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Nosocomial klebsiellas
II. Transfer in a hospital ward

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SUMMARY

During a 6-month period an epidemiological survey of the carriage of *Klebsiella* was conducted in a hospital ward where no outbreak of nosocomial infection occurred. In this endemic situation the regular sampling of several sites on patients, members of the nursing staff, and the environment, and the biotyping of *Klebsiella* made it possible to analyse the patterns of transmission between sites. There was abundant evidence for striking transmission of *Klebsiella* between the throat, hands, and faeces of patients. Transmission between patients seemed to be mainly through hands. The role of nurses' hands in transmission was not evident from this survey, probably due to the relatively long interval (a week) between samplings. Through the hands of patients, wash stands and the surrounding floor were contaminated with *Klebsiella*. The biotyping of *Klebsiella* facilitated the epidemiological analysis of the results.

INTRODUCTION

Gram-negative bacteria are a leading cause of infections acquired in hospital (Finland, 1970; McGowan & Finland, 1974). Except in some common-source epidemics, the infecting organisms arise from the patients' endogenous flora or from sources within the hospital environment. Nosocomial urinary-tract infections are probably frequently caused by cross-contamination. The epidemiology of colonization by *Klebsiella* and several other Gram-negative bacteria has been studied during 6 months in a ward for urological patients at the University Hospital at Rotterdam. The patterns of colonization have been reported in a previous paper (Haverkorn & Michel, 1979). This paper describes the transmission of *Klebsiella* within a hospital ward.

METHODS

The design of the survey, and the methods used for sampling, isolation, and identification of *Klebsiella* from patients have been previously described (Haverkorn & Michel, 1979). To investigate transmission within the hospital ward

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weekly samples were also collected from the hands of nurses, from foods, and from the ward environment.

Swabs were taken from one hand of nurses in the ward as described for the hands of patients (Haverkorn & Michel, 1979). Samples were taken from uncooked foods in the ward kitchen. Samples of 0·5 g of solid food were incubated overnight in broth which was then subcultured to blood agar plates. Samples from liquid food were inoculated directly on blood agar plates, and also into broth which, after overnight incubation at 37 °C, was inoculated on blood agar.

Samples collected from the ward environment on swabs moistened in 0·9% saline solution were plated on MacConkey, nalidixic acid cetrimide and nitrogen-deficient media. Four samples were taken in each ward: from the table top, from the floor in front of the wash stand, from the grating on the outflow of the wash basin, and from the room side of the door; in the kitchen, samples were taken from the bread board and the orange squeezer; in the central service room from the lid of the garbage can, from the hinge of the bedpan washer, from the grating of the sink for disposal of liquid waste, and from the wash basin near the tap.

Several methods of epidemiological anaysis have been used, depending on the sites involved. All methods of analysis, however, began by considering the particular site from which a bacterial strain was isolated an 'index site' and the sites from which the same bacterial strain was isolated as 'reference sites'. Thus, the isolation of a certain biotype of *Klebsiella* from a patient's hand in a given week is considered to be the 'index isolation' and the hand the 'index site'. The throat and faeces of the same patient, the throats, hands and faeces of other patients; the hands of staff, and the environment, examined in the same week and in the week preceding and following the 'index isolation', are considered to be 'reference sites'. A site can thus be both an index site, and a reference site in relation to some other index site. Sites can be reference sites for several index sites at the same time, so that the numbers of reference sites can be greater than the number of sites examined at that time.

In the analysis of transfer between sites on patients with an index site, the isolation rates at reference sites on these patients are compared with the isolation rates at reference sites on other patients. An excess of positive reference sites in patients with index sites indicates either direct or indirect transfer of bacteria between index and reference sites. Where transfer appears likely, the direction of transfer, from index to reference site or vice versa, can be determined by including in the analysis isolations from reference sites during the week preceding and the week following the index isolation. If transfer in both directions occurs with equal frequency, the result of analysis will be inconclusive. A difference in the frequency of transmission in one direction is however significant.

When analysing transfer between patients and the ward environment the isolation rates at reference sites in the same ward as the index sites are compared with isolation rates from reference sites in the other wards.

In the analysis of transfer between patients and the environment outside the ward, isolation rates at reference sites in the same week as index isolations are compared with isolations in the preceding and following week. Only index isolations are analysed as repeat isolations cannot be the result of transfer since the preceding week.

RESULTS

Transfer within and between patients

The transfer of *Klebsiella* only has been analysed, as biotyping and the distribution of biotypes afforded sufficient information for this purpose. Transfer of *Klebsiella* between the three sites systematically sampled on each patient was frequent (Table 1). The prevailing direction of transfer is presented in Table 2. The throat carriage rate for *Klebsiella* in the week following an index isolation from faeces is about nine times the rate in the week preceding, indicating an excess in transfer from faeces to throat in the same patient. The remaining data suggest an excess transfer from faeces to hand, and from hand to throat in the same patient.

Transfer between patients is analysed by comparing isolations in the same ward as the index with those in other wards (Table 3). When *Klebsiella* was isolated from a patient's hand, the same biotype was isolated significantly more often from the hands of other patients in the same ward (31 per 1000) than from the hands of patients in other wards (7 per 1000).

Transfer in the ward environment

In the analysis of transfer between patients and the ward environment and between sites sampled in the ward environment, ward doors, from which few isolations were made, are omitted. Of the sites studied, the wash stands were most often colonized (Table 4). Significant transfer rates of *Klebsiella* were shown between the hands of patients and the wash stands in their rooms ($P = 0{\cdot}03$) and between these wash stands and the surrounding floor ($P = 0{\cdot}03$).

The isolation rate from wash stands after the patients' hands became positive was about double the rate in the preceding week, suggesting that colonization of hands occurred before colonization of the wash stands, but the difference was not statistically significant. No statistical analysis of the direction of transfer between the wash stands and the surrounding floor has been attempted as the biotype isolated from the wash stands was never isolated in the week preceding or the week following the positive isolation.

Transfer from hands of nursing staff, foods, and the kitchen environment

Nursing staff in the wards at the times of routine sampling formed a heterogeneous group as the result of different working hours and transfers of staff between wards. None of the reference sites examined in relation to index isolations from the hands of nursing staff showed a significant excess of isolations in the week preceding or following the index isolations (Table 5).

Many foods were sampled, including milk and milk products, sliced cheese and cold meat for sandwiches, but no cooked meals were examined. The foods examined were eaten at breakfast and lunch. More positive samples were found at lunch than at breakfast. Positive samples were obtained from all types of food

Table 1. *Transfer of* Klebsiella *in patients*

Index and reference sites ...	First isolation of biotype similar to the one isolated at the index-site in the same week							
	In the same patient			In other patients				
	Number			Number				
Reference sites	At risk	Positive	Rate*	At risk	Positive	Rate	Ratio between rates	P
				Index isolation from throat				
Hand	61	13	213	1673	14	8	26·6	< 0·0001
Faeces	39	10	256	1428	36	25	10·2	< 0·0001
				Index isolation from hand				
Throat	64	12	188	1780	16	9	20·9	< 0·0001
Faeces	48	18	375	1554	30	19	19·7	< 0·0001
				Index isolation from faeces				
Throat	140	14	100	3444	43	12	8·3	< 0·0001
Hand	138	23	167	3560	54	15	11·1	< 0·0001

* Rate, in this and the other five tables, is rate/1000.

Table 2. *Prevailing direction of transfer of* Klebsiella *within patients*

Same patient		Isolation at reference site in week preceding a first isolation at an index site			First isolation at reference site in week after isolation at an index site			
Index sites	Reference sites	No. at risk	No. positive	Rate	No. at risk	No. positive	Rate	P
Throat	Hand	50	5	100	41	2	49	0·4514
Hand	Throat	57	2	35	45	5	111	0·2359
Throat	Faeces	41	9	220	21	2	95	0·3052
Faeces	Throat	95	1	11	95	9	95	0·0183
Hand	Faeces	52	9	173	24	4	167	> 0·90
Faeces	Hand	97	4	41	88	9	102	0·1497

Table 3. *Transfer of* Klebsiella *between patients*

Index and reference sites (on different patients) . . .	First isolation of biotype similar to the one isolated at the index site in the same week							
	In the same room			In other rooms				
	Number			Number				
Reference sites	At risk	Positive	Rate	At risk	Positive	Rate	Ratio between rates	P
				Index isolation from throat				
Throat	152	3	20	1446	15	10	2·0	0·4029
Hand	160	0	0	1513	14	9	—	—
Faeces	133	5	38	1295	31	24	1·6	0·3748
				Index isolation from hand				
Throat	151	1	6	1626	15	9	0·7	> 0·90
Hand	159	5	31	1687	11	7	4·4	0·0088
Faeces	132	4	30	1422	26	18	1·7	0·3149
				Index isolation from faeces				
Throat	325	4	12	3119	39	13	0·9	> 0·90
Hand	337	6	18	3223	36	11	1·6	0·2833
Faeces	295	11	37	2696	81	30	1·2	0·4766

Table 4. *Transfer of* Klebsiella *in relation to wash-stand in patient's room*

Reference sites	First isolation of biotype similar to the one isolated from the wash-stand the same week: In the same room, Number, At risk	Posi-tive	Rate	In other rooms, Number, At risk	Posi-tive	Rate	Ratio between rates	P
Patient								
Throat	139	4	29	1130	11	10	2·9	0·0721
Hand	145	5	34	1169	12	10	3·4	0·0315
Faeces	122	6	49	979	23	23	2·1	0·1235
Floor	74	2	27	663	1	2	13·5	0·0279
Table	72	0	0	663	0	0	—	—

Table 5. *Transfer of* Klebsiella *in relation to hands of nurses*

Reference sites	First isolates of biotype similar to that isolated from the hand of a nurse: In week preceding positive index, No. at risk	No. positive	Rate	In same week as positive index, No. at risk	No. positive	Rate	In week after positive index, No. at risk	No. positive	Rate	χ^2 (D.F. = 2)	P
Patient											
Throat	763	9	12	629	3	5	663	4	6	2·6631	0·30–0·20
Hand	791	7	9	646	6	9	684	8	12	0·3220	0·90–0·80
Faeces	662	14	21	546	9	16	581	13	22	0·5561	0·80–0·70
Other nurses	682	3	4	644	3	5	623	2	3	—	—
Food	271	1	4	265	0	0	265	0	0	—	—
Objects in patients' rooms	1187	4	3	1208	11	9	1245	11	9	3·5732	0·70–0·60
Kitchen	85	0	0	86	1	12	85	1	12	—	—
C.S.R.*	172	0	0	172	2	12	170	1	6	—	—

* Central Service Room.

Table 6. *Transfer of* Klebsiella *in relation to food*

Reference sites	First isolates of biotype similar to the one isolated from food								
	In week preceding positive index			In same week as positive index			In week after positive index		
	No. at risk	No. positive	Rate	No. at risk	No. positive	Rate	No. at risk	No. positive	Rate
Patients'									
Throat	214	3	14	218	3	14	237	1	4
Hand	224	2	9	227	2	9	247	2	8
Faeces	188	7	37	195	3	15	210	2	10
Nursing staff	191	0	0	191	0	0	201	0	0
Objects in patients' rooms	359	2	6	387	2	5	386	0	0
Kitchen	26	0	0	28	0	0	26	0	0
C.S.R.*	52	0	0	56	0	0	56	1	18

* Central Service Room.

so that analysis of individual items was unrewarding. Even the combined data relating to all 13 isolations from foods was not sufficient to warrant statistical analysis (Table 6).

So few isolations of *Klebsiella* were made from the kitchen and from the central service room that no analysis was attempted.

DISCUSSION

In the absence of an outbreak of infection, a systematic study of sites in a ward where colonization is uniform throughout the study makes it possible to analyse the transfer of bacteria between sites by the methods employed in this survey.

A basic assumption of this method of analysis is that the pattern of isolations found results from the transfer of bacteria. For bacterial genera isolated only sporadically this assumption may be acceptable, but for bacteria commonly isolated it may not be realistic. Subdivision of bacterial genera improves the value of analysis. The isolation of *Esch. coli* from the faeces of two patients does not yield epidemiological information, whereas the simultaneous isolation of a rare *Esch. coli* serotype may well do so.

Another problem inherent in this type of survey is that the population of patients studied is heterogeneous in that antibiotic treatment, confinement to bed, operation, catheterization and many other factors which influence isolation rates are not uniformly and mutually independently distributed. It is possible to correct for these factors if the assumptions made are justified, but a great number of observations would be required. In view of the limited number of observations made in this survey, these corrections have not been attempted.

An increase in the carrier rate after admission to hospital does not by itself prove transmission from other sites as the extended stay of a carrier in hospital will result in higher isolation rates. This possibility is excluded in this survey by considering only the first isolation of a particular biotype at the particular sampling site.

Gram-negative bacteria are known to be particularly susceptible to desiccation. They proliferate when moisture is supplied (Marples, 1965; Petit & Lowbury, 1968; Noble & Somerville, 1974). The conditions for skin colonization are thus more favourable if a patient is feverish and confined to bed and higher isolation rates in such patients might be expected. Other factors controlling skin flora, e.g. bacterial interference, have been mentioned and studied but still remain poorly understood (Selwyn & Ellis, 1972; Marsh & Selwyn, 1977). The skin of healthy individuals does not carry Gram-negative organisms to any extent (Noble & Somerville, 1974; McBride, Duncan & Knox, 1977).

Gram-negative bacteria have been cultured from the throats of patients in hospital and of persons outside hospital. The throat carrier rate increases during hospitalization (Harvey & Dunlop, 1960; Johanson *et al.* 1972; Rosenthal & Tager, 1975). Carrier rates of Gram-negative bacteria other than *Esch. coli* increase during stay in hospital especially in patients receiving antibiotic treatment (Shooter, 1971; Selden *et al.* 1971; Rose & Babcock, 1973; Haverkorn &

Michel, 1979). The transfer of bacteria from sources in the hospital environment would appear to be the most likely source involved.

In hospital epidemics the hands of nurses have been frequently suggested as transmitters of the epidemic strain although proof has not always been provided (Burke *et al.* 1971; Eisenach *et al.* 1972; Edwards *et al.* 1974; Rose & Babcock, 1975; Schaberg, Weinstein & Stamm, 1976). Salzman, Clark & Klemm (1967) found the hands of nurses frequently colonized by *Klebsiella* and other coliform organisms.

The carriage of Gram-negative bacteria on the hands is transient (Knittle, Eitzman & Bear 1975). Often a brief wash is sufficient to remove the majority of organisms but in epidemics even careful antisepsis of the hands may not suffice (Lowbury *et al.* 1970; Sprunt, Redman & Leily, 1973; Casewell *et al.* 1977). If frequent recontamination is necessary to maintain carriage of *Klebsiella* on the hands, repeated self-contamination by patients might prove of greater importance than contamination from the hands of nurses between washings. This survey has produced evidence of hand-to-hand transmission of *Klebsiella* between patients but no evidence of transmission from nurses' hands in an endemic situation. The long interval between swabbings and the frequent interchange of ward nursing staff, however, may have reduced the probability of finding evidence on this method of transmission.

Frequent contamination of wash rooms and toilets by faecal bacteria has been reported (Mendes & Lynch, 1976). During this survey the gratings of the waste pipes of wash basins in wards were often found to be contaminated, especially by *Pseudomonas* sp. The strains of *Klebsiella* isolated from wash stands were probably transferred mainly from the hands of patients and to a lesser degree from their throats. Owing to the frequent transfer of *Klebsiella* between patients' throats, hands, and faeces, it is not possible to distinguish between direct and indirect sources of contamination. *Klebsiella* isolated from the floors around the wash stands probably originated from the wash stand but direct contamination from patients cannot be excluded.

A waste-disposal system has been recognized as a reservoir for enteric bacteria and *Pseudomonas* sp. (Grieble *et al.* 1974) which are also present in hospital and domestic sewage (Fontaine & Hoadley, 1976). The number of isolations made from sites on the waste disposal system in the Central Service Room of the ward in this survey is too small for statistical analysis. The sites sampled, however, were metal surfaces like handles, usually dry but often touched by the hands of workers.

Several of the bacteria looked for in the survey were isolated from foods. The distribution of isolations during the survey and among the food samples was uniform. Most of the foods sampled were milk and milk products, in which *Esch. coli* has been shown to survive passage through the stomach (Cooke *et al.* 1970).

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