Epidemiology of Severe Acute Respiratory Infection (SARI) Cases at a sentinel site in Egypt, 2013–15

Mohamed M. Elhakim, Sahar K. Kandil, Khaled M. Abd Elaziz, Wagida A. Anwar

Community, Environmental and Occupational Medicine Department, Faculty of Medicine, Ain Shams University, 11566, Cairo, Egypt
Address correspondence to Dr Mohamed Elhakim, E-mail: melhakim@med.asu.edu.eg

ABSTRACT

Background Sentinel surveillance for severe acute respiratory infection (SARI) in Egypt began in 2006 and occurs at eight sites. Avian influenza is endemic, and human cases of influenza A (H5N1) have been reported annually since 2006. This study aimed to describe the epidemiology of SARI at a major sentinel site in the country.

Methods Data included in the study were collected from a major SARI sentinel site in Egypt during three consecutive years (2013–15).

Results A total of 1254 SARI patients conforming to the WHO case definition were admitted to the sentinel site, representing 5.6% of admitted patients for all causes and 36.6% of acute respiratory infection patients. A total of 99.7% of the patients were tested, and 21.04% tested positive; 48.7% of cases involved influenza A viruses, while 25% involved influenza B. The predominant age group was under 5 years of age, accounting for 443 cases. The seasonality of the influenza data conformed to the Northern Hemisphere pattern.

Conclusions The present study's results show that SARI leads to substantial morbidity in Egypt. There is a great need for high-quality data from the SARI surveillance system in Egypt, especially with endemic respiratory threats such as influenza A (H5N1) in Egypt.

Keywords Egypt, influenza, sentinel surveillance, severe acute respiratory infection

Introduction

Emerging respiratory infectious diseases pose a substantial risk to humans due to their extremely high potential to spread from person-to-person. These diseases can produce high morbidity and mortality.[1] There have been several incidents of emerging respiratory infectious diseases in the last hundred years, including the influenza pandemic of 1918 known as the 'Spanish flu', the 'Asian flu' pandemic in 1957, the 'Hong Kong flu' pandemic in 1968, the severe acute respiratory syndrome (SARS) pandemic in 2003, and the influenza A (H1N1) pandemic of April 2009.[2] All these events demonstrate the importance of having a surveillance system for respiratory infections that can detect new viruses rapidly and provide information to assess impact on the population and having operational preparedness plans.[3]

Influenza, with its capability for mutational changes, is one of these major respiratory infectious diseases with a high potential of transmissibility among humans.[4] Influenza causes a wide range of clinical illnesses ranging from asymptomatic infection to severe hospitalized disease and death. Humans, as well as viruses, can now easily circumnavigate the globe in less than 24 hours.[5] Influenza typically presents with sudden onset of fever accompanied by headache, sore throat, myalgia, malaise, anorexia and dry cough. Symptoms may be atypical in young children and the elderly.[6] The most common complication of influenza is pneumonia, which may be a primary viral pneumonia or secondary bacterial pneumonia, most commonly caused by *Streptococcus pneumoniae*, *Staphylococcus aureus*, *Haemophilus influenzae* and *Streptococcus pyogenes*. A wide range of other complications may occur less commonly, including neurologic, cardiac and musculoskeletal diseases.[7]

Surveillance of influenza is important for determining the timing and spread of the virus, for tracking changes in circulating viruses to recognize the seasonal influenza vaccine

Mohamed M. Elhakim, Medical Epidemiolgist
Sahar K. Kandil, Assistant Professor
Khaled M. Abd Elaziz, Professor
Wagida A. Anwar, Professor

composition, and as an alert mechanism for potential pandemic viruses.[5] Sentinel influenza surveillance focuses on the two extreme presentations of the disease: influenza-like illness (ILI) sentinel surveillance, which monitors persons with milder forms of the disease seeking outpatient care, and severe acute respiratory infection (SARI) sentinel surveillance, which is aimed to identify persons with severe forms of the disease who have been admitted to a hospital for treatment.[8]

Effective SARI surveillance includes the element of influenza sentinel surveillance, namely, the collection of data from a limited number of surveillance sites, complementing the routine surveillance. This approach enhances the quality of epidemiologic and laboratory data on influenza and strengthens a country's capacity for detection and prevention of severe cases of seasonal, novel and pandemic influenza. Improved epidemiological understanding of the influenza viruses and their seasonal trends is critical for effectively preparing for epidemics as well as pandemics.[9]

The SARI surveillance system in Egypt is employed for suspected novel influenza viruses, pneumonia and avian influenza surveillance; the programme started in early 2006. It has been leveraged for the detection and testing of suspected cases of Middle East respiratory syndrome coronavirus (MERS-CoV).[10] It is important to mention that avian influenza is endemic in Egypt; human cases of influenza A (H5N1) have been reported annually since 2006, and a total of 346 human cases of avian influenza A (H5N1), including 116 deaths (case fatality rate—CFR: 33.5%), have been reported in Egypt up to December 2015.[11]

This study aimed to describe the epidemiology of circulating viruses among SARI patients admitted to a sentinel site in Egypt during the study period and identify the symptoms associated with SARI cases among these patients.

Materials and methods

- **Surveillance site:** The data included in this study were collected from a major SARI sentinel site in Egypt during the period from January 2013 to December 2015.
- **Selected data:** All SARI patients who were admitted to the sentinel site in Egypt during three consecutive years (2013, 2014 and 2015) and met the World Health Organization Case Definition for Severe Acute Respiratory Infection (SARI) within the same period of the study, were included in the data analysis process.
- **Case definition:** Cases involved an acute respiratory infection with a history of fever or measured fever of ≥ 38°C and cough, with an onset within the last ten days and a requirement for hospitalization.[12]
- **Study duration:** Data of SARI patients admitted to the sentinel site in Egypt were collected and registered by the sentinel surveillance system of the site, supervised and under control of the Surveillance Department at the Ministry of Health and Population in Egypt during three consecutive years 2013, 2014 and 2015.
- **Laboratory results:** All samples collected from SARI patients at the sentinel site in Egypt were transferred to be tested for viruses at the Virology Laboratory, Central Public Health Laboratory, Ministry of Health and Population, Cairo, Egypt.
- **Data management and analysis:** The collected data were revised, tabulated and entered into a PC Excel file (Microsoft Office). Data cleaning and checking for quality of data entry were performed. The demographic, epidemiological and clinical characteristics were summarized. Further data analysis was conducted by epidemiological week and year against the number of SARI-positive cases over the study period to show the influenza peaks and seasonal variation and the influenza virus types and subtypes. The Moving Epidemic Method application (memapp),[13] through the R free software for statistical computing and graphics, was used to assess the quality of data and generate graphs of all seasons included in the study allowing the visual comparison of the magnitudes and timings of all epidemics in the dataset. Additionally, the application was used to calculate and display some estimators as follows: the number of influenza seasons included in the study, the average epidemic start week, the average epidemic length, the epidemic percentage and the epidemic and intensity thresholds (medium, high and very high).

Results

During the study period, from 1 January 2013, to 31 December 2015, a total of 1254 SARI cases fulfilling the SARI case definition were admitted to the sentinel site of our study. The highest percentage of SARI cases (34%, 424 cases) was reported during the three winter months: 137 SARI cases in December (10.9%), 129 SARI cases in January (10.3%), and 158 SARI cases in February (12.6%). The highest epidemiological week with SARI cases reported was week 6, with 62 (39.2%) SARI patients admitted to the hospital, representing approximately 5% of total SARI patients admitted to the hospital during the three years.

Of the study population, 540 (43.06%) were male and 714 (56.94%) were female. Most of the cases were among two age groups, less than 5 years old and between 18 and 64 years old. The age group of less than 5 years old was the most affected group among SARI male patients [237 (61.6%) patients with an average age of 2.1 years], while the age group of 19–64 years old was the most affected group among SARI female patients [335 (74.4%) patients admitted to the sentinel site during the study period, with an average age of 40.4 years] (Table 1).

Regarding the laboratory results, during the study period, 1250 specimens (percentage of tested cases is 99.7%) from both nasopharyngeal and oropharyngeal swabs were collected and tested from SARI patients. Of these cases, 263 (21.04%) tested positive for different respiratory viruses. Among these specimens that tested positive, 128 (48.7%) were influenza A viruses, 66 (25%) were influenza B viruses, 67 (25%) were respiratory syncytial virus (RSV), and 2 specimens (1%) were mixed viruses. Of the 128 influenza A viruses, 64 (24%) were influenza A (H1N1) pdm09, 60 (23%) were influenza A (H3), and 4 (2%) were influenza A (H5N1). Of the collected specimens, 196 specimens (75%) were influenza virus positive, and 67 specimens (25%) were other respiratory viruses (Fig. 1).

Using the Moving Epidemic Method (MEM), through the R software, two complete influenza seasons (2013/2014) and (2014/2015), and two incomplete influenza seasons (2012/2013) and (2015/2016) were plotted. The graphs showed that the highest peak of SARI cases reported at the sentinel site during the study period was in season (2013/2014), crossing the high epidemic threshold in the epidemiological week 7/2014 (Fig. 2).

The mean of the influenza epidemic (season) starting during the four influenza seasons (2012/2013, 2013/2014, 2014/2015, 2015.2016) was epidemiological week 3, and the mean of the end of the influenza epidemic (season) during

Table 1 Distribution of age groups by gender of severe acute respiratory infection (SARI) cases in the study's sentinel site from 1 January 2013 to 31 December 2015

Age		*Number (%)*		*OR (95% CI)*	P-*value*
	Total	*Male*	*Female*		
median (I-Q)		*4*	*20*		
<5	443 (35.3)	273 (61.6)	170 (38.4)	2.1 (1.70–2.65)	<0.001
5 to 18	45 (3.6)	10 (22.2)	35 (77.8)	0.38 (0.18–0.75)	0.005
>18 to 64	450 (35.9)	115 (25.6)	335 (74.4)	0.45 (0.36–0.58)	<0.001
>64	316 (25.2)	142 (44.9)	174 (55.1)	1.08 (0.84–1.38)	0.548
Total	**1254**	**540 (43.06)**	**714 (56.94)**	**1 (Reference)**	

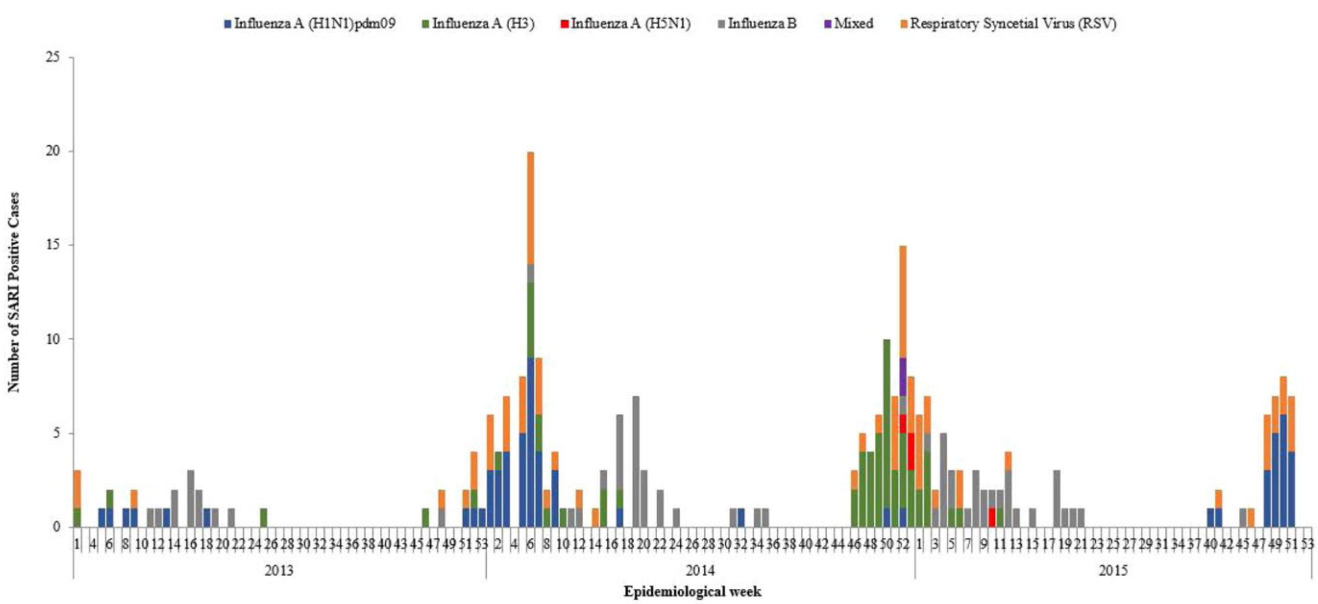

Fig. 1 Distribution of severe acute respiratory infection (SARI) positive cases by subtype, from 1 January 2013 to 31 December 2015.

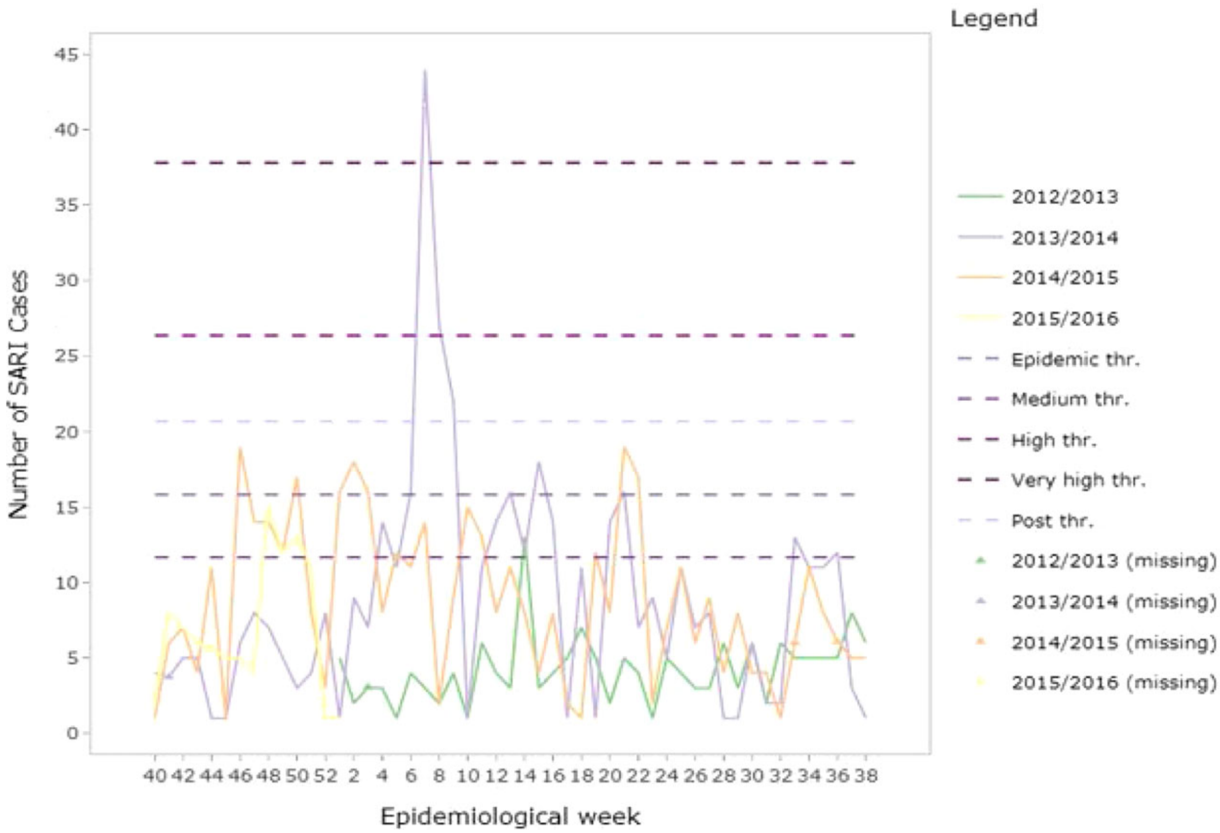

Fig. 2 Line graph presenting data from complete influenza seasons (2013/2014 and 2014/2015) and incomplete influenza seasons (2012/2013 and 2015/2016) with epidemic thresholds by MEM method—data from 2013 to 2015, sentinel site in Egypt.

the same four influenza seasons was epidemiological week 7 (Fig. 3). This figure also shows the average number of SARI cases reported during each of the four influenza seasons included in the study.

During the study period, the number of deaths in the study sentinel site, from all diseases, was 848 deaths, and the number of deaths among SARI patients was 48 deaths, representing 5.66% of the total number of deaths at the site. Table 2 shows that the higher percentage of deaths occurred in the age group less than 5 years old, with 30 deaths (62.5%); among female patients, with 28 deaths (58.3%); in the year 2014, with 23 deaths (47.9%); and during the winter season, with 22 deaths (45.8%).

As previously mentioned, in the majority of reported SARI cases from the site, 443 cases (35.3%), occurred in children less than 5 years old; therefore, the mortality rates due to smoking, chronic diseases and asthma were nonsignificant (Table 2). The highest number of deaths was recorded from patients with respiratory viruses other than influenza, such as RSV, with 40 deaths (83.3%).

The most common symptoms associated with SARI patients admitted to the sentinel site during the study period were fever in 1254 cases (100%) and cough in 1253 cases (99.9%), as these two symptoms are essential criteria of the SARI case definition mentioned by WHO and are used in the SARI surveillance system in Egypt.

Regarding other symptoms associated with SARI cases in the sentinel sites, during the study period, wheezes, nasal discharge and abnormal breath sounds were detected in 1245 cases (99.3%); nasal flaring in 535 cases (42.7%), grunting in 461 cases (36.8%), sputum in 433 cases (34.5%), tachypnoea in 333 cases (26.6%), indrawing in 325 cases (25.9%), sore throat in 272 cases (21.7%), and vomiting in 122 cases (9.7%). Finally, lethargy was reported in 32 cases (2.6%), dyspnoea in 27 cases (2.2%), pain in 10 cases (0.8%), haemoptysis in 9 cases (0.7%), and convulsions in 3 cases (0.2%) (Fig. 4).

Discussion

SARI represents an essential burden on health services worldwide. Influenza viruses are the most common cause of these severe infections that can be caused during a specific season (seasonal influenza) and can be transmitted from

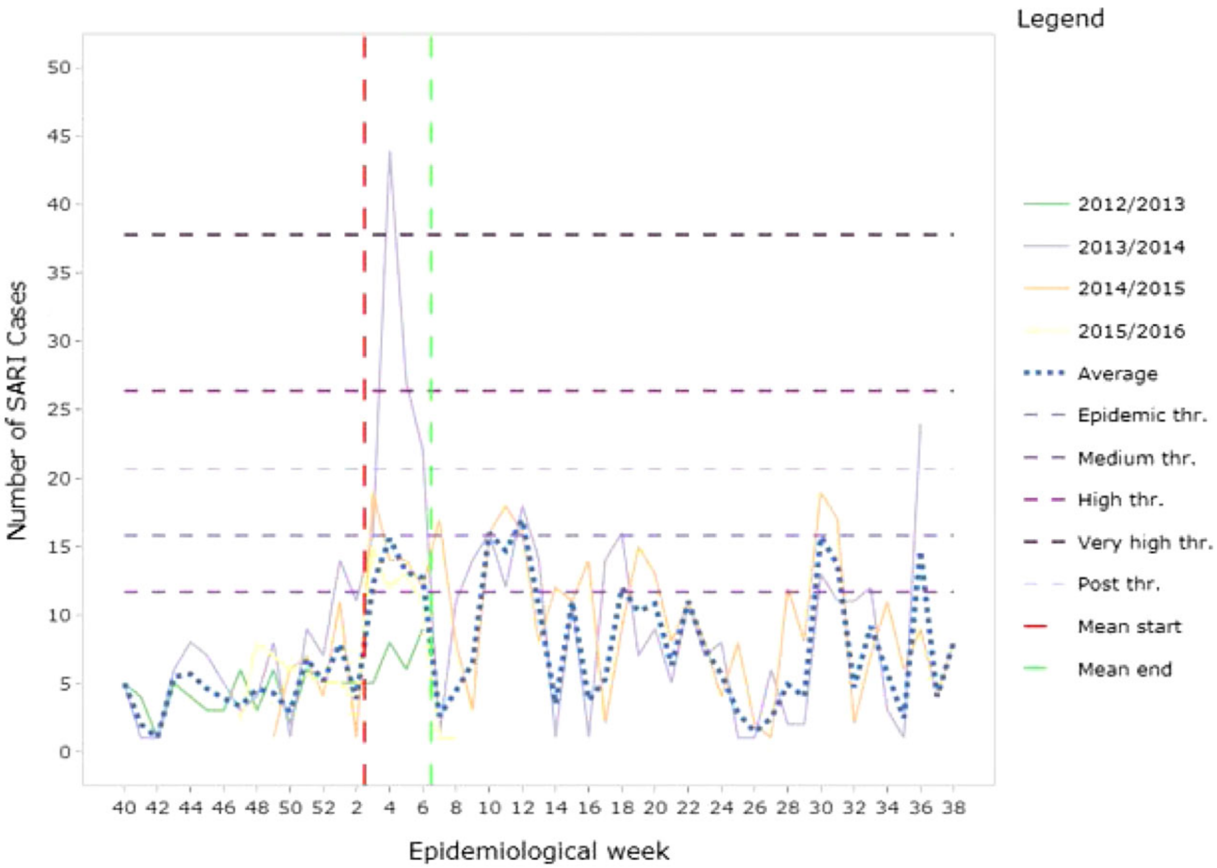

Fig. 3 The moving epidemic graph, showing all influenza seasons centered around their epidemic periods.

animals or poultry to humans (zoonotic and avian influenza).[10] The influenza burden rises from its potential to be transmitted across many parts of the globe, causing a pandemic—as in 2009, when a new influenza virus spread quickly across the globe and affected 74 countries in six continents, with an estimated number of human deaths reaching hundreds of thousands, all of which were attributed to this pandemic.[14]

Main finding of this study

The highest percentage of SARI cases in the sentinel site was reported in the less than 5-year-old age group (35%), with an average age of 2.1 years, and in the more than 18-to-64-year-old age group (36%), with an average age of 40.4 years. Additionally, the median age of SARI cases admitted to the hospital was 8 years, and the range was from 2 months to 85 years.

The results show that 1250 of 1254 SARI cases were tested. The positive cases for influenza and other respiratory viruses represented 21.04% of the total tested patients. The tested specimens showed that 49% of the positive cases involved influenza A virus, 25% of the positive cases involved influenza B virus, 25% of the tested cases tested positive for RSV, and 1% of the positive cases were reported to have more than one influenza virus, which is called a mixed virus infection.

The distribution of SARI patients admitted to the site showed a seasonal pattern, where the season starts around epidemiological (epi) week 40 and ends around epi week 20 of the following year. The findings showed that the highest percentage of SARI cases (34%) was reported during this period in the three consecutive years of the study. The highest percentage of SARI cases admitted to the hospital in a single epi week (39.2%) was reported in epi week 6 in the three years, representing approximately 5% of the total SARI patients admitted during the study period.

The trend of SARI cases in the sentinel site during the study period showed the highest peak of cases between epi week 4 and epi week 7. This finding was clearly obvious, especially during the two complete seasons (2013/2014 and 2014/2015), with the highest peak in epi week 6.

Concerning the use of the MEM application on the 2013–15 SARI data, the SARI incidence exhibited a clear

Table 2 Demographic, epidemiologic and clinical characteristics of mortality among SARI cases

	Total		*Survived*		*Died*		P-*value*	*OR (95% CI)*
	N°	%	N°	%	N°	%		
Age group								
<5	443	35.3	413	34.2	30	62.5	0.000	8.099 (2.829–23.187)
5–18 years	316	25.2	310	25.7	6	12.5	0.236	2.158.604–7.711)
>18–64 years	450	35.9	446	37	4	8.3	-	Ref
>64 years	45	3.6	37	3.1	8	16.7	0.000	24.108 (6.933–83.825)
Gender								
Female	714	56.9	686	56.9	28	58.3	-	Ref
Male	540	43.1	520	43.1	20	41.7	0.842	1.061 (0.591–1.905)
Year								
2013	235	18.7	226	18.7	9	18.8	-	Ref
2014	613	48.9	590	48.9	23	47.9	0.958	0.979 (0.446–2.148)
2015	406	32.4	390	32.3	16	33.3	0.944	1.03 (0.448–2.37)
Season								
Summer	235	18.7	228	18.9	7	14.6	-	Ref
Autumn	274	21.9	265	22	9	18.8	0.844	1.106 (0.406–3.017)
Winter	424	33.8	402	33.3	22	45.8	0.191	1.783 (0.75–4.237)
Spring	321	25.6	311	25.8	10	20.8	0.926	1.047 (0.393–2.793)
Smoke								
Yes	87	6.9	84	7	3	6.3	0.848	0.890 (0.271–2.926)
No	1167	93.1	1122	93	45	93.8	-	Ref
Chronic diseases (cardiac/ renal)								
Yes	61	4.9	58	4.8	3	6.3	0.650	1.320 (0.398–4.373)
No	1193	95.1	1148	95.2	45	93.8	-	Ref
Asthma								
Yes	5	0.4	3	0.2	2	4.2	0.002	0.057 (0.009–0.352)
No	1249	99.6	1203	99.8	46	95.8	-	Ref
Laboratory results								
RSV	67	5.3	64	5.3	3	6.3	-	Ref
H5N1	4	0.3	0	0	4	8.3	0.999	0.00 (0.00–0.00)
Influenza viruses	192	15.3	191	15.8	1	2.1	0.060	0.112 (0.011–1.093)
Other respiratory viruses	991	79.0	951	78.9	40	83.3	0.860	0.897 (0.270–2.980)

seasonality upon visual inspection of the data being plotted, which indicated one season per year for all the considered seasons. These seasons typically peak between December and March, as is the case in countries belonging to the Northern Hemisphere, with the highest peak of SARI influenza cases reported in season 2013/2014 and crossing of the high epidemic threshold in epidemiological week 7/2014.

What is already known about this topic

The findings of our study are in agreement with (Horton *et al.*, 2017a),[15] who reported that all pathogens examined in their study of SARI patients in the Eastern Mediterranean Region (EMR) from 2007 to 2014 were more frequently identified in participants who were less than five years of age than in older participants. Additionally, (Tarnagda *et al.*, 2014)[16] reported in their study that children less than 5 years old represent more than (40%) of the total influenza-positive cases.

The laboratory results are not far from what (Kadjo *et al.*, 2013)[17] reported in their study involving seven years of sentinel surveillance in Ivory Coast, a Northern Hemisphere country like Egypt, where 39% of specimens collected from sentinel surveillance patients were positive for influenza viruses, a percentage that is normal to be observed during the winter season in a Northern Hemisphere temperate climates.

The study's seasonal pattern exactly conforms to the WHO guidelines regarding the influenza season start and

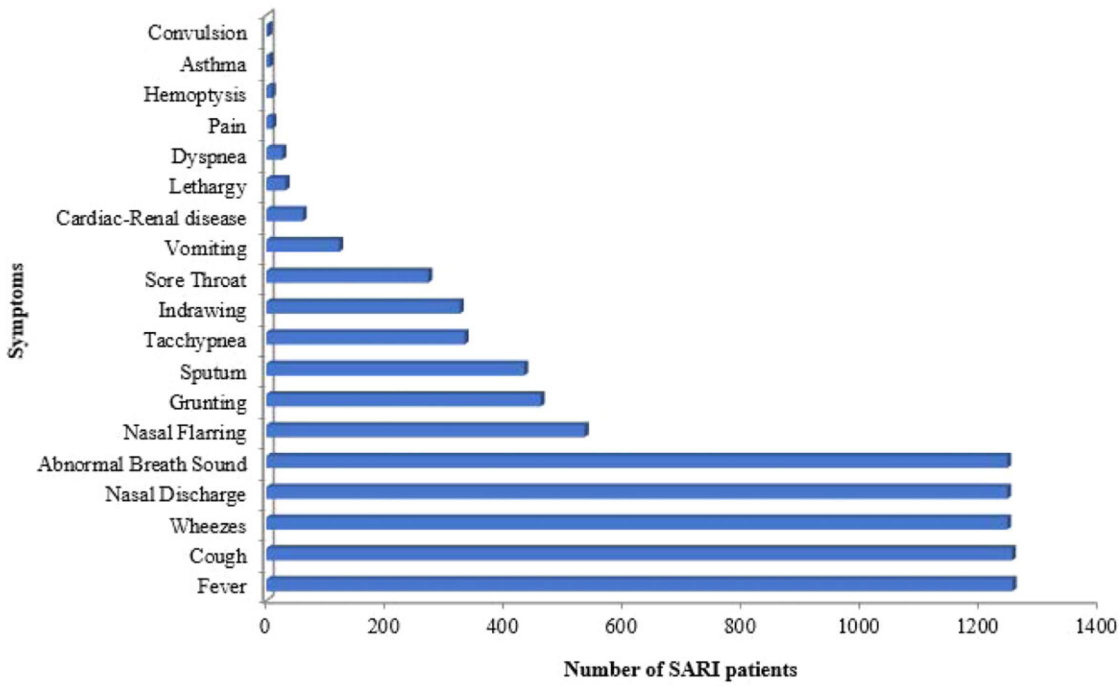

Fig. 4 Stacked bar chart showing associated symptoms in SARI patients admitted to the study sentinel site. 1 January 2013 to 31 December 2015.

end dates in the Northern Hemisphere. According to (Nair H, 2012),[18] the influenza season starts in countries of the Northern Hemisphere in week 40 (+ or – 5 weeks) and ends in these countries in epi week 20 (+ or – 5 weeks).

The trend of SARI cases in our study is similar to that observed by (Amato-Gauci *et al.*, 2011),[19] who described the trend of influenza cases (both SARI and ILI cases) before the 2009 influenza A (H1N1) pandemic during the seasonal influenza epidemic and then during the pandemic. Additionally, (Rowlinson *et al.*, 2017)[20] showed in their study that the months with the highest percentage of patients eligible for enrolment were October and December.

MEM application findings are consistent with those of (Cox, 2014)[21] and (Horton *et al.*, 2017b)[22] who described the seasonality of the viral respiratory pathogens examined in their study as following the temperate climates, where influenza virus was most common in winter months between October and February.

What this study adds

This study focuses on the Sentinel Surveillance System of Severe Acute Respiratory Infections (SARI) at one sentinel site in Egypt. Few studies conducted previously in Egypt have focused on this topic, assessing the situation in the whole country rather than focusing on a single sentinel site. The present investigation will enrich the available information on SARI in the country and will encourage more researchers to study the burden of acute respiratory infections (ARIs) in Egypt.

Limitations of this study

First, the catchment population of the SARI sentinel site was not available or easy to calculate, as this site is a major referral centre in Egypt for different types of fevers and acute infections. Therefore, it was not possible to calculate the burden of the disease (BoD), which is important for addressing the threat that seasonal influenza may pose, for strengthening the national and global preparedness as well as prevention and control efforts, and for understanding the overall global burden of influenza disease and preparing for influenza pandemics. Second, studying SARI in one sentinel site out of eight sites in Egypt, a country with more than 90 million people, cannot give a holistic picture of the real state of surveillance of this disease in the country.

Conclusion

This current study shows consistency of its results with respect to influenza seasonality, its comparability to the results in other Northern Hemisphere temperate countries, and the proportion of SARI cases that are influenza positive, suggesting that the surveillance system in the chosen sentinel site is performing very well according to global standards.

The study also indicates that SARIs lead to substantial morbidity in Egypt in different age groups and sexes. There is a great need for high-quality data from the SARI surveillance system in Egypt, especially with endemic respiratory threats such as influenza A (H5N1) in Egypt as well as similar threats in neighbouring countries, such as Middle East respiratory syndrome (MERS) in Saudi Arabia. Finally, it is obvious that the Ministry of Health and Population (MOHP) in Egypt is highly concerned with expending all possible resources to build the country's capacities for enhancing the sentinel surveillance system for SARI.

Acknowledgements

The corresponding author would like to thank Dr Amr Kandeel, Dr Alaa Eid, Dr Samir Refaey, and Dr Manal Fahim. The authors also appreciate the Department of Epidemiology and Surveillance, Preventive Sector, MOHP, Cairo, Egypt, which is the owner of the collected data used in the study. The sentinel site was mentioned anonymously in the manuscript because this research paper is an essential requirement for the corresponding author to receive his Master of Science (M.Sc.) degree in epidemiology from the Faculty of Medicine, Ain Shams University, Cairo, Egypt.

Conflict of interest

None declared.

Authors' contributions

All authors contributed equally to the manuscript.

Funding

This research paper is a part of the corresponding author's fulfilment of the requirements for the Degree of Master of Science (M.Sc.) in Epidemiology, Department of Community, Environmental and Occupational Medicine, Faculty of Medicine, Ain Shams University, Cairo, Egypt. Thus, the study did not receive any specific grant from funding agencies in the public, commercial, or nonprofit sectors.

Ethical consideration

The aggregated data list collected in this study is anonymous; thus, neither informed consent nor approval from an institutional review board was required.

References

1 Zumla A, Hui DS, Al-Tawfiq JA *et al.* Emerging respiratory tract infections. *Lancet Infect Dis* 2014;**14**(**10**):910–1.

2 McCloskey B, Dar O, Zumla A *et al.* Emerging infectious diseases and pandemic potential: status quo and reducing risk of global spread. *Lancet Infect Dis* 2014;**14**(**10**):1001–10.

3 Briand S, Mounts A, Chamberland M. Challenges of global surveillance during an influenza pandemic. *Public Health* 2011;**125**(**5**): 247–56.

4 El Shesheny R, Halasa NB, Williams JV *et al.* Molecular epidemiology and evolution of A(H1N1) pdm09 and H3N2 viruses in Jordan, 2011–2013. *East Mediterr Health J* 2016;**22**(**7**):491–502.

5 Meerhoff TJ, Simaku A, Ulqinaku D *et al.* Surveillance for severe acute respiratory infections (SARI) in hospitals in the WHO European region - an exploratory analysis of risk factors for a severe outcome in influenza-positive SARI cases. *BMC Infect Dis* 2015;**15**:1.

6 Fiore AE, Uyeki TM, Broder K *et al.* Prevention and control of influenza with vaccines: recommendations of the Advisory Committee on Immunization Practices (ACIP), 2010. *MMWR Recomm Rep* 2010;**59**(**RR-8**):1–62.

7 Madhi SA, Klugman KP. A role for Streptococcus pneumoniae in virus-associated pneumonia. *Nat Med* 2004;**10**(**8**):811–3.

8 Barakat A, Ihazmad H, Benkaroum S *et al.* Influenza surveillance among outpatients and inpatients in Morocco, 1996–2009. *PLoS One* 2011;**6**(**9**):e24579.

9 Ortiz JR, Sotomayor V, Uez OC *et al.* Strategy to enhance influenza surveillance worldwide. *Emerg Infect Dis* 2009;**15**(**8**):1271–8.

10 Kandeel A, Manoncourt S, Abd el Kareem E *et al.* Zoonotic transmission of avian influenza virus (H5N1), Egypt, 2006–2009. *Emerg Infect Dis* 2010;**16**(**7**):1101–7.

11 WHO. Cumulative number of confirmed human cases for avian influenza A(H5N1) reported to WHO, 2003–2016. 2016.

12 WHO. *WHO Surveillance Case Definitions for ILI and SARI.* Geneva: WHO Press, 2014.

13 Vega T, Lozano JE, Meerhoff T *et al.* Influenza surveillance in Europe: establishing epidemic thresholds by the moving epidemic method. *Influenza Other Respir Viruses* 2013;**7**(**4**):546–58.

14 Haq Z, Malik M, Khan W. The H1N1 influenza pandemic of 2009 in the Eastern Mediterranean Region: lessons learnt and future strategy. *East Mediterr Health J* 2016;**22**(**7**):552–6.

15 Horton KC, Dueger EL, Kandeel A *et al.* Viral etiology, seasonality and severity of hospitalized patients with severe acute respiratory infections in the Eastern Mediterranean Region, 2007–2014. *PLoS One* 2017;**12**(**7**):e0180954.

16 Tarnagda Z, Yougbare I, Ilboudo AK *et al.* Sentinel surveillance of influenza in Burkina Faso: identification of circulating strains during 2010–2012. *Influenza Other Respir Viruses* 2014;**8**(**5**):524–9.

17 Kadjo HA, Ekaza E, Coulibaly D *et al.* Sentinel surveillance for influenza and other respiratory viruses in Cote d'Ivoire, 2003–2010. *Influenza Other Respir Viruses* 2013;**7**(**3**):296–303.

18 Nair HCH, Mounts A. *A Manual for Estimating Disease Burden Associated with Seasonal Influenza in a Population.* Geneva: World Health Organization, 2012.

19 Amato-Gauci A, Zucs P, Snacken R *et al*. Surveillance trends of the 2009 influenza A(H1N1) pandemic in Europe. *Euro Surveill* 2011;**16**(**26**).

20 Rowlinson E, Dueger E, Mansour A *et al*. Incidence and etiology of hospitalized acute respiratory infections in the Egyptian Delta. *Influenza Other Respir Viruses* 2017;**11**(**1**):23–32.

21 Cox N. Influenza seasonality: timing and formulation of vaccines. *Bull World Health Organ* 2014;**92**(**5**):309–384.

22 Horton KW, Carlson NE, Grunwald GK *et al*. A population-based approach to analyzing pulses in time series of hormone data. *Stat Med* 2017;**36**(**16**):2576–89.