Food as a source of *Klebsiella* species for colonisation and infection of intensive care patients

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**Summary**

Food prepared for intensive care patients was frequently contaminated with *Klebsiella* species. Sixty-eight per cent of nasogastric feeds were contaminated with up to $10^5$ *klebsiella* per ml. Hospital kitchens were the source of contamination. Three patients ingested *klebsiellae* and subsequently excreted the same serotype in their faeces. Over a four-week period there was a correlation between kitchen, food, faecal, and clinical serotypes of *klebsiellae*. Serotypes ingested by intensive care patients occurred more frequently in clinical isolates from intensive care patients than from other hospital patients. Patients often acquired a food strain that had been ingested by another patient on the same ward.

The sources of *Klebsiella* species that colonise or infect hospital patients are poorly understood (Eickhoff, 1971). It is often difficult to know whether the patient has been infected by organisms hitherto commensal on his own body, by organisms derived from staff or other patients, or by reservoirs of *klebsiella* in the inanimate environment.

It is now recognised that hospital inpatients are more likely to be intestinal carriers of *klebsiellae* than the non-hospital population, a finding probably related to antibiotic therapy (Rose and Schreier, 1968). One study (Selden et al., 1971) suggests that acquisition of a particular serotype in the bowel during hospitalisation provides a source for auto-infection with that strain. Intestinal carriage also provides a reservoir for cross-infection within the hospital community. Shooter et al. (1971) have recorded the presence of *Klebsiella* spp in contaminated hospital food while others (Montgomery et al., 1970), on the basis of limited evidence, have suggested that food serotypes may provide a source of organisms for bowel colonisation.

This study explores more fully the role of contaminated food as a source for *klebsiella* infection and colonisation, reports the results of a survey on an intensive care unit (ICU) where patients receive particularly thorough bacteriological monitoring, and correlates the *klebsiella* serotypes from food and other potential sources with the serotypes from clinical specimens.

**Material and methods**

Exceptionally thorough routine bacteriological monitoring enabled us to identify those patients colonised or infected with *Klebsiella* spp. Swabs from in-use respirators, samples of material obtained from endotracheal suction, and, where possible, sputum and urine specimens were examined daily. Samples from potentially infected lesions were collected when clinically indicated.

**Survey 1: Potential sources of *Klebsiella***

Between 22 May and 24 June 1972, specimens were obtained from ward food, staff and patients' faeces, hospital kitchens, and the ward environment. All isolates of *klebsiellae* were saved for typing.

Fifteen visits were made to the ward to sample patient and staff meals. Nasogastric feeds, ice-creams, milk shakes, cold sweets, cold meat, salads, and hot food were all sampled on several occasions. A record was kept of which patient or staff subsequently ate the sampled food.

Intensive care medical, nursing and technical staff provided stool specimens approximately twice a week. Stools passed by the patients were also examined, rectal swabs being substituted only when patients failed to produce stools within a few days.

Samples were taken on four visits to the diet kitchen and on four different occasions from the main hospital kitchens. The nasogastric feeds for intensive care patients were prepared in a confined area of the main hospital kitchen. Feeds were
weighed, mixed, and homogenised the day before they were required for use, and were usually stored at 4°C overnight.

A few months before the beginning of this survey there had been a widespread search in this ward for ‘Pseudomonas thomasi’, which had caused a serious outbreak of hospital infection. Klebsiellae were not found at that time, and a limited number of fluids and instruments were examined in this survey for sources. However, sinks, open medicines, skin lotions and ointments, thermometers, ward furniture surfaces, and floors, were sampled, as well as dish mops, taps, soap, hand cream, scouring paste, and draining boards.

**Survey II: Correlation of Ingested Serotypes with Patient Isolates**

This survey (19 June to 10 September 1973) was to determine whether the klebsiella serotypes ingested by ICU patients were particularly frequent among the clinical klebsiella isolates from ICU patients during the same period. All nasogastric feeds, ice-creams, milk shakes, cold sweets, and drinks were sampled before being ingested by ICU patients. Consecutive sputum samples from patients in other parts of the hospital were screened for *Klebsiella* spp. and the isolates were saved for typing.

**Bacteriology**

Clinical specimens, for bacteriological monitoring of patients, were inoculated on blood agar, and *Klebsiella* spp. were identified by methods based upon those of Cowan and Steel (1965).

Solid food samples were suspended in nutrient broth. Faeces, food, and environmental samples were inoculated on lactose bromothymol blue (I. Òrskov, 1971, personal communication), and MacConkey enrichment plates, and into a single-strength MacConkey enrichment broth. Between four and 14 coliform colonies were selected from each positive specimen for biochemical screening with a scheme based on motility, adonitol fermentation, urease activity, citrate utilisation, and decarboxylase activity (Casewell, 1977). Viable klebsiella counts in nasogastric feeds were made by spreading 0·1 ml of feed, and 10-fold dilutions, over the surface of MacConkey agar plates.

All klebsiella isolates were capsular typed by the method developed in this laboratory (Casewell, 1972, 1975).

**Results**

**Survey I: Potential Sources of Klebsiellae**

During this four-week survey, clinical isolates of *K. aerogenes* were found in 14 of the 54 patients admitted to the ICU. Five patients acquired type 21, two a non-typable strain, and there were single patient-isolates of types 8, 9, 12, 19, 47, 55, and 74.

Of 175 samples of ICU food, 74 (42%) yielded *Klebsiella* spp (Table 1). None of 20 samples of hot food yielded klebsiella, but 68% of 47 nasogastric feeds, and 55% of 22 ice-creams and other cold sweets were contaminated with klebsiella. Of seven nasogastric feeds, five contained more than 1·5 × 10⁸ viable klebsiella per ml, and one contained 10⁴ per ml. Capsular type K47, the most frequent ICU endemic serotype between 1969 and 1973, was the commonest food isolate during the month of the survey. Type 21, which accounted for five of the 14 patient clinical isolates during this survey, was not found in any of the 175 ward food samples but was found in a nasogastric feed sample in survey II.

*Klebsiella* spp were isolated from 37% of the 70 samples collected from the hospital kitchens that prepared ice-creams, nasogastric feeds, and salads. Serotypes 47, 74, and 60 were found in ward ice-cream and kitchen ice-cream utensils that were kept in warm water. Type 74 was isolated from the ice-cream mixer, and types 47 and 74 from recently mixed ice-cream in the kitchen. Similarly, the second commonest nasogastric-feed serotype (type 10) was also isolated from the homogeniser and dishcloths in the diet kitchen. Of 18 specimens from the salad kitchen, seven yielded a total of six different serotypes, all of which had been demonstrated in ward salads. Of 12 samples from unwashed salad, 11 were negative and only one yielded a type that could not be related to those found in ward food.

Two hundred and ninety-one stool samples from

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**Table 1** Survey I: Isolation of *K. aerogenes* from intensive care unit food

<table>
<thead>
<tr>
<th>Food</th>
<th>No. of samples examined</th>
<th>No. of samples yielding klebsiella</th>
<th>Capsular types found (no. of samples, if more than one, in parentheses)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nasogastric feeds</td>
<td>47</td>
<td>32</td>
<td>47(12), 10(11), 44(5), 12(3), 26(2), 18, 29, 31, 39, 54, 64, 66, NT(6)</td>
</tr>
<tr>
<td>Ice-creams</td>
<td>13</td>
<td>9</td>
<td>47(4), 74(2), 29, 41, 43, 46, 60, NT(6)</td>
</tr>
<tr>
<td>Cold meat</td>
<td>13</td>
<td>5</td>
<td>74(5), 47, 68, 64, NT(2)</td>
</tr>
<tr>
<td>Salads</td>
<td>47</td>
<td>21</td>
<td>74(5), 47, 68, 29(5), 14(3), 80(2), 4, 9, 17, 18, 27, 32, 36, 53, 64, NT(6)</td>
</tr>
<tr>
<td>Cold sweets</td>
<td>9</td>
<td>3</td>
<td>47(3), 74, 19, 18, 29, NT(6)</td>
</tr>
<tr>
<td>Milk, cream, and butter</td>
<td>12</td>
<td>3</td>
<td>46, 69, NT(2)</td>
</tr>
<tr>
<td>Cold drink</td>
<td>15</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Hot food</td>
<td>20</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

NT = non-typable

*Commonest endemic patient serotype, 1969-73*
51 intensive care staff (42 nurses, five doctors, and 45 technicians) were collected during the month. Forty-five staff provided a specimen at least every three or four days while on the ward. Ten staff (19.6%) were shown to excrete Klebsiella spp on one or more occasions. Only two staff excreted a single klebsiella serotype throughout the month, one of whom was colonised with type 21, the commonest patient-isolate for the same period. Eight other staff showed intermittent excretion, klebsiella being found on only one occasion in six staff, and twice in two staff, both of whom excreted a different type on each occasion. Of 54 stool specimens from 15 of the patients admitted to the intensive care ward for some part of the month of the survey, eight (53%) were shown to have klebsiella in at least one stool sample. One patient excreted type 68 for the whole month. Serotypes 21, 10, 68, 47, 55, and a non-typable strain were found in one of several stools of three, two, two, one, and one patients, respectively. Three patients with positive stools had ingested the same strain two, three, and seven days, respectively, before the stool isolation.

Apart from ward sink-traps and ward-kitchen dishcloths there were only three specimens from the ward environment that yielded klebsiella (Table 2).

Table 2 Survey I: Isolation of K. aerogenes from ICU ward environment

<table>
<thead>
<tr>
<th>Sample</th>
<th>Number examined</th>
<th>Number positive for K. aerogenes</th>
<th>Capsular types found (number samples, if more than one, in parentheses)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sink and basin drain traps</td>
<td>21</td>
<td>9</td>
<td>37(2), 7, 8, 21, 30, NT(2)</td>
</tr>
<tr>
<td>Dishcloths in ward kitchens</td>
<td>8</td>
<td>4</td>
<td>13(2), 71(2), 11, 47, NT(2)</td>
</tr>
<tr>
<td>Flower vase water</td>
<td>2</td>
<td>1</td>
<td>47, 54, 68, NT</td>
</tr>
<tr>
<td>Wet thermos flasks</td>
<td>2</td>
<td>2</td>
<td>71(2)</td>
</tr>
<tr>
<td>Cutlery, sink surfaces, detergents, soaps, floor cloths, floors, work surfaces, antisepsis, skin application, medicines</td>
<td>62</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

NT = non-typable

Table 3 summarises all the capsular types of klebsiella found in the kitchens, ICU food, patient and staff stools, and from the 14 patients who acquired klebsiella in their clinical specimens during the month of this survey for sources.

SURVEY II: CORRELATION OF INGESTED SEROTYPES WITH PATIENT-ISOLATES

During this separate survey, 23 nasogastric feeds, 13 milk-shakes and dietary milk allowances, and eight ice-creams were fed to intensive care patients. Klebsiella were isolated from 34 (77%) of these items, and 22 serotypes were found. During the same period, 27 ICU patients acquired klebsiella with 37 distinct strains, and 35 of these patient-isolates were typable. Of these 27 patients, nine had ingested contaminated food and also acquired klebsiella in clinical samples, but only one patient acquired a serotype that he himself had ingested.

Table 4 shows the overall frequency with which klebsiella were isolated from different sources and for each serotype.

With Yate's correction, $\chi^2 = 11.9, p < 0.001$

*Serotypes 5, 9, 10, 21, 26, 27, 28, 41, 47, 62, 66, and 68

Table 3 Survey I: Overall distribution pattern of klebsiella serotypes isolated from kitchen, ward food, stools, and clinical sites

<table>
<thead>
<tr>
<th>Serotype</th>
<th>Serotypes isolated at least once from:</th>
<th>Kitchen</th>
<th>Ward food</th>
<th>Stools</th>
<th>Clinical sites (no. patients in parentheses)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+ (4)</td>
</tr>
<tr>
<td>47, 74, NT</td>
<td></td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+ (2)</td>
</tr>
<tr>
<td>9, 12</td>
<td></td>
<td>+</td>
<td>+</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>10, 60, 68</td>
<td></td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+ (1)</td>
</tr>
<tr>
<td>55</td>
<td></td>
<td>+</td>
<td>-</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td></td>
<td>-</td>
<td>+</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>18, 27, 29</td>
<td></td>
<td>+</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>8, 21</td>
<td></td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+ (6)</td>
</tr>
<tr>
<td>24, 41</td>
<td></td>
<td>-</td>
<td>+</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>37, 71</td>
<td></td>
<td>+</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>48, 60, 63</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>7, 13, 17, 26, 31, 32, 36, 39, 43, 44, 46, 53, 54, 64, 66, 80</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>NT</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

NT = non-typable
Discussion

This study not only confirms that hospital food may be frequently contaminated with *Klebsiella* spp but, more importantly, by using a discriminatory typing method, survey I for potential sources of *Klebsiella* shows a definite, but not exclusive, correlation between food serotypes, faecal serotypes, and patient clinical isolates over a four-week period (Table 3). Because this intensive survey lasted for only a month some patient clinical isolates, such as types 21 and 55, were not found in any food samples. However, these two strains were found several months later in both food and patient-isolates during survey II.

The immediate source of food *Klebsiella* was the hospital kitchen where liquidisers, ice-cream utensils, dishcloths, and working surfaces were contaminated with *Klebsiella* of corresponding type. The overnight delay between preparation and ingestion of nasogastric feeds provided an opportunity for multiplication of contaminating organisms.

The inherent bacteriological difficulties associated with homogenising and storing liquid feeds in a warm part of the hospital environment make a strong case for end-sterilisation of feeds, or, more conveniently, using commercially produced sterile feeds that are ready for use in the ward.

Although others (Montgomerie et al., 1970) considered that food may provide the source of faecal *Klebsiella*, they did not demonstrate this in individual patients. We have shown such a sequence in three patients, all of whom were receiving broad-spectrum antibiotics.

It seems clear from the comprehensive survey of staff stool specimens that staff excretion of *Klebsiella* is relatively infrequent and usually represents intermittent excretion rather than prolonged colonisation. The epidemiological significance of the respiratory technician, who excreted type 21 at the beginning of survey I and remained colonised with this type for the whole month, remains speculative. It is possible that he had ingested type 21 before the survey started, colonised his bowel, and then acted as a source for at least one of the five patients who acquired this type in the month of the survey.

It proved more difficult to obtain a comprehensive collection of stool samples from ICU patients during survey I but it was clear that the *Klebsiella* excretion was more frequent than in ward personnel. It seems unlikely that patient faecal strains always serve as a source for autoinfection for we, unlike Selden et al. (1971), were unable to demonstrate a patient who excreted *Klebsiella* and subsequently acquired the same type in a clinical specimen.

Many of the capsular types, such as the commonest clinical isolate type 47, known to be endemic in ICU patients between 1969 and 1973, were also found in the hospital kitchens or ward food. This, together with the correlation demonstrated in survey I between food and faecal and clinical serotypes, could theoretically merely reflect the serotypes that happen to be common throughout the hospital. However, survey II showed that, for a prospective period of three months, ICU food strains were significantly more prevalent among ICU clinical isolates than strains from patients in other parts of the hospital.

It might be expected that prevalent contaminating strains in the kitchens will change from time to time, and this would cause a corresponding change in the prevalent clinical infecting types. Indeed, we have already shown (Caswell and Phillips, 1978) that clusters of infection with the same serotype do occur in this ward.

The finding that individual ICU patients rarely acquire infection or colonisation with the type that they had ingested themselves, but rather one that had been fed to some other patient on the ward, suggests that there must be a route of transmission from one patient to the next. Our findings implicating staff hands as a significant route of transmission have recently been published elsewhere (Caswell and Phillips, 1977).

We thank the staff of the intensive care unit for their willing cooperation, and Mrs V. Dawes and Miss A. King for technical help. This study was supported by a grant from the Medical Research Council.

References


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