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The relation between anti-hepatitis A virus antibodies and residence water access in Rio de Janeiro, Brazil

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Abstract

Objectives: The objective of this study was to analyse the relation between residence water access (water taps) and hepatitis A virus (HAV) antibodies, associated with socio-economic, environmental and demographic factors. Methods: A logistic regression model was used for estimating the relation between residential water access (presence of water taps inside the house) and HAV antibodies, related to confounding effects of selected variables. The odds ratios estimated by the model were used as incidence density ratios (IDR) for the analysis of the water access-antibody association. Data were obtained from a cross-sectional study on the seroprevalence of hepatitis A in 3779 volunteers from Duque de Caxias city, greater Rio de Janeiro, Brazil. Participants were selected according to an age-specified random sampling survey. Results: Besides water access (main variable of interest), age, monthly family income, housewife schooling, persons per room, proximity to open sewage channels and consumption water treatment were statistically associated to hepatitis A seroprevalences. An interaction between water access and proximity to open sewage channels was detected. Persons living in residences distant from an open sewage channel had a water access-antibody IDR of 2.5 (95% CI [1.4; 4.3]), in contrast to 1.1 for those living close to such channels. Conclusions: Although indirectly measured through the proxy variable water access, personal hygiene, in conjunction with the absence of open sewage channels in the proximity of the residence, was an important factor for low HAV seroprevalence study population.

Key words: Hepatitis A seroprevalence – sectional study – water access – logistic regression

Introduction

Environmental interventions, for instance, making clean water available for a population, have a direct impact on human health and quality of life. The improvement of sanitary conditions affects the transmission mechanisms of many diseases, and assessing the impacts of sanitary improvement projects represents an important methodological challenge for epidemiology (Blum and Feachem, 1983; Cvjetanovic, 1986). An example of this challenge is the development of adequate health impact indicators, capable of distinguishing diseases transmitted through water and through the absence

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of sufficient water (Cairncross and Feachem, 1990; Cairncross, 1997). Indeed, a large proportion of water-communicable diseases, in populations in which these diseases are endemic, is due to the limited amount of water available for residence consumption and personal hygiene. Thus, two "disease domains" should be considered in an analysis: the public (e.g. sanitation projects) and the residential or domestic domain (Cairncross and Cliff, 1987; Cairncross et al. 1996).

Esrey and Habicht (1986), in a seminal work reviewing the impact of sanitation projects on health, identified three types of interventions with possible positive results: improvements on water supply quality, on water quantity and on water use (sanitary facilities). However, some studies indicate that sanitation and water supply improvements may be a necessary, but not a sufficient condition for eliminating the multiple transmission routes of infection (Briscoe, 1984). Therefore, new studies should not simply address questions such as if basic sanitation improves health in a population. Research hypotheses should be made more specific, for instance, they should try to specify and quantify the explanatory factors pertaining the water-health association. Thus, the effectiveness (benefit under actual use conditions), and not just the efficacy (ideal benefit) of sanitation projects could be assessed (Roberts, 1997).

The aim of the present work was to study the relation between the supply of water for residence consumption and hepatitis A seroprevalence. The study population comprised a district in the city of Duque de Caxias, Rio de Janeiro, Brazil, and the data were obtained from a cross-sectional survey performed in 1997.

Materials and methods

Data

Data were obtained from the Health and Life Quality Impact Assessment Project (PAISQUA), developed since 1996 by the Institute of Public Health Studies of the Federal University of Rio de Janeiro, Rio de Janeiro, Brazil (NESC/UFRJ). PAISQUA concerned the assessment of the health impacts of a depollution program in the Guanabara Bay, Rio de Janeiro State, Brazil. Depollution actions consisted of the construction of water treatment centres, the improvement and development of residential water connections, the draining of rivers, garbage collection projects and educational programs on health, environment and sanitation.

PAISQUA comprised eight components, one of which was the epidemiological survey component, a study of hepatitis A virus (HAV) antibody seroprevalence in a community in which a large water treatment reservoir was being built. The community is located in the city of Duque de Caxias, greater Rio de Janeiro City. Duque de Caxias, a coastal city 30 min away from Rio de Janeiro city, has 700000 inhabitants. Its socio-economic and environmental conditions are usually classified as poor, although the city is not considered to be a slum area. Children below 1 year old were excluded from the study, because of the confounding effect of maternal antibody transmission.

HAV antibody prevalence rates were obtained from an age-specified random sample of the population of interest. According to 1991 census data, the research area had 29729 inhabitants and 7565 residences. For the sampling procedure, all residences in the area were identified, and records of the age of all residents were made. From these records, a simple random sample was defined for each age group of interest. Sample size was based on the expected prevalence for each age group, obtained from a previous pilot study (Luiz et al., 1997). The sampling scheme divided the population in thirteen age groups: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 – 14 years old, 15 – 19, 20 – 29 and 30+ years old. More than one individual could be sampled from the same residence. This scheme demanded the use of weights in order to recover the reference population structure, since sample fractions among age groups varied from 63.4% (2 years old) to 1.3% (30+ years old). The weight wr_i, applied to individual i, was defined as $wr_i = w_i/w_m$, with w_i the inverse value of the selection probability of individual i, and w_m the average sample weight (Lee, 1989).

Fieldwork took place between June and December 1997. Written consent was obtained from all participants (for minors, the guardian's consent was obtained). Besides blood sample collection, a questionnaire on socio-economic and sanitary conditions was applied to each residence (Almeida et al., 1999). In case a resident was not found at home in a first visit, two more visit attempts were performed. Blood drops were spread on two 2.5 mm diameter circles on filter-paper. Eluates were obtained from these filter papers and kept frozen at $-20°C$. Total HAV antibodies were assessed by using the competitive ELISA test, ETI-AB-HAVK-3, Sorin Biomedica Diagnostics S.p.A., Italy (Almeida et al., 2001).

The main concern of the present analysis was the effect of the presence of water taps inside a residence (water access) over HAV seroprevalence. In another paper, such prevalences have also been used for estimating incidence rates in the same community (Struchiner et al., 1999). Variables used for the present work were selected with the help of the literature concerning hepatitis A infection mechanisms, and were defined as:

Water access (main explanatory variable of interest): defined as the presence of water taps (at least one) inside a residence.

Monthly family income: measured in terms of minimum wages (approximately US$ 150 at the time of the survey), and categorised as below 3 minimum wages (MW), between 3.01 and 8 MW and above 8 MW.

Housewife schooling: measured in number of years of education and categorised as zero, 1 to 4, 5 to 8 and 9 to 16 years of schooling.

Residence location: either on the top of a hill or in a valley.

Proximity to open sewage channels: categorised as yes or no, according to the existence of visible sewage in front of the house.

Adequate residence sanitary conditions: defined as toilet and bathroom connected to the piped public system, and categorised as yes or no.

Persons per room: categorised as below 2 and 2.01 or above.

Water storage: The variable was categorised as either adequate or non-adequate/no water storage. Adequate was defined as a cement-built water reservoir, cleaned at least once every six months.

Well construction quality: classified as inadequate (use of a borehole) vs. adequate (a dug well or none).

Consumption water treatment: defined as the use of filtered, boiled or chlorinated water, categorised as yes or no.

House consumption of well water: categorised as yes or no.

Age: defined in age ranges as 1, 2, 3, 4, 5, 6, 7, 8, 9, 10–14, 15–19, 20–29 and 30+ years old.

Data analysis

Since the initial objective of the survey was the determination of HAV seroprevalence rates, larger samples were obtained for the younger age strata, where such rates are known to be smaller. For the present study, however, this procedure would result in a selection bias, since the sample thus obtained would not truly represent the reference population. Following a classical statistical procedure, this problem was corrected by the incorporation of weights according to age strata. These weights are defined as the inverse of the selection probability for each participant, divided by the average study population weight (Lee, 1989).

Missing data imputation was performed for the variable monthly family income, for which 10% of data was missing. The EM algorithm was used for missing data imputation (Little and Rubin, 1987). This variable was also highly skewed, and was therefore square-root transformed.

Data were analysed by a logistic regression model (Hosmer and Lemeshow, 1989). The SPSS software version 9 was used for all data processing. At first, a model consisting only of the explanatory variables age and water access was considered. This model was further improved by the addition of the remaining explanatory variables, step by step, according to the order presented before. This order tries to incorporate variables in a direction that goes from the macro-level towards the individual level of analysis (Victora et al., 1997). Variables were then retained in the model, as long as they were statistically significant at the 95% confidence level. At each step, the association between water access and HAV antibodies was assessed by means of their adjusted OR and 95% confidence intervals. The possibility of interaction with the water access variable was investigated for all the explanatory variables.

Incidence density ratios (IDR) were used for data interpretation. These are defined as the ratio of hepatitis A incidence in the exposed group (without water access) divided by the incidence ratio in the non-exposed group (with water access). In sectional studies, IDRs can be approximated by the expression $IDR = OR(T_e/T_{ne})$; where OR is the prevalence odds ratio; T_e is the average disease duration in the exposed group and T_{ne} this average in the non-exposed group (Miettinen, 1976; Kleinbaum et al., 1982). Since, in the present study, the ratio of duration of antibody seroprevalence among the "exposed" and "non-exposed" groups can be accepted to approach "1", the final adjusted odds ratios prevalence was interpreted as an Incidence Density Ratio (IDR).

Results

A total of 3779 persons were examined, representing a subject loss close to 0%. This high participation rate was achieved by the mentioned procedure of performing, if necessary, three residence visit attempts. Missing data were negligible, except for the mentioned monthly family income variable. The weighing procedure described above altered the relative weights of the age range fractions so that the younger age groups had their relative sample contributions decreased. For instance, the relative contribution of the age group 2 years old declined from 0.11 in the original sample to 0.02 in the analysis below.

Concerning the time of residence of the study participants, no difference could be detected between the exposed and non-exposed groups (proportion of living in the area since birth: 24.1% vs. 25.6%, respectively. Within children under ten years the proportions were 58.2% and 62.7, respectively). Figure 1 presents the serological prevalences of hepatitis A according to the variables water access and age. For both residences with water access (solid line – 88.5% of the sample) and without water access (dotted line) a clear tendency for serological prevalence increase according to age can be noticed. This tendency is systematically higher for the residences without water access.

Table 1 shows the hepatitis A seroprevalences according to the distribution of the studied variables. The study population had an overall hepatitis A seroprevalence around 75%.

Table 2 summarises the model building strategy. Variables with a statistically significant association with HAV antibodies (besides water access) were

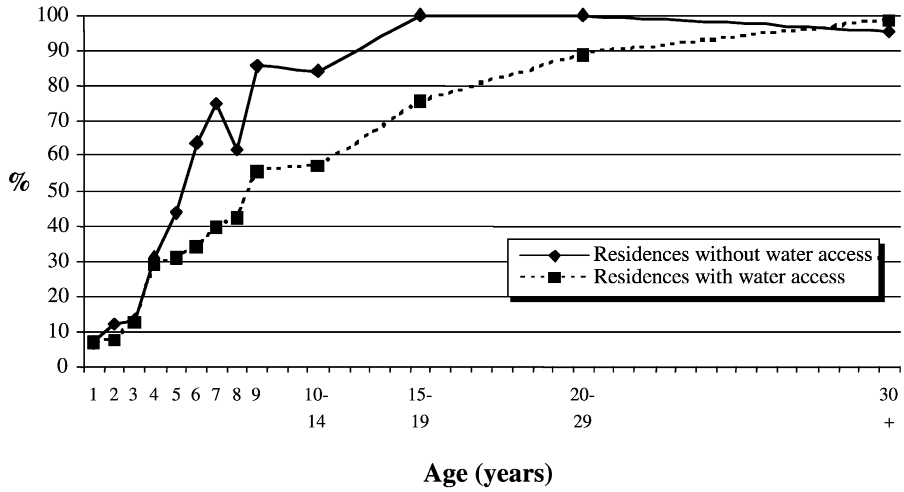

Fig. 1. Hepatitis A seroprevalence according to age and water access, Duque de Caxias, RJ, Brazil, 1997.

Table 1. Hepatitis A seroprevalence, Duque de Caxias, Rio de Janeiro, Brazil/1997.

Variables	Frequency (%)	Hepatitis A seroprevalence (%)
Water access (main explanatory variable of interest)		
Presence of water taps inside the residence	3344 (88.5)	77.3
No water taps inside the residence	436 (11.5)	79.4
Other covariates		
Monthly family income		
Below 3 minimum wages (MW)	1967 (52.0)	81.0
3.01 – 8 MW	1469 (38.9)	74.8
Above 8.01 MW	343 (9.1)	69.4
Housewife schooling		
Zero	495 (13.1)	88.5
1 – 4 years of schooling	1131 (29.9)	80.7
5 – 8 years of schooling	1486 (39.3)	73.7
9 – 16 years of schooling	666 (17.6)	72.4
Residence location		
Valley	3669 (97.1)	77.5
Top of a hill	110 (2.9)	77.3
Proximity to open sewage channel		
Yes	1844 (48.8)	80.8
No	1935 (51.2)	74.4
Adequate residence sanitary conditions		
Yes	1867 (49.4)	75.0
No	1912 (50.6)	80.0
Persons per rooms		
Below 2	1499 (39.7)	79.4
2.01 or above	2280 (60.3)	76.3
Water storage		
Adequate	1891 (50.0)	77.6
Inadequate/no storage	1888 (50.0)	77.4
Well construction quality		
Inadequate	1233 (32.6)	78.8
Adequate/no use	2546 (67.4)	76.9
Consumption water treatment		
Yes	2811 (74.4)	75.5
No	968 (25.6)	83.6
House consumption of well water		
Yes	1005 (26.6)	81.0
No	2774 (73.4)	76.2

Table 2. Logistic regression model building for the analysis of the association between HAV antibodies and water access, Duque de Caxias, Rio de Janeiro, Brazil/1997.

Models	HAV antibody – water access association		Model significance: Relatively to "only constant" model		Model significance: Relatively to the previous model	
	IDR	95% CI	df	p-value	df	p-value
1) Age + water access	2.40	1.72 – 3.35	13	< 0.001	13	< 0.001
2) Model 1 + monthly family income	1.94	1.38 – 2.74	15	< 0.001	2	< 0.001
3) Model 2 + housewife schooling	1.82	1.29 – 2.57	18	< 0.001	3	0.001
4) Model 3 + residence location	1.81	1.29 – 2.56	19	< 0.001	1	0.570*
5) Model 3 + proximity to open sewage channel	1.75	1.23 – 2.47	19	< 0.001	1	< 0.001
6) Model 5 + adequate sanitation conditions	1.71	1.21 – 2.42	20	< 0.001	1	0.352*
7) Model 5 + persons per room	1.65	1.17 – 2.34	20	< 0.001	1	< 0.001
8) Model 7 + water storage	1.58	1.11 – 2.26	21	< 0.001	1	0.197*
9) Model 7 + well construction quality	1.63	1.15 – 2.31	21	< 0.001	1	0.019
10) Model 9 + consumption water treatment	1.49	1.04 – 2.13	22	< 0.001	1	0.001
11) Model 10 + house consumption of well water	1.48	1.04 – 2.11	23	< 0.001	1	0.650*

Note: variables added at each step were retained in the model as long as they were statistically significant relatively to the immediately previous model. Variables marked * not retained.
IDR = Incidence Density Ratio estimated from Odds Ratio (OR)
95%CI = 95% Confidence Interval to IDR
df = degrees of freedom

Table 3. Water access-HAV seroprevalence relation*, Duque de Caxias, Rio de Janeiro, Brazil/1997.

Variables	Water access-HAV antibody effect	
	IDR	95% CI
General (no interaction term)	1.49	1.04 – 2.13
Residence near open sewage channel	1.06	0.68 – 1.65
Residence not near open sewage channel	2.45	1.42 – 4.26

* controlled for age, monthly family income, housewife schooling, proximity to open sewage channel, persons per room, quality of well water and consumption water treatment (general), and controlled also for water access-proximity to open sewage channel interaction.
IDR = Incidence Density Ratio, estimated from Odds Ratio (OR).
95%CI = 95% Confidence Interval to IDR.

monthly family income, housewife schooling, proximity to open sewage channels, persons per room, well construction quality and consumption water treatment.

Only the variable proximity to open sewage channels had a statistically significant interaction with water access. When control for the remaining covariates was taken into account, the association between water access and HAV antibodies resulted in an estimated IDR of 2.45 for persons living in residences distant from an open sewage channel, and of 1.06 for participants living close to such channels (Table 3). Thus, the absence of water access in a residence located in areas distant from an open sewage channel means an increase of 145% for HAV seroprevalence compared to residences with water access (95% CI: [42; 326]). For participants living near an open sewage channel, no effect could be detected (IDR = 1.06; 95% CI = [0.68; 1.65]).

Discussion

HAV is generally transmitted by the fecal-oral route. Therefore, personal hygiene habits, sanitation conditions and crowding are well-identified risk factors for transmission (Moyer et al., 1996). Both the incidence and prevalence of hepatitis A are known to be directly related to socio-economic conditions (Mausezahl et al., 1996; Pinho et al., 1998; Vitral et al., 1998). Serological surveys indicate that the

HAV antibody prevalences range from 15% to almost 100% in Third World populations (WHO, 2000). Thus, although not a lethal condition, high prevalence rates in some regions characterises a serious public health problem.

Measuring the association between sanitation improvements (intervention) and health conditions is one of the main objectives in any sanitation impact assessment program. However, epidemiological studies are limited by the many, difficult to measure, intermediate steps of this causal chain, e.g., personal hygiene habits (Cairncross, 1999). Ideally, water consumption inside a residence should be measured through water meters. These instruments are frequently non-existent in many regions of developing countries. A possible approach is the one used in the present paper: the measurement of a proxy variable for water consumption estimation (here, access to water, represented by the presence of water taps inside a residence).

Studies trying to relate water-communicable diseases to sanitation conditions are common in the literature (Cvjetanovic, 1986; Esrey and Habicht, 1986; Briscoe, 1984; Almeida et al., 2001; Rosenberg et al., 1980; Shuval et al., 1981; Esrey, 1996; Pruss, 1998). Shuval et al. (1981) proposed the theory of "saturation-limits" for the relation between sanitation, health and socio-economic conditions. In this theory, towards the extremes of socio-economic conditions (very high or very low), no health impact would be achieved through sanitation improvements. Briscoe (1984) argued that, behind the (sometimes observed) paucity of sanitation effects on health, a "black box" of transmission routes is hidden. These routes, with variables and mechanisms not yet sufficiently understood, imply distinct effects for similar health interventions. Therefore, important scientific questions remain unanswered, for instance, if, for a same amount of resources, it would be better to increase water supply (e.g. the number of residences with water access) or to improve water quality (Cairncross, 1996).

A limitation of serological prevalence studies is that, actually, only the "scars" of a disease (the biological marker) are observed. This marker indicates that, at some previous moment, the carrier was infected, but the exact onset of infection cannot be precisely ascertained. This may represent a problem for analysing the association of environmental variables and hepatitis A seroprevalence, especially concerning older persons, which, in some cases, could have been exposed at different locations. However, in the present study, this limitation only would introduce a bias if it could be supposed that the two groups (exposed and non-exposed) had, in the past, dissimilar living conditions. As mentioned above (results section), such differences could not be detected for the studied population.

Since hepatitis A seroprevalence increases with age, the present analysis used weights for the age-specific sample fractions. This avoided the selection bias that would be created by the use of the original sampling design. This procedure is especially important for the age groups comprising the first decade of life, in which hepatitis A seroprevalences are markedly smaller. In 70% of the residences, only one resident was incorporated into the sample. It can be supposed that this would not substantially affect the independence assumption necessary for the data analysis. At worst, a small reduction in the observed standard errors would be observed (Kreft, 1999).

As can be seen in Figure 1, seroprevalence differences between the exposed and non-exposed groups are roughly the same during early childhood, with differences arising around the fifth year of life. Coincidentally, this is the age in which the child begins to escape the direct protection of the mother, with resulting greater contamination risk through environmental factors, such as exposure to open sewage. In the higher age groups, a saturation phenomenon can be observed, due to the long time these groups were already exposed to the disease.

Data were analysed by means of a logistic regression model. The water access-HAV seroprevalence ORs were visibly altered at each step of the model building process, suggesting that the covariates indeed were confounding factors for the relation of interest. The final estimated Odds Ratios were interpreted as incidence density ratios. An IDR is a more direct measure of effect, which is more adequate for causality interpretations (Kleinbaum et al., 1981). Usually, association measures directly derived from cross-sectional studies have no causal interpretation. However, as showed by Miettinen (1976) and Kleinbaum et al. (1981), under certain assumptions prevalence ORs provide a good estimation of IDRs. This is the case when the average duration of a disease is the same between an exposed and a non-exposed group; other assumptions being that the population is stable, that the disease incidence and prevalence are constant along time and that a long period of risk exposure is observed. As mentioned, under theses assumptions $IDR = OR(T_e/T_{ne})$. In the present study, due to the known absence of hepatitis A epidemic outbreaks, it can be accepted that the necessary assumptions are valid. Also, since hepatitis A is endemic in the studied region, the "long time of exposure" assumption can be easily accepted.

As its main objective, the present work had to answer if access to water could be a protective factor for hepatitis A, taking into account possible confounding factors. The lack of water access was an identifiable risk factor for the population not directly exposed to open sewage contamination (Table 3). The water access variable used in this study represented a proxy of hygiene conditions in a residence. Thus, in spite of being indirectly measured, it can be concluded that personal hygiene is an important factor for the prevention of hepatitis A, especially when no environmental factors such as open sewage channels are present. Water access and proximity to open sewage channels had a synergic effect on HAV seroprevalence. Therefore, it can be concluded that sanitation interventions cannot be implemented in isolation. Projects that provide water connection (the "domestic" domain) and general sanitation improvements to the residence environment (the "public" domain) represent, thus, important and synergic factors in the reduction of waterborne diseases such as hepatitis A.

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