Mannose-sensitive Haemagglutinins in Adherence of 
Vibrio cholerae eltor to Intestine

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INTRODUCTION

Vibrio cholerae agglutinates red blood cells from chicken, sheep, rabbit and humans (for review of early work, see Lankford & Legsomburana, 1965) and this characteristic of vibrios was exploited to differentiate the classical and eltor biotypes (Barua & Mukherjee, 1963, 1965; Finkelstein & Mukerjee, 1963). Attempts to associate haemagglutination with fimbriae on the surface of V. cholerae have not been conclusive (Barua & Chatterjee, 1964; Tweedy et al., 1968).

Attachment of bacteria to mucosal cells is probably an essential step in colonization. The mechanisms of haemagglutination and adherence of vibrios to brush border membrane of rabbit intestine may be similar (Jones et al., 1976). A few reports with other pathogenic bacteria suggest a correlation between haemagglutination and adherence to mucosal cells, and surface antigens facilitating colonization of intestine have been identified (Stirm et al., 1967; Jones & Rutter, 1972, 1974; Burrows et al., 1976; Koransky et al., 1975; Buchanan & Pearce, 1976). Mannose or mannosides inhibit binding of Escherichia coli to erythrocytes and to intestinal epithelial cells (Duguid & Gillies, 1957; Jones & Rutter, 1974; Ofek et al., 1977) and the adherence of V. cholerae to brush border membranes via L-fucose receptors has been reported (Jones & Freter, 1976). The apparent correlation between haemagglutination and adhesion suggested the possibility that carbohydrate receptors might be involved in vibrio adhesion. We have found that mannose-sensitive haemagglutinins play a role in the adherence of vibrios to intestine and that mucosal cells bear mannose receptors.

METHODS

Organisms. Vibrio cholerae strain K8207 was selected as wild-type eltor Ogawa and is highly pathogenic in experimental models of cholera. Following N-methyl-N'-nitro-N-nitrosoguanidine treatment (Adelberg et al., 1965) of strain K8207, several non-motile and a motile but poorly adhering strain (designated as cD11) were isolated by Ranjana Srivastava in this laboratory (Table 1).

Growth condition and media. Bacteria were grown overnight at 37 °C on nutrient agar slants [Difco nutrient broth solidified with 1% (w/v) Oxoid agar]. Growth was harvested in phosphate buffered saline (PBS; Cruickshank, 1966). The 3 or 18 h broth cultures were obtained by diluting organisms from slant cultures into fresh nutrient broth and shaking gently at 37 °C. Viable counts were made on nutrient agar.

Haemagglutination (HA). Human red blood cells (r.b.c.), group B, were collected, washed three times in PBS and resuspended to 1% (v/v). Serial dilutions of bacteria in PBS were made in microtitre plates (Cooke Engineering Co., Alexandria, Virginia, U.S.A.) using 0.05 ml microdiluters. An equal volume of r.b.c. was added, mixed and the plates were then incubated at 22 °C for 1 h. The highest dilution giving HA was recorded. The effect of D-mannose (BDH) on HA was examined by including D-mannose (100 µg ml⁻¹) in the PBS.

Adherence. Vibrios diluted in 5 ml PBS to 10⁷ cells ml⁻¹ were exposed to freshly isolated rabbit intestine discs (10 mm diam.) for 30 min. The discs were washed twice with PBS (20 ml) to remove non-adhering vibrios, homogenized and the viable count of the bacteria adhering to discs was made. To examine the effect
Table 1. Strains of V. cholerae eltor and their characteristics

<table>
<thead>
<tr>
<th>Strain</th>
<th>Culture</th>
<th>HA titre (reciprocal)</th>
<th>Adherence index*</th>
<th>Motility</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Without mannose</td>
<td>With d-mannose (100 µg ml⁻¹)</td>
<td>Without mannose</td>
</tr>
<tr>
<td>kn207</td>
<td>Agar</td>
<td>64</td>
<td>4</td>
<td>6-3</td>
</tr>
<tr>
<td></td>
<td>Broth</td>
<td>64</td>
<td>64</td>
<td>0-35</td>
</tr>
<tr>
<td>CD11</td>
<td>Agar</td>
<td>64</td>
<td>64</td>
<td>0-06</td>
</tr>
<tr>
<td></td>
<td>Broth</td>
<td>64</td>
<td>64</td>
<td>0-1</td>
</tr>
<tr>
<td>CD12</td>
<td>Agar</td>
<td>32</td>
<td>32</td>
<td>0-02</td>
</tr>
<tr>
<td></td>
<td>Broth</td>
<td>64</td>
<td>64</td>
<td>ND</td>
</tr>
</tbody>
</table>

ND, Not done.

* Adherence index is the number of vibrios adhering expressed as a percentage of the number of vibrios to which the slice of intact intestinal mucosa was exposed. Indices given are the average from three to five experiments.

of d-mannose on adherence, 10⁶ vibrios were exposed to d-mannose (1 mg ml⁻¹) for 15 min. The bacteria were then diluted 100-fold in PBS and exposed to intestine discs as described above.

Motility. Bacterial motility was observed microscopically and quantified using 10 µl micropipettes (Kimble disposable; Illinois, U.S.A.) according to Adler (1969, 1973). The non-motile mutants were characterized as being aflagellate by electron microscopy.

RESULTS

The broth culture of kn207 was less adhesive than the agar culture although haemagglutininins were present in both (Table 1). Haemagglutininins from agar cultures were mannose-sensitive (m.s.) and a 16-fold drop in HA titre was observed, whereas broth cultures, either shaken or unshaken for 3 or 18 h, consistently gave mannose-resistant (m.r.) haemagglutination. D-Mannose also inhibited the adherence of agar cultures and pre-incubation of agar cultures with the sugar led to a significant fall in the adherence index. In contrast, the adherence of broth cultures, which had m.r. haemagglutininins and were less adhesive than agar cultures, was not affected by D-mannose. Incubation of the intestinal discs, instead of vibrios, with D-mannose for 15 min did not inhibit adherence.

Several non-motile strains were isolated and all produced haemagglutininins. The HA titres obtained with agar cultures of one such strain (CD12) were lower than those obtained for kn207 and a prozone was usually observed, although 3 h shake broth cultures consistently gave high HA titres like kn207 (Table 1). Strain CD12 exhibited m.r. haemagglutination in both broth and agar cultures, and the adherence indices were very low for all the non-motile strains.

Strain CD11 was as motile as the parent strain kn207 and was the least adhesive among the motile strains examined. There was no difference in the adherence of agar or broth cultures. Like CD12, this strain exhibited only m.r. haemagglutination and 3 h broth cultures gave optimal HA titres (Table 1).

Several other wild-type classical strains of V. cholerae were studied. Although all showed good adhesion, some were HA positive and others negative. The HA negative strains were grown under several different conditions (for example, in tryptone and peptone water, on agar, in broth for 3, 18 and 72 h with three subcultures in fresh broth) but were always HA negative.

DISCUSSION

From our studies, no direct relationship was found between HA and adherence of V. cholerae to intestine. Non-adhesive strains derived from kn207, both motile and non-motile, possessed HA activity. Of the several adhesive strains examined, some were HA
positive and others negative. The HA activity of non-motile aflagellate mutants of classical and eltor *V. cholerae* has been reported previously (Sweet, C. E., 1963; cited in Lankford & Legsomburana, 1965). However, in more recent work, Jones & Freter (1976) found that non-motile mutants of classical vibrios were HA negative and non-adhesive.

The agar cultures were more adhesive than the broth cultures, a finding that is contrary to those of Jones et al. (1976). There is no obvious explanation for this difference except that we used eltor vibrios whereas Jones et al. (1976) used classical vibrios.

The adherence and HA activity of broth and agar cultures of KB207 and their differential sensitivity to D-mannose suggested that with this strain the m.s. haemagglutinins synthesized in agar cultures play a role in adhesion of vibrios to intestinal mucosa. The non-adhesive strains, CD11 and CD12, exhibited only m.r. haemagglutination, which thus supports this conclusion. In KB207, D-mannose caused inhibition of both HA and the adherence of agar cultures. It appears, therefore, that some other haemagglutinins present in broth culture might be responsible for the residual adherence of vibrios to intestinal mucosa. D-Mannose sensitivity of HA by eltor vibrios has been reported previously (Barua & Chatterjee, 1964; Barua & Mukherjee, 1965).

Pretreatment with D-mannose of agar cultures producing m.s. haemagglutinins greatly impaired their adhesiveness. Thus it seems that mannos-containing receptors are located on the intestinal mucosal surfaces to which vibrios adhered. The observations that strains CD11 and CD12 adhered poorly and exhibited only m.r. haemagglutinins and that D-mannose had no effect on the adhesiveness of KB207 producing m.r. haemagglutinins support this conclusion. Mannose-resistant adhesion of broth cultures suggested that vibrios also adhered to mucosal surfaces via receptors other than mannos-containing receptors.

Jones & Freter (1976) have described inhibition of adherence of vibrios to isolated brush border membranes by L-fucose and, to a lesser extent, by D-mannose (since there was no additive effect; it is likely that D-mannose forms part of the L-fucose receptor). Yet, using slices of intact intestinal mucosa, similar to those used by us, neither L-fucose nor D-mannose inhibited adhesion of vibrios (Freter & Jones, 1976).

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REFERENCES


