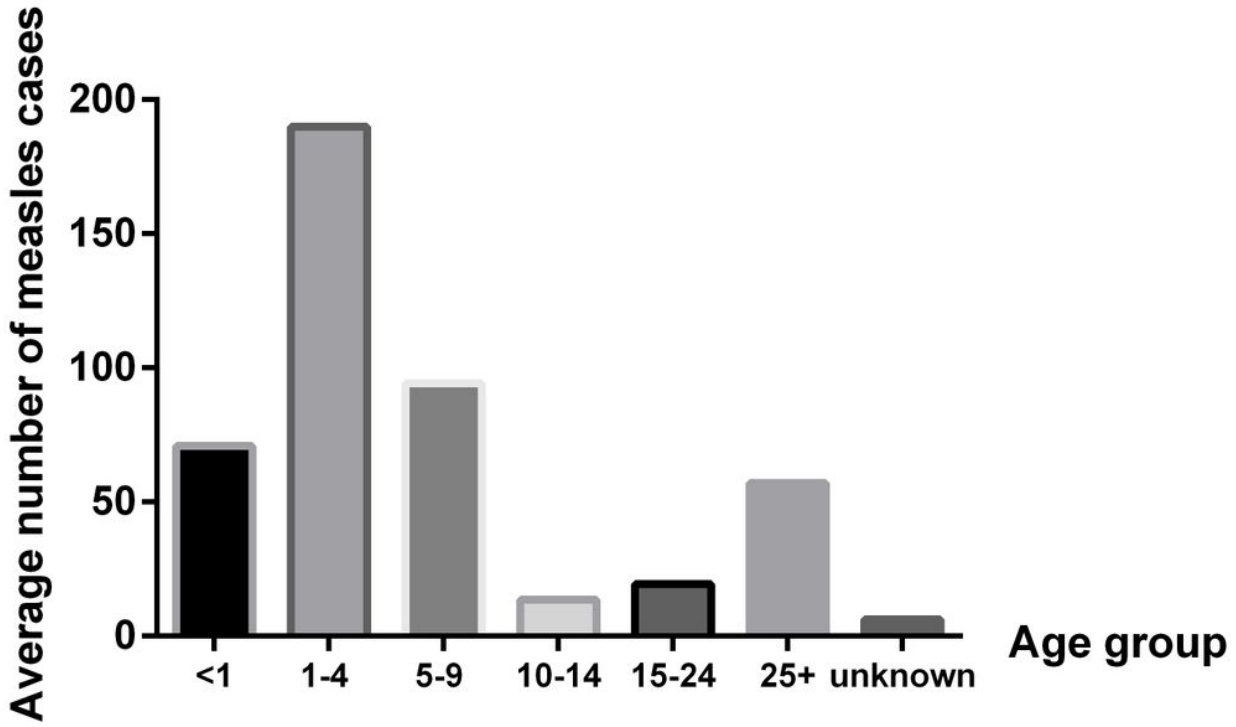

Figure 1: Distribution of measles cases among different age groups

Figure 1

Distribution of measles cases among different age groups

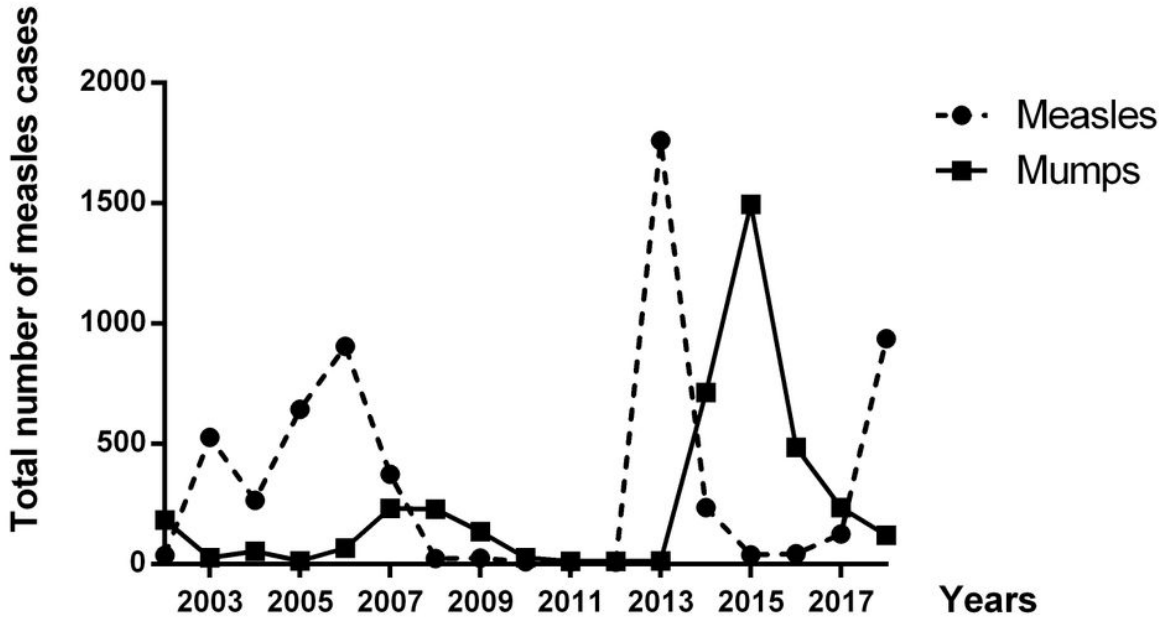

Figure 2: Total number of cases of mumps and measles in the period between 2002 and 2018

Figure 2

Total number of cases of mumps and measles in the period between 2002 and 2018

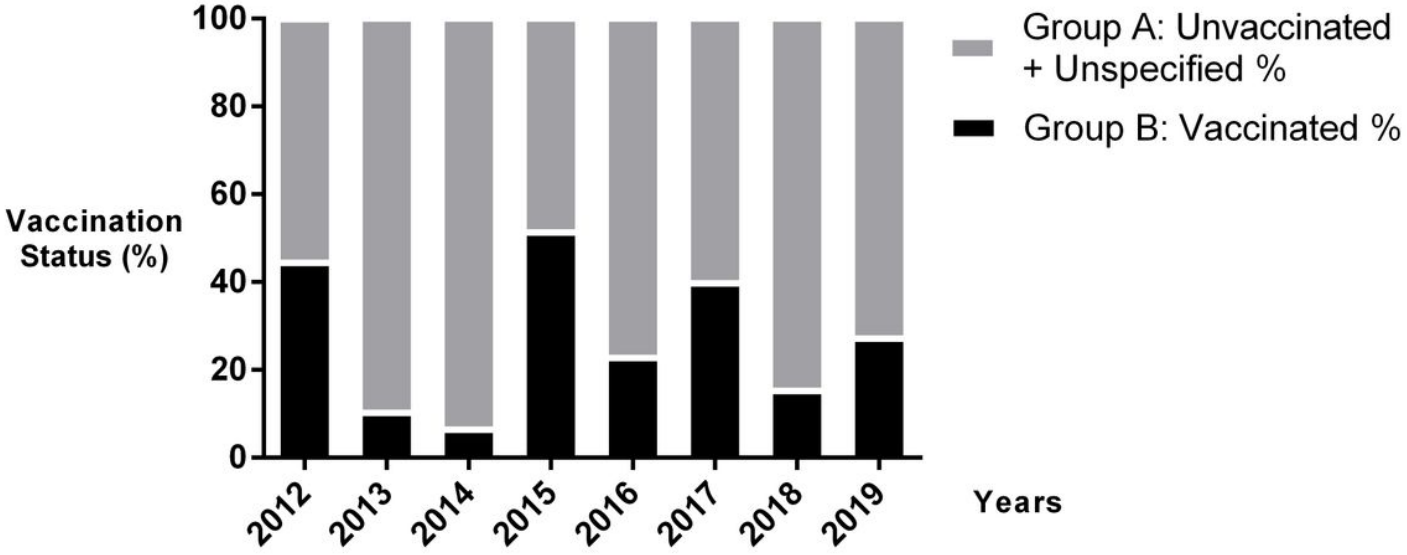

Figure 3: Vaccination status of individuals who conrtracted measles in the period between 2012 and 2019

Figure 3

Vaccination status of individuals who contracted measles in the period between 2012 and 2019