Epidemiol. Infect. (1990), **105**, 21–27
Printed in Great Britain

International increase in *Salmonella enteritidis*: A new pandemic?

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(*Accepted 26 March 1990*)

SUMMARY

Over the past 5 years *Salmonella enteritidis* infections in humans have increased on both sides of the Atlantic ocean. The WHO salmonella surveillance data for 1979–87 were reviewed and show that *S. enteritidis* appears to be increasing on at least the continents of North America, South America, and Europe, and may include Africa. *S. enteritidis* isolates increased in 24 (69%) of 35 countries between 1979 and 1987. In 1979, only 2 (10%) of 21 countries with reported data reported *S. enteritidis* as their most common salmonella serotype; in 1987, 9 (43%) of 21 countries reported *S. enteritidis* as their most common serotype; 8 (89%) of 9 were European countries. Although the reason for the global increase is not yet clear, investigations in individual countries suggest it is related to consumption of eggs and poultry which harbour the organism.

INTRODUCTION

Over the past 5 years reported *Salmonella enteritidis* infections in humans have increased on both sides of the Atlantic ocean [1, 2]. The WHO salmonella surveillance data for 1979–87 show that *S. enteritidis* appears to be increasing in several continents. Although the reason for the global increase is not yet clear, investigations in individual countries suggest it is related to consumption of eggs and poultry which harbour the organism.

METHODS

The WHO salmonella surveillance system is based on voluntary national reporting of laboratory results. Summaries of the numbers of salmonella of each of the 15 most frequently isolated serotypes are submitted annually by participating countries to the Division of Enteric Pathogens, Central Public Health Laboratory, London, United Kingdom. We reviewed and analysed these reports for the years 1979 through 1987. Not every country submitted reports every year; countries were excluded from analysis if they submitted fewer than three annual reports during the 8-year period, if they reported a mean of fewer

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Table 1. S. enteritidis (*SE*) *isolates reported to the WHO salmonella surveillance system by 35 countries, 1979 & 1987**

Country	Number and (percentage) *S. enteritidis* (SE) Total 1979 (A)	Total 1987 (B)	Interval A to B	Isolation rate of SE per 100000 1987
North America				
Canada	40 (4·7)	888 (8·6)	(+) 85·0%	3·57
United States	2633 (8·5)	6950 (15·6)	(+) 84·2%	2·96
South America				
Argentina	1 (0·2)	228 (55·6)	(+) > 1000·0%	2·84
Brazil	5 (0·4)	29 (9·2)	(+) > 1000·0%	0·02
Peru	6 (0·4)	3 (0·2)	(−) 48·1%	0·02
Europe				
Austria	765 (24·6)	841 (35·4)	(+) 42·4%	11·20
Belgium	314 (4·2)	320 (5·0)	(+) 18·6%	3·23
Bulgaria	498 (20·7)	797 (45·4)	(+) 119·0%	8·96
England/Wales	787 (6·3)	5784 (33·0)	(+) 427·0%	11·64
Finland	236 (9·2)	2003 (38·7)	(+) 321·0%	40·88
France	551 (5·1)	1250 (11·2)	(+) 121·1%	2·29
Scotland	84 (5·6)	940 (40·9)	(+) 629·3%	18·08
Spain	108 (22·1)	2888 (68·2)	(+) 208·9%	7·56
Sweden	353 (10·6)	1712 (34·2)	(+) 223·0%	20·63
Hungary	1304 (16·3)	11843 (55·5)	(+) 240·2%	110·60
Romania	2913 (32·0)	1218 (15·5)	(−) 51·2%	5·41
Greece	13 (7·0)	201 (25·2)	(+) 260·4%	2·05
Asia				
Israel	289 (9·4)	65 (2·1)	(−) 78·0%	1·59
Mongolia	0 (0·0)	0 (0·0)	0·0%	0·00
Africa				
Senegal	8 (4·7)	4 (1·0)	(−) 79·0%	0·06
Tunisia	0 (0·0)	33 (0·8)	(+) > 1000·0%	0·51
Incomplete data				
Australia b	67 (2·2)	82 (2·6)	(−) 10·2%	0·37
Denmark !	177 (21·1)	654 (40·0)	(+) 89·3%	12·80
Iraq c	31 (1·8)	18 (1·3)	(−) 24·3%	0·12
Germ Dem Rep c	717 (7·5)	200 (1·8)	(−) 75·0%	
Fed Rep Germ **	2359 (4·9)	817 (5·8)	(+) 17·8%	
El Salvador !	0 (0·0)	0 (0·0)	0·0%	0·00
Italy !	763 (6·9)	885 (6·8)	(−) 1·1%	1·60
Mexico bb	14 (4·5)	24 (1·4)	(−) 70·0%	0·01
Netherlands !	202 (2·1)	149 (3·7)	(+) 71·9%	1·00
New Zealand bb	12 (0·0)	14 (1·2)	0·0%	
Norway !!	40 (12·8)	373 (44·6)	(+) 247·6%	9·10
Poland cc	9053 (34·1)	41757 (75·9)	(+) 122·3%	
Portugal ***	37 (9·6)	123 (55·7)	(+) 596·8%	1·23
Yugoslavia !	2138 (28·1)	4179 (41·8)	(+) 48·5%	18·30

* Unless other year indicated by footnote.
b 1983/1986 data. bb 1982/1987 data.
! 1979/1986 data. !! 1979/1985 data.
c 1979/1984 data. cc 1982/1985 data.
** 1979/1983 data. *** 1981/1986 data.

https://doi.org/10.1017/S0950268800047609 Published online by Cambridge University Press

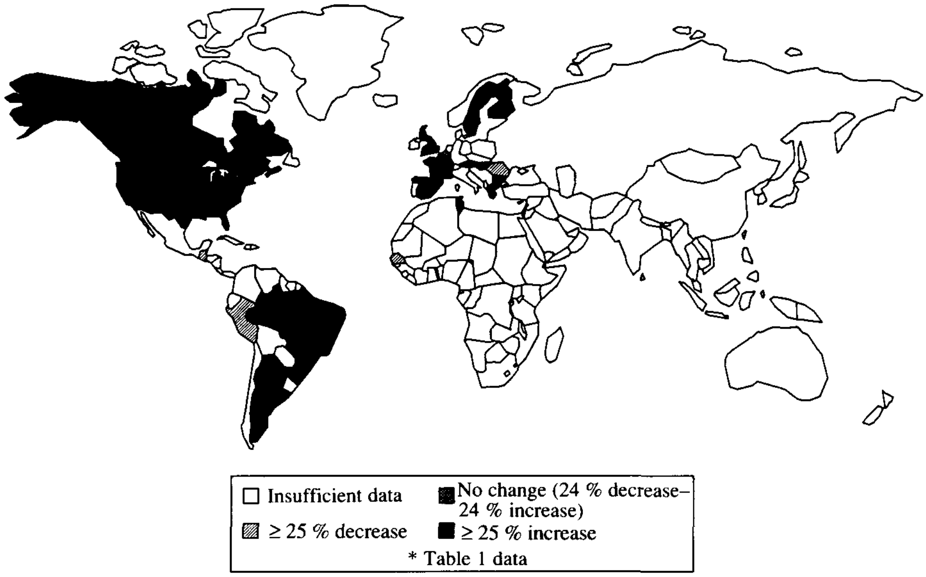

Fig. 1. World map of the percentage change between 1979 and 1987 in the proportion of *Salmonella enteritidis*/total *salmonella* isolates reported to the WHO *salmonella* surveillance system.

than 180 salmonella isolates per year, or if they reported only salmonella serogroups. Annual isolation rates for *S. enteritidis* were calculated by dividing each country's total yearly reported isolates of *S. enteritidis* by their mid-1983 population [3]. Where complete data spanning 1979–87 were not available, shorter time spans were used as indicated. The interval change in *S. enteritidis* (SE) infections between 1979–87 was calculated by subtracting the proportion SE/total salmonella for 1979 from SE/total salmonella for 1987, and dividing this quantity by the proportion Se/total salmonella for 1979.

RESULTS

Fifty countries submitted salmonella surveillance reports to the WHO salmonella surveillance system between 1979 and 1987. Ten (20%) of these were excluded from analysis; seven countries submitted fewer than three reports, two countries reported a mean of fewer than 180 total salmonella isolates per year, and one country reported salmonella serogroups only. Five of the remaining 40 countries (Bahrain, Chile, India, Malaysia, and Thailand) did not report *S. enteritidis* in their top 15 serotypes so exact numbers were not available for comparison; this left 35 countries for analysis. The number of reported *S. enteritidis* isolates increased in 24 (69%) of 35 countries between 1979 and 1987 (Table 1). Among these 24 countries, the proportion of total reported salmonella isolates that were *S. enteritidis* increased in 22 (92%). The interval change in the numbers of reported *S. enteritidis* infections between 1979 and 1987 was greatest in northern Europe and countries in South America (Table 1, Figure 1). Only 2 (10%) of 21 countries with reported data from both 1979 and 1987 reported *S.*

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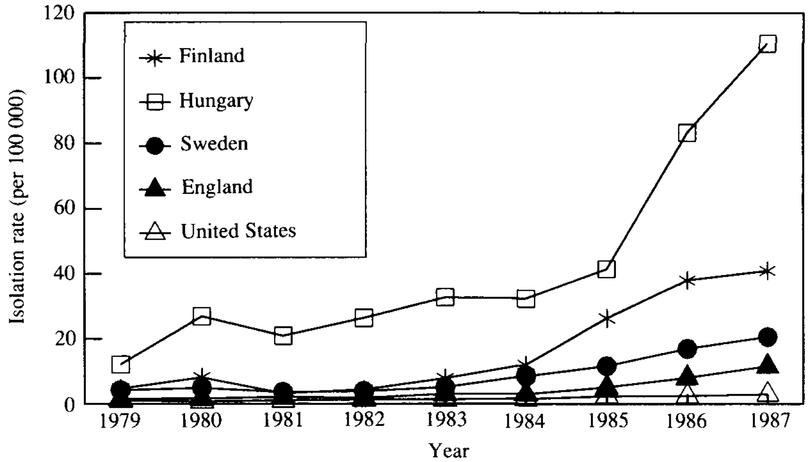

Fig. 2. *Salmonella enteritidis* isolation rates reported by five countries, 1979–87.

enteritidis as their most common salmonella serotype in 1979. In 1987, 9 (43%) of the 21 reported *S. enteritidis* as their most common serotype; 8 (89%) of 9 were European countries. In contrast, 14 (67%) of 21 countries reported *S. typhimurium* as their most common salmonella isolate in 1979, and this figure dropped to 8 (38%) of 21 in 1987. Although the increases in *S. enteritidis* isolation rates occurred at varying times in varying countries (Figure 2), the median percent increase in *S. enteritidis* isolation rates among these 21 countries between 1979 and 1987 was 126%.

DISCUSSION

Analysis of the WHO surveillance data has limitations. Surveillance of salmonella is not standardized between countries, and the proportion of cases which are reported may vary widely; however, the degree of incompleteness for each country should be consistent from year to year for most countries [4]. The proportion of salmonella reported as *S. enteritidis* should not be affected if all serotypes are equally likely to be reported. Therefore, the trend of increasing isolation rates of *S. enteritidis* noted in many countries simultaneously is unlikely to be an artifact.

The reported increase in *S. enteritidis* infections involves at least the continents of North America, South America, and Europe, and may include Africa where countries not participating in the WHO surveillance system, such as Rwanda [5] and Uganda [6], have also reported that *S. enteritidis* is a common salmonella serotype. It does not yet appear to include Asia or Australia. *S. enteritidis* was the most common salmonella isolate reported between 1977–81 in the South Moravian region of Czechoslovakia [7].

The reasons for the massive increase in *S. enteritidis* in many countries are not yet clear. Local epidemiologic data from the United States, Hungary, Spain, France, and Norway suggest that eggs may be an important vehicle for this pathogen in these countries. Recent epidemiologic investigations of the fivefold

Table 2. *Countries reporting* Salmonella enteritidis *as their most common* salmonella *isolate, 1979 and 1987 (n 21 countries)*

Year 1979	Year 1987
Austria	Argentina
Romania	Austria
	Bulgaria
	Finland
	Hungary
	Portugal
	Spain
	Sweden
	Scotland

increase in *S. enteritidis* isolation rate in the north-eastern region of the United States identified grade A shell eggs as the dominant vehicle for outbreaks of this infection [1]. In Hungary, a large outbreak involving 453 patients was traced to contaminated eggs and a poultry breeder in Dunaszentgyorgy [8]. In 1985, 46 (92%) of 50 reported salmonella foodborne outbreaks in Spain were caused by *S. enteritidis*, and eggs and egg-containing foods were the most commonly implicated vehicles [9]. Epidemiologic investigations of *S. enteritidis* outbreaks in France have implicated a wide variety of egg-containing vehicles ranging from an asparagus egg sauce to chocolate mousse [10]. In Norway an outbreak of *S. enteritidis* infections involving 16 children and 4 adults was traced to consumption of a lemon mousse made from raw eggs [11]. In the United Kingdom, poultry as well as eggs are associated with the increase in *S. enteritidis* infections; the majority of *S. enteritidis* isolated from humans in England, Scotland, and Wales are of the same phage type 4, as are the *S. enteritidis* isolated from both poultry and eggs [2, 12–15].

Eggs have long been associated with salmonella infections [16–18]. They can become contaminated after contact with chicken faeces if pores or cracks in the shell allow bacteria entry. A second mode of contamination has been demonstrated for several serotypes; an ovarian or oviduct infection can contaminate egg contents before the shell is formed around the yolk and albumin [19–21]. If infected primary poultry breeding flocks can transmit *S. enteritidis* infections to their progeny via a transovarian route, and the progeny subsequently lay contaminated eggs, then commercial egg quality control measures that merely focus on elimination of cracked eggs or external sanitation of eggs can not fully protect the consumer. Furthermore, primary prevention by embargoing eggs from symptomatically infected flocks may not be effective since this organism appears to be host-adapted and the infected chickens usually do not demonstrate any clinical illness [1].

Although international trade of a common vehicle has caused international outbreaks of salmonellosis in the past [22, 23], it is not clear that a common source such feed, chicks or contaminated eggs is responsible for the global increase in *S. enteritidis*. The results of outbreak investigations in a few countries may not apply to the other countries with increases in *S. enteritidis* infections. Although many sporadic cases may represent unrecognized outbreaks caused by dissemination of salmonella through the foodchain [24], sporadic cases do not necessarily stem from

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the same food sources as recognized outbreaks, and sporadic cases constitute the majority of isolates. In addition, the global epidemic has more than one molecular epidemiologic marker: the dominant *S. enteritidis* phage type in the United Kingdom is Colindale phage type 4, while in the United States phage types 8 and 13-a predominate [2]. In many western European countries, phage type 4 has been responsible for the recent increase (B. Rowe, unpublished data). One would expect to see the same *S. enteritidis* phage type reported from different countries is a single common source dispersed through international trade was primarily responsible for the global increase.

The information from the WHO surveillance system suggests that *S. enteritidis* is becoming a predominant pathogen in many countries, but no consensus has yet been reached about the best control methods. If the transovarian route is shown to be the major mode of contamination eggs with *S. enteritidis*, and eggs are shown to be important causes of *S. enteritidis* infections in many countries, a rational control program would focus on detecting infected primary breeding flocks and eliminating *S. enteritidis* from animal feeds; this should control spread of this serotype from breeding poultry flocks to their progeny, and subsequently to eggs reaching consumers. Meanwhile, in countries reporting high isolation rates of egg-associated *S. enteritidis*, consumers should be advised to avoid recipes using raw eggs, and to cook shell eggs and other foods of animal origin adequately. When poultry, as well as eggs, are major vehicles for dissemination of this serotype, modifying poultry production methods to decrease contamination will also be important.

When should a country be considered to have an *S. enteritidis* problem? It is difficult to establish a universal criterion. Large differences in isolation rates among countries may be due to differences in surveillance systems alone, so that absolute isolation rate is difficult to compare from one country to another. However, a country in which *S. enteritidis* is the most frequently reported salmonella serotype is very likely to be affected, as is a country in which either the isolation rate or the proportion of all salmonellae that are *S. enteritidis* is rapidly increasing. Furthermore, investigations of a fivefold regional increase of *S. enteritidis* infections in the north-eastern United States [1] showed that a low national *S. enteritidis* isolation rate may conceal an important regional increase. Examination of *S. enteritidis* surveillance data for separate regions within a country may hold important clues to its epidemiology, especially in countries reporting relatively low *S. enteritidis* isolation rates.

The solution to the *S. enteritidis* problem will require a multidisciplinary approach with cooperation between academic, commercial, and public health sectors. The use of molecular markers, such as phage typing and plasmid profiles, will be crucial to understanding the epidemiology of *S. enteritidis* and to separate distinctive *S. enteritidis* strains that have unique virulence factors, such as the reported increased virulence of *S. enteritidis* phage type 4 in poultry [2, 25–27]. Current egg and poultry production and distribution methods will need re-evaluation. Epidemiologic investigations and laboratory-based surveillance will continue to be the cornerstones for development of a rational control program.

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