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4

Magnitude and impact of diarrhoeal disease

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Diarrhoea seems to be a minor problem in humans and other mammals living in small, isolated tribes or groups. Under such conditions there is limited, if any, introduction of pathogenic agents and, if agents are introduced, there may not be sufficient critical mass to guarantee transmission and the production of an endemic state of a given agent of diarrhoea. Furthermore, small groups of individuals tend to handle water and faeces more carefully, with fewer opportunities for spread of the aetiological agents of diarrhoea. When humans cluster in crowded cities and villages without having attained the desirable level of environmental sanitation and personal hygiene, microbial pathogens rapidly become endemic, and diarrhoea is then a leading cause of morbidity, malnutrition and mortality.

Much has been learned regarding the epidemiology and aetiology of acute diarrhoeal disease since the time it was believed to be caused by 'indigestion', 'cold' or 'unwholesome' foods. While shigellosis, salmonellosis, cholera, enteric fevers, giardiasis, amoebiasis and other specific enteropathies had been well characterized for many decades, the acceptance that most diarrhoeas of the general population are of an infectious nature took longer. As recently as 1963, some still considered 'weanling diarrhoea' (Gordon et al, 1963) to be caused by the change from maternal milk to solid foods, without regard to the microbial flora and bacterial toxins that might be present in such foods. Fortunately, epidemiologists, microbiologists and paediatricians continued to pursue infectious causes of diarrhoea for several reasons: (1) diarrhoea is always prevalent whenever there is faecal contamination; (2) diarrhoea mainly affects children, sparing most adults, suggesting the development of immunity; and (3) acute diarrhoea spreads like other infections, from one (or several) index case to other persons, causing outbreaks and epidemics. Indeed, in recent decades, new viral, enterotoxigenic bacterial and parasitic agents have become recognized as causes of the majority of endemic diarrhoeal illnesses in children in tropical, developing areas. When personal hygiene and environmental sanitation improves, a decline in morbidity and mortality and a subsequent improvement in nutrition and growth are observed (Mata, 1985a).

Table 1. Incidence of diarrhoea and dysentery.

Community	Social condition	Age group (years)	Study period	Child-years of study	Episodes	Episodes/ child/year	Reference
Cauqué, Guatemala	Rural, very poor	0–3	1964–1969	132.5	1050	7.9	Mata (1978)
Matlab, Bangladesh	Rural, very poor	0–2	1978–1979	120	727	6.1	Black et al (1982)
Pacatuba, Brazil	Rural, very poor	0–5	1978–1980	86	519	6.0	Guerrant et al (1983)
Goncalves-Dias, Brazil	Urban, very poor	0–5	1984–1986	254	2896	11.4	Schorling et al (1987)
Puriscal, Costa Rica	Rural, relatively poor	0–2	1981–1984	70.7	44	0.6	Simhon et al (1985)
Charlottesville, US	Suburban, not poor	0–3	1975–1977	39.4	97	2.5	Hughes et al (1978)
Winnipeg, Canada	Urban, not poor	0–2	1976–1979	139	165	1.2	Gurwith et al (1981)

Adapted from Mata et al (1983), Simhon et al (1985) and Guerrant et al (1989).

MORBIDITY

In poor, traditional communities, diarrhoea is the leading cause of illness, disability and death. Children in a Guatemalan Indian village experienced, on average, eight episodes of diarrhoea per child per year (Mata, 1978). Similarly high morbidity rates have been documented in Bangladesh, Brazil, India and other countries whenever good field methodology has been applied (Black et al, 1982; Guerrant et al, 1983; Bhatnagar and Dosajh, 1986). According to the Guatemalan study (Mata and Urrutia, 1977; Mata, 1978), there were about 2 billion cases of diarrhoea per year in the world (Mata et al, 1980), a higher figure than the 500 million cases proposed by Rohde and Northrup (1976). Another estimate of global morbidity yielded about 1 billion cases per year (Snyder and Merson, 1982). The great majority of cases occur in less-developed countries, where hygiene and sanitation are generally deficient. The original description of eight different episodes of diarrhoea per child per year (Mata, 1978) was not immediately accepted by the scientific community. However, such high attack rates were confirmed, and even higher ones were documented in Brazil and India (Guerrant et al, 1983; Schorling et al, 1987; Bhatnagar and Dosajh, 1986). In contrast, diarrhoea morbidity rates in industrial nations are significantly lower, as revealed by the Cleveland study (Dingle et al, 1964) and more recent studies in Charlottesville and Winnipeg (Hughes et al, 1978; Gurwith et al, 1981).

However, diarrhoea morbidity in impoverished subpopulations within advanced nations remains as much a problem as in underdeveloped nations, as revealed by a recent analysis in the United States (Ho et al, 1988a). When environmental conditions and personal hygiene improve, however, very low diarrhoea rates can be attained in rural areas in less-developed countries, as illustrated by the Puriscal data in Table 1 (Simhon et al, 1985).

Breast-feeding confers significant protection against diarrhoea, and rates are lower during the period of exclusive breast-feeding (Mata, 1978; Guerrant et al, 1983). The highest rate of diarrhoea occurs during weaning, early in infancy in societies in transition, and into the second year of life or later in traditional ones. Diarrhoea exerts its greatest negative effect on child health and survival in these critical years.

IMPACT ON THE NUTRITIONAL STATE

Several intestinal habitats are suitable for microbial invasion and colonization. Pathogens may live in the intestinal lumen and virtual spaces near plicae; they may also penetrate beyond plicae, villi, and even intervillous spaces. With chronic malabsorption, malnutrition or other pathological conditions, hollow spaces or microcaverns may form, favouring stagnation of secretions and debris suitable for microbial proliferation (Luckey, 1974). Enteric pathogens have a wide range of effects. Some bacteria (cholera vibrios, enterotoxigenic coliforms and *Aeromonas*) alter the absorption–secretion balance by releasing enterotoxins. Other bacteria (enteropatho-

genic *Escherichia coli*) attach to villous tips, damaging the brush border, or multiply inside crypt cells, inducing fluid loss. Some agents like *Cryptosporidium* adhere to the surface of enterocytes, disturbing the brush border. *Giardia* may attach strongly to enterocytes, inducing anatomical and functional alterations. Rotaviruses and small-round viruses invade epithelial cells and replicate within them, causing structural damage with loss of disaccharidases and impaired absorption. *Shigella* and other enteroinvasive bacteria invade epithelial cells and burrow into the lamina propria, eliciting an inflammatory response, with loss of plasma, blood and cells, formation of microabscesses and ulceration. Some enteric pathogens are enterohaemorrhagic, and others may reach the lymph and blood circulation, lodging in distal organs.

All these microbial mechanisms contribute to diminished food intake, reduced nutrient absorption, increased secretion and many metabolic alterations. There may be also protein-losing enteropathy in diarrhoea. These phenomena may lead to malnutrition, especially if rehydration and alimentation are not promptly instituted. Cultural traditions, taboos and beliefs account for significant intentional suppression of oral intake by the mother or attendant; in some cases, children with diarrhoea are fasted. Purgatives, equivocal medication and other damaging procedures may be instituted. Diarrhoea itself results in decreased food consumption mediated by anorexia and vomiting. Increased peristalsis and intestinal lesions impair digestion and absorption. Diarrhoea, a hypersecretory state due to stimulation of cAMP and cGMP and other actions of infectious agents or their products, results in losses of water, sodium, potassium, chloride, vitamins and trace elements. Diarrhoea places the patient in a condition of acute malnutrition. Structural and functional alterations of the intestinal mucosa lead to protein-losing enteropathy. These alterations may precipitate oedematous protein-energy malnutrition, while many diarrhoeas cause a negative balance of nitrogen, magnesium, potassium and phosphorus, breakdown of muscle protein, increased synthesis of acute-phase reactant proteins and sequestration of trace elements. A significant number of episodes become chronic with added negative consequences (Mata, 1985a; McAuliffe et al, 1986; Schorling et al, 1987).

These effects are observed in the growth curves of poor Cauqué infants (Guatemala) as weight losses and arrests in linear growth, after the period of exclusive breast-feeding, immediately following attacks of diarrhoea and other infectious diseases (Mata, 1978). In addition, Pacatuba children (Brazil) showed a negative effect on weight, height and arm circumference (independent of prior nutritional status) within 3 to 5 months of the diarrhoeal attack (Guerrant et al, 1983). The maximum nutritional impact in Guatemala and Brazil occurred in the second year of life, when diarrhoea was associated with a considerable arrest in linear growth. The negative effect of diarrhoea on nutrition and growth is enhanced in infants who experienced fetal growth retardation, in those exposed to more infections and other forms of stress, in those already malnourished, and in those with deficient mothers and homes (Mata, 1978). Wasted and stunted children may show immunological abnormalities and they have a distinctly higher

mortality rate than well-nourished children. Thus, diarrhoea leads to malnutrition and increases the risk of death. However, well-nourished children may also die if they become dehydrated and toxic and are not treated and supported promptly.

MORTALITY

A prospective study into the causes of death in four Guatemalan rural villages, conducted in 1956–1957, showed that 43% of the diarrhoeal deaths were not recorded in the official statistics (Béhar et al, 1958); this seems to be the case in many less-developed countries. Furthermore, diarrhoeal death statistics are very poor the world over. Global estimates of diarrhoea mortality ranged from 5 to 18 million for children under 5 years of age in Africa, Asia and Latin America in 1975 (Rohde and Northrup, 1976). Other authors estimated about 5 million deaths for children under 5 years old (Puffer and Serrano, 1973; Barua, 1981; Snyder and Merson, 1982). Since some of these estimates are in turn based on morbidity estimates which tended to be too low, a greater mortality toll than that already indicated is to be expected (Mata et al, 1980). This prediction is supported by a recent summary of 276 surveys conducted with WHO/CDD methodology (World Health Organization, 1988a) (Table 2). The rates recorded in three regions (Africa, Americas and Eastern Mediterranean) are exceedingly high, in fact as high as those countries which had the highest mortality before the advent of oral rehydration therapy (ORT).

Table 2. Diarrhoea mortality in children aged 0–4 years (1981–1986).

Region	No. of surveys	Mortality/1000		Total deaths associated with diarrhoea (%)
		Range	Median	
Africa	67	3.1–54.9	10.6	15.1–65.2
Americas	12	1.2–9.2	4.2	16.6–60.0
Eastern Mediterranean	47	1.0–25.3	5.8	20.0–63.3
South-East Asia	96	0–17.2	3.6	0–48.0
Western Pacific	54	0–6.5	2.9	0–43.9

From World Health Organization (1988a).

Diarrhoeal disease mortality and infant mortality

The profiles of these two health indicators in Costa Rica (Figure 1) show concordance of peaks, plateaus and depressions; the correlation coefficient was 0.967 because most of the diarrhoeal deaths occurred among infants (Mata et al, 1980). A derivation of this simple analysis is that control and prevention of diarrhoeal illnesses is a *sine qua non* for a decrease in infant mortality. Costa Rica is a good example that this is the case.

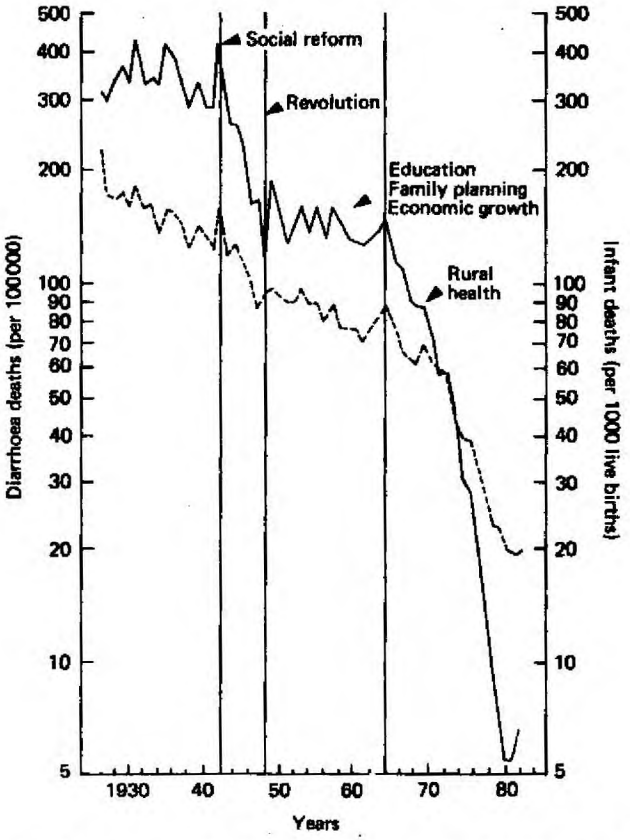

Figure 1. Diarrhoeal disease mortality (—) and infant mortality (---) in Costa Rica (1928–1982).

Differentials in diarrhoea mortality

In addition to differentials for age and sex (in some countries), there is wide variability in mortality between the various less-developed countries (Mata, 1986). For instance, Figure 2 shows diarrhoea death rates per 100 000 for infants and for children aged 1–4 years in the Americas between 1973 and 1977 (Pan American Health Organisation, 1980). The variability in mortality figures during a comparable year reflects existing differences in socio-economic development, education, hygiene and sanitation. As might be expected, Canada and the United States had the lowest rates, while Paraguay, Ecuador, Guatemala, El Salvador, Peru and Nicaragua had diarrhoea infant death rates in excess of 1000 per 100 000 live births. Similar rates were recorded in New York and other large metropolitan centres at the turn of the century, and it can be assumed that sanitary conditions in such cities were similar to those prevailing in Latin American cities today. However, high

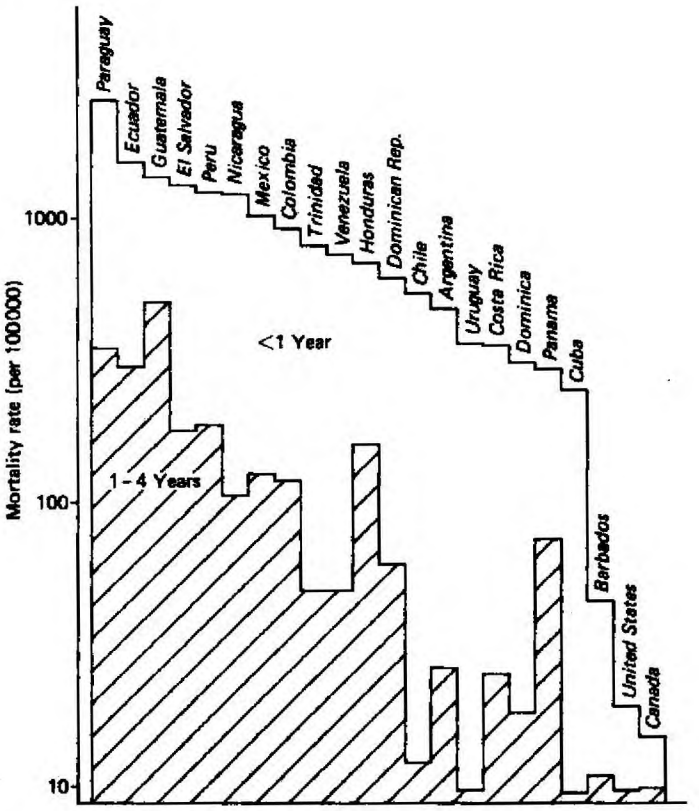

Figure 2. Diarrhoeal disease mortality for infants and preschool children in the Americas (1973–1977). Data from Pan American Health Organisation (1980).

rates still prevail in industrial nations in marginal and deprived sub-populations. For instance, in the United States, diarrhoea remains a prominent cause of preventable postneonatal infant mortality among groups of Blacks and American Indians (Ho et al, 1988b).

The record of many developing countries is improving and further gains will be made in the future as nations improve their living conditions. This has been the case in Costa Rica, Cuba, Chile and similar nations in transition, a portent that other countries will follow.

Evolution of diarrhoea mortality

Data on diarrhoea deaths for the period 1973–1977 were available for most Latin American countries (World Health Organization, 1982). These data serve to study changes in mortality, as shown in Table 3 (Mata, 1986). Countries were clustered in categories according to their current level of infant mortality. Countries with high infant mortality had the highest rates

Table 3. Evolution of diarrhoeal disease death rates and infant mortality rates—Latin America (1970–1978).

Country	Diarrhoea mortality*			Infant mortality c. 1980†
	1970	1978	Change (%)	
High infant mortality				
Peru	1037	752	−27	100
Nicaragua	1225	1409	+15	90
Ecuador	969	1144	+18	80
Honduras	793	873	+10	80
El Salvador	1458	1345	− 8	70
Guatemala	1818	1311	−28	70
Dominican Republic	1178	539	−54	60
Middle infant mortality				
Mexico	1802	1259	−30	50
Venezuela	875	601	−31	39
Uruguay	479	521	+ 9	38
Argentina	880	463	−48	36
Chile	1418	265	−81	32
Panama	589	306	−48	27
Low infant mortality				
Costa Rica	1509	195	−87	21
Cuba	565	123	−78	21

* Deaths per 100 000.
† Infant deaths per 1000.
Adapted from Pan American Health Organisation (1980) and World Health Organization (1982).

of diarrhoeal disease mortality among infants and preschool children. It is well known that more than 80% of all diarrhoea deaths occur among infants which accounts for the strong correlation observed between diarrhoea mortality and overall infant mortality rates. Three countries with high infant mortality, Nicaragua, Ecuador and Honduras, experienced an increase in mortality during the comparison period. Countries in the middle group also had a decline in diarrhoea deaths, except for Uruguay where an increase in diarrhoea deaths in infants was recorded.

The most prominent changes were observed in Chile, Costa Rica and Cuba, where deaths are so few at present that they could all be accounted for, and could even be easily investigated, if there were the political commitment to do so. Costa Rica represents a good example because the decline in diarrhoea mortality occurred within a short period, as shown in Figure 1 (Mata, 1985b; 1986), and because there is considerable information to elucidate potential aetiologies. The small size and relative poverty of Costa Rica did not discourage a national effort to steadily improve *per capita* expenditure on education and health, while at the same time there was a steady decrease in expenditure on defence and policing (Mata and Rosero, 1988); by 1948 there had been a great reduction in the size of the Army, which then was abolished in 1949. This political situation favoured the commencement, development and completion of health initiatives which were evident during the period 1930–1970. The most visible accomplish-

ments, however, were in the 1960s and 1970s, a period of development of water supply, sanitation, health education, immunization, and breast-feeding. The initiatives resulted in improved maternal nutrition and health, in fewer births with low birth weight, and in better child growth and development. While the contribution of each initiative has not been assessed (and may be precluded by the complex interactions of developmental advances), each group of initiatives presumably had a partial or synergistic impact on the drastic reduction in diarrhoea and infant mortality. Before the Second World War, the decline in diarrhoea mortality was slow but steady. The period 1940–1948 was noted for considerable social and health achievements (for example, labour legislation and improved education and social security) and during this time the first striking decline in diarrhoea and infant mortality was recorded (Figure 1). Advances were temporarily halted when a limited and short-lived civil war occurred in 1948. The ensuing 10 years witnessed an arrest in the trend of diarrhoea mortality to decline. By the middle of 1960, women had attained almost the same opportunity for education as men. There were considerable advances in family planning and in the emancipation of women. Between 1960 and 1970, the fastest decline in child birth in Costa Rica was recorded (Mata, 1986) and this was closely associated with a further decline in the rate of diarrhoeal disease. (An improved maternal environment will reduce prematurity and fetal growth retardation and, therefore, the incidence of diarrhoea.) The largest contribution, however, appears to have been that of improved water supply, sanitation, education and income. The most precipitous decline was observed during the 1970s, when the rural health programme (primary health care; PHC) started, and the malaria control programme entered a consolidation phase. The emphasis of PHC was to cover most of the rural population, working centripetally. Rural health workers had to immunize, provide education on health and nutrition, refer cases, teach ORT, and so forth.

Finally, ORT was started in Costa Rica in 1978 and has been maintained with improved acceptance on the part of the population. A significant reduction in hospital mortality was documented with the advent of ORT and there is evidence of decreased infant mortality in poor rural areas after its introduction (Mata, 1986). However, such effects have been difficult to determine due to the fact that deaths had already declined considerably by that time. Data from countries where rates are still high show a significant impact of ORT in preventing death (Rahaman et al, 1979; Lasch et al, 1983; Kielmann, 1986; Gabr, 1986; World Health Organization, 1988b). Nevertheless, the strong evidence in favour of non-clinical initiatives in the fight against diarrhoeal diseases must be stressed (Feachem, 1986), as well as the importance of a holistic approach to disease control (Mata, 1985b; 1986).

SUMMARY

Diarrhoeal disease still occupies a prominent place as a leading cause of illness, disability and death. It affects people in less-developed countries and

its incidence is highly correlated with poor hygiene and sanitation. The greatest impact of diarrhoea is on infants and small children, especially if they were of low birth weight, were born prematurely or suffered from malnutrition, birth defects or other pathology. Many children experience eight episodes of diarrhoea per year, or even more. Over 2 billion cases of diarrhoea per year have been estimated to occur globally. However, this may be an underestimate, as suggested by recent data from the World Health Organization. Estimates of mortality also are not precise and many countries still have problems with notification. Diarrhoea is considered to be a leading cause of death in most developing nations and its occurrence is strongly correlated with infant mortality. Thus, the control of diarrhoea will result in a decline in such mortality. There is wide variation in the current situation among Latin American countries, suggesting an evolution towards diarrhoeal control. Data for different years but for the same countries show a declining trend in most of them. Such control appears to be related to improvements in both the host and the environment through non-clinical interventions.

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