



Behaviour and control of influenza in institutions and small societies

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DECLARATIONS

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Summary

A literature review was undertaken to assess the impact of influenza in enclosed societies. The literature spanned 120 years and included both readily accessible material from online keyword searches, as well as more obscure paper documents found through in-depth library research. Enclosed societies have been predominantly found in some type of institution through this period although noticeable similarities exist in communities isolated by distance and geography. We observe that no matter how isolated a community is, it is not necessarily insulated from infection by influenza and that even where there are no complicating factors, such as the age distribution or the presence of individuals with greater susceptibility in the enclosed population, their organization tends to increase influenza transmission and the risk of secondary infection. The collected accounts demonstrate important features of outbreaks in such societies and the necessity of considering them in pandemic planning: in particular, rapid intervention is essential for the control of influenza spread in such circumstances. Recent experience has shown that administration of modern antiviral drugs, such as neuraminidase inhibitors are effective at moderating outbreaks of influenza, but only in combination with other methods of control. In more remote communities where such drugs are not, or less, readily available, and medical care is limited, such outbreaks can still pose particular difficulties. In all cases delay in correct diagnosis, detection of an outbreak or the implementation of control measures can result in the majority of the enclosed population succumbing to the disease.

Introduction

Of the many transmissible diseases that threaten modern society, influenza is one of the few that retains the capability to sweep through all populations across the globe. Containment of new influenza strains is largely unfeasible and currently most public health responses aim to reduce the peak number of cases and spread out the case

load.¹ With this in mind, in any sufficiently large population there will be groups of people who live apart from the rest of society. Some of these groups will form part of an institution (prisons, schools, the military, etc.); others are isolated by natural factors, as in the case of island populations, or by necessity such as those on board ship. Within an enclosed society, individuals generally live and work together and make repeated

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contacts with the same people throughout the day. This repeated contact serves to define such societies more than factors such as isolation from the wider population *per se* or the activities members of that society are engaged in.

Influenza presents these communities with particular difficulties. It is easily transmitted from person to person, not simple to identify and quarantine carriers of the disease, and the typical social structure of these groups often leads to rapid and extensive infection of the members.^{2–6} The separation of these communities from the wider population can be beneficial, as not all such groups will suffer an outbreak during a broader epidemic or pandemic. However, in those communities that *are* attacked, the proportion of people in that population who suffer from the disease (the attack rate) can be much higher than in the population as a whole.^{7,8} The rapid influx of patients to hospitals from such enclosed societies adds to the burden on local healthcare facilities.

Methods

We reviewed of all of the hard copy literature known to the authors; and electronically searched each of the online indexes Scopus, Web of Knowledge and Google Scholar for the search terms: “pandemic influenza”, and “seasonal influenza” with a qualifier of enclosed society type (*e.g.* “school” *etc.*). All publications from 2008 onward were searched, restricted only by the term “pandemic”. These initial articles were read, citations of relevance obtained and the process repeated until no new documents were found. The initial searches produced about 6000 articles of which approximately 300 were pertinent.

The earliest records, collated by Hirsch for his 1883 book,⁹ date back to the early middle-ages but are difficult to interpret as they lack rigorous case definition. The first influenza outbreaks in which there can be confidence of the disease and its spread, date from the 1889–90 pandemic and it is reports from this date onward that we consider here. To further ensure quality and comparability between outbreaks, we used as our primary criterion for inclusion a requirement that the article contained a quantitative characterization of the outbreak. At minimum we looked for a measure of attack rate. Of the 26 articles

that remained following the application of this criteria, several report details of multiple outbreaks bringing the total number of outbreaks reported on to 43. Table 1 reports full details of all outbreaks identified.

Outbreak aetiology

A typical outbreak in an enclosed society has three key features: rare importations, particular contact patterns and the rapid transmission of the disease through the population. A simple example of this occurred in the psychiatric unit of a New South Wales prison during the height of the southern hemisphere’s influenza season, August, in the year 2000.⁶ The disease was brought into the unit by an asymptomatic visitor, who became symptomatic on the evening after visiting. The person who had been visited succumbed to the disease and was hospitalized within 24 hours but not before attending a “medication group” meeting with six other prisoners. Three of the attendees of this meeting, two prisoners and a nurse, were taken ill within the week. Before realizing they were sick, they had been in contact with others in the community and by then the disease was established in the population. It went on to infect a further six prisoners and three staff.

In larger communities such outbreak features are still present, although because of the scale these are not quite as clear as above. During the 1919 pandemic at the California State Prison at San Quentin there were three influenza outbreaks, one for each wave of the pandemic.¹⁰ Between the waves there were periods when there was no disease activity within the prison and in all cases importation was through the arrival of a new prisoner bearing the disease. Disease transmission was assisted by placing arriving prisoners in a holding cell of up to ten other prisoners, “old timers” seeking out newcomers for news of the outside, the entire population eating together in communal mess halls and congregating at the weekends for entertainment. Control measures were introduced after the first wave and entertainment gatherings were cancelled for a period of six weeks. Measures such as quarantining new arrivals, the use of masks made from flour sacks and an attempt at vaccination were

Table 1**Detailed listing of historical influenza outbreaks in institutions and small societies**

<i>Location and reference</i>	<i>Type</i>	<i>Year</i>	<i>Group</i>	<i>Number in group</i>	<i>Attack rate %</i>
"Shaftsbury", Exmouth ³	Training ship	1890	Boys	395	51.6
"Mount Edgecumbe", Saltash ³	Training ship	1890	Boys	196	43.4
St Mary's Orphanage, Southall ³	Orphanage	1890	Officers	12	33.3
		1890	Boys	601	12.6
London Orphan Asylum ³	Orphanage	1890	Staff	24	25
		1890	Boys	302	23.2
		1890	Girls	167	26.4
		1890	Officers	21	9.5
Gordon Boy's Home, Chobham ³	School	1890	Servants	28	14.3
		1890	Boys	185	45.9
		1890	Staff	32	18.8
Kerrison Reformatory ³	School	1890	Boys	87	77
King Edward's Schools ³	School	1890	Girls	240	72.9
		1890	Staff	14	14.3
Industrial Schools, Swinton ³	School	1890	Children	589	29
Pentonville ³	Prison	1890	Staff	33	30.3
		1890	Prisoners in solitary labour	1126	5.7
		1890	Prisoners in associated labour	220	12.4
		1890	Prisoners in associated labour (not including the wheel)	120	17.7
Wormwood Scrubs ³	Prison	1890	Warders	98	19.2
		1890	Prisoners in associated labour	188	22.9
		1890	Prisoners in solitary labour	231	5.2
Wandsworth ^{3,13}	Prison	1890	Warders	86	11
		1890	Prisoners	902	18
Birmingham ^{3,12}	Prison	1890	Warders	87	22
		1890	Male prisoners	289	14.5
		1890	Female prisoners	58	29.3
Asylum for Imbeciles, Dareth ³	Asylum	1890	Warders	49	16.3
		1890	Male patients	495	8.1
		1890	Female patients	610	10.1
		1890	Male staff	37	35
		1890	Female staff	69	14.3

(Continued)

Table 1
Continued

<i>Location and reference</i>	<i>Type</i>	<i>Year</i>	<i>Group</i>	<i>Number in group</i>	<i>Attack rate %</i>
School for Imbecile Children, Dareth ³	School	1890	Male children, workers	25	56
		1890	Female children, workers	37	29
		1890	Male children at school	226	11
		1890	Female children at school	105	9.5
		1890	Helpless male children	142	10.6
		1890	Helpless female children	115	0
King's College School, Cambridge ²	School	1918	Boys	24	58.3
Friends' School, Saffron Walden ²	School	1918	Children	163	88.7
San Quentin, California ¹⁰	Prison	1918	Prisoners first wave	1900	27
		1918	Prisoners second wave	1900	3.7
		1918	Prisoners third wave	1900	3.1
HMS Africa ²³	Naval vessel	1918	Crew	779	75
HMS Britannia ²³	Naval vessel	1918	Crew	800	58
HMS Weymouth ²³	Naval vessel	1918	Crew	437	55
HMS Newcastle ²³	Naval vessel	1918	Crew	450	51
RN School Greenwich ²³	School	1918	Boys	1000	63
		1920	Boys	1000	44
		1957	Children 3 – 5 years	37	100
		1957	Children 6 – 12 years	124	70
Junior Village ¹⁶	Children's home	1957	Children 13 – 17 years	62	62
		1972	Prisoners	213	69
		1972	Solders	3935	19.8
Ramsey Unit II, Texas ¹¹	Prison	1972	Prisoners	213	69
US Air Force Academy, Colorado ¹⁹	Barracks	1972	Solders	3935	19.8
Christ's Hospital, Horsham ¹⁷	School	1976	Pupils	859 ^(average)	24
		1978	Pupils	859 ^(average)	49
Queen Margaret's school, Escrick, York ²⁴	School	1978	Girls	248	64.6
Christ's Hospital, Horsham ¹⁷	School	1980	Pupils	859 ^(average)	23
		1983	Pupils	859 ^(average)	29
		1986	Pupils	859 ^(average)	21

(Continued)

Table 1
Continued

<i>Location and reference</i>	<i>Type</i>	<i>Year</i>	<i>Group</i>	<i>Number in group</i>	<i>Attack rate %</i>
Hellenic Air Force recruit training centre, southern Greece ⁵	Barracks	1996	Recruits	1304	45.4
USS Arkansas ⁴	Naval vessel	1996	Crew	>500	42
Sheffield ⁸	Nursing home	1997	Nursing home A, upper floor	30	83
		1997	Nursing home A, lower floor	30	67
		1997	Nursing home A, staff	73	15
		1997	Nursing home B	28	57
		1997	Nursing home C	50	25
Psychiatric unit, New South Wales ⁶	Prison	2000	Prisoners	17	35
		2000	Staff	24	13
Infectious disease Ward, Barcelona ²⁵	Hospital	2001	Staff	57	29
		2001	Patients	23	34
IDF base, Israel ¹⁸	Barracks	2002	Solders, acute respiratory illness	3000	4.7
		2002	Solders, of which influenza like illness	3000	2.8
San Patrignano, Italy ⁷	Drug Rehab	2004	All patients	1310	15.9
Long term care facilities, USA ²⁶	Nursing home	2009	HIV positive Residents, Colorado	171	25.7
		2009	Staff, Colorado	39	28.2
		2009	Residents, Maine	25	40
		2009	Staff, Maine	125	6
		2009	Staff, Maine	175	5
		2009	Residents, New York	368	11
		2009	Staff, New York	615	22
First Nations community, Canada ²²	Isolated community	2009	General population	3200	18
Alexander Maconochie Centre, Australia ²⁰	Prison	2009	Prisoners	140	8.6
ATC 131 ²¹	Naval vessel	2009	Crew	355	22

also employed at various points during the pandemic.

The effect of setting

An enclosed society and its regime create conditions where influenza transmission is amplified

and the risk of complication is increased. We might expect military establishments, which comprise some of the fittest and healthiest adults, to remain relatively disease free, however, influenza attacks in these groups appear to be reasonably frequent. For example in 1996, influenza attacked 45% of the 1300 recruits at a Hellenic Air Force

training centre in southern Greece. This precipitated a meningitis outbreak that then infected 2.3% of the same recruits. Indeed, during times of pandemic influenza a significant portion of a fighting force can be affected: for instance during the 1890 pandemic 7.5% of the force, across the whole British Home Army, was attacked.³

Institutional regime strongly affects attack rates, a phenomenon particularly exhibited by prisons. Ramsey Unit II, a unit of the Texas Department of Corrections reported the greatest attack rate in prisons of 69% in the winter of 1972–1973. The men in this prison worked as farm labourers, were housed in seven large dormitories of around 60 men and ate in a common mess so providing ample opportunity for disease transmission.¹¹ The lowest attack rates were seen in English prisons during the 1890 pandemic. Inmates were typically confined to solitary cells with only one “social cell” in twenty; holding four prisoners.^{3,12,13} Prisoners were assigned work contemporaneously classified as communal or solitary. At Pentonville and Wormwood Scrubs, higher attack rates were observed amongst those groups involved in “associated labour” (12.4% and 22.9% respectively) as opposed to those that were not (5.7% and 5.2%).

Complicating factors

With educational establishments, a location of interest in studies of influenza transmission,¹⁴ there is the important additional feature of the increased number of contacts each child makes compared with adults,¹⁵ as well as the reduced immunity that children display toward the influenza virus. A pattern of attack rates consistent with the expected interactions of children with each other and the distancing that occurs as they age, was shown at Junior Village during the 1957 pandemic.¹⁶ Excluding vaccinated babies, over two-thirds of the children in the institution suffered from influenza. When the community is broken down by age, all of the 3 to 5 year olds, seventy percent of the 6 to 12 year olds and only half of 13 to 17 year olds suffered from the disease. Each age band lived in a separate “cottage” and so mostly associated with children their own age. The greatest overall attack rate to be reported, 89%, was at co-educational Friends School, Saffron Waldon in 1918.² In this school,

mixing between children in different classes was actively encouraged using measures such as mixed age playgrounds and alternating girls and boys at the dinner table. A more typical modern picture is provided by the multi-year (1976 to 1986) study at the school, Christ’s Hospital.¹⁷ Attack rates were between 20% and 30% each year, with a single year peak of 49% in 1978.

A severe outbreak that spread across three nursing homes in Sheffield during the very quiet 1997 influenza season illustrates that the reduction in contact rates compared to other age groups is offset by the additional frailty and reduced immune response brought on by age.⁸ The epidemic was centred on a home containing 60 residents split equally over two floors. On the upper floor 83% of the residents became ill, whilst on the ground floor the infection rate was lower with 67% residents becoming ill. Nine of the residents in this home died, giving a mortality ratio of fifteen percent. This outbreak spread back into the general population with eleven of the staff (15%) and “several” of their immediate family contracting the disease. One of the staff needed hospitalization with atypical pneumonia.

Immuno-compromised individuals are expected to be more susceptible to influenza infection. We see evidence of this at the, inpatient only, drug-user rehabilitation facility at San Patrignano in northern Italy.⁷ At this location there was an outbreak during the 2003–2004 influenza season. Taking the community as a whole, 16% of the population were attacked. However, separating out those individuals with HIV, one finds that 26% of these were attacked.

Mitigation

Containment of an outbreak of influenza in an enclosed society is difficult. Careful monitoring of the population and extreme control measures are often required to moderate an outbreak. Examples of both can be seen during the January 2002 epidemic at a large military base in central Israel.¹⁸ Over a two day period, 48 patients sought treatment for respiratory tract infections causing stringent disease and movement control measures to be implemented. The final acute respiratory illness attack rate was 4.7% with an influenza-like illness attack rate of 2.8%, but only

with levels of control that would be unlikely to be accepted or possible in a civilian situation.

Vaccination can be effective but requires foreknowledge of the strain of the virus. Prior vaccination of a group of 400 midshipmen visiting the US Air Force Academy in Colorado during the 1972 influenza season, saw only a single midshipman develop the disease while a fifth of the resident, unvaccinated cadets became ill.¹⁹ Whereas, substantial mismatch between the epidemic strain and the vaccine aboard the USS Arkansas saw 42% of the crew suffering acute respiratory disease despite 95% of the crew having received the 1995–96 influenza vaccine.⁴

Modern antiviral drugs were first used widely during the 2009 influenza pandemic, including in enclosed communities. In some cases, such as the outbreak at the newly-commissioned flagship prison, the Andrew Maconochie Centre, Canberra, Australia,²⁰ vigilance in identifying the index case as soon as symptoms became apparent, quarantine and targeted use of oseltamivir was able to limit the disease to 8.6% of prisoners. In communities where there are fewer resources available for mitigation measures, such as Peruvian Naval Vessel ATC 131 cruising from San Francisco, greater attack rates are reported. In this case, 22% of the crew became ill despite the enactment of “respiratory health” measures and limited treatment (6 of the 78 cases) with oseltamivir.²¹ Antiviral drugs were not available to all enclosed societies in 2009 and in particular aboriginal populations. In Australia, aboriginal people accounted for 15% of all ICU H1N1 cases despite making up only 2.6% of the population. In Canada, pregnant women with severe illness in the general population suffered just over half the hospitalization rate of all those living in the enclosed first nation communities.²²

Conclusion

This review elucidates the qualitative patterns of disease behaviour in enclosed communities. The separation of an enclosed society makes importation of influenza a rare event. After introduction, the rapid spread of the disease causes later importations to have very little influence on the course of the outbreak. Once established, each outbreak is essentially the result of a series of random events

marked by the nature of the enclosed society, the choices and contacts made by the people involved, any prior immunity, the response of public health officials, and the susceptibility and size of the population into which the disease is brought. All these events occur in an epidemic effecting the general population, but transmission rates are exacerbated by the smaller population sizes and tighter contact networks in an enclosed society.

Extensions to this work should seek to quantify the linkage between epidemic parameters and the demographics of an enclosed community. With the aid of the reports gathered here it should be possible to produce theoretical simulations of such communities that allow the effectiveness of different methods of intervention to be assessed. Nevertheless, to implement effective countermeasures good surveillance is essential. Delay in deploying influenza control measures, often unavoidable due to asymptomatic infections, can lead to particularly large outbreaks. Where non-pharmaceutical measures appear successful, they primarily sought to reduce the transmission of the disease by altering the structure of contacts made in the society. Current antiviral drugs, where they are available, serve to increase the effectiveness of physical methods of control but do not replace them.

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