Faecal elastase 1: a novel, highly sensitive, and specific tubeless pancreatic function test

Chr Löser, A Möllgaard, U R Fölsch

Abstract

Background—Indirect pancreatic function tests available today are unreliable for clinical practice in early chronic pancreatitis due to their low sensitivity in mild and moderate exocrine pancreatic insufficiency.

Aim—to evaluate the sensitivity, specificity, and practicability of faecal elastase 1 determination in patients with mild, moderate, and severe exocrine pancreatic insufficiency categorised according to the secretin-caerulein test as ‘gold standard’.

Patients and methods—Faecal and duodenal elastase 1 concentration (commercial enzyme linked immunosorbent assay (ELISA)), faecal chymotrypsin activity, faecal fat analysis, and the secretin-caerulein test were performed on 44 patients with mild (n=8), moderate (n=14), and severe (n=22) exocrine pancreatic insufficiency and 35 patients with gastrointestinal diseases of non-pancreatic origin. Fifty healthy volunteers were studied as normal controls. Morphological examinations were carried out to definitely confirm or exclude chronic pancreatitis.

Results—With a cut off of 200 μg elastase 1/g stool the sensitivity was 63% for mild, 100% for moderate, 100% for severe, and 97% by this method for all patients with exocrine pancreatic insufficiency, and specificity was 93%. Values for chymotrypsin were 64% (sensitivity) and 89% (specificity). Significant (p<0.001) correlations were found for faecal and duodenal elastase with duodenal lipase, amylase, trypsin, volume, and bicarbonate output. Individual day to day variations of faecal elastase 1 concentrations were very low (mean CV=15%) and sample storage at room temperature is possible for at least one week.

Conclusions—Faecal elastase 1 determination proved to be a highly sensitive and specific tubeless pancreatic function test. (Gut 1996; 39: 580–586)

Keywords: chronic pancreatitis; lipase, pancreatic insufficiency; pancreatic function test; secretin-caerulein test.

The diagnosis of chronic pancreatitis is hampered by the absence of easily available histological confirmation and is therefore based on morphological and functional variables.1–3 Direct pancreatic function tests such as the secretin-cholecystokinin or secretin-caerulein test have the highest sensitivity and specificity for the detection of exocrine pancreatic insufficiency and remain the ‘gold standard’ for testing pancreatic function.4–6 Direct pancreatic function tests, however, have various practical disadvantages: they are time consuming, invasive, expensive, uncomfortable, not standardised, and require fluoroscopic tube placement. Therefore the secretin-caerulein test is unsuitable for routine application and is confined to a few academic centres.

Several simple indirect pancreatic function tests for clinical practice, such as the fluorescein dilute test, NBT-PABA or bentirimide test, faecal chymotrypsin determination, or different breath tests, have been established.13–17 However, these proved to have limited sensitivity in mild and moderate exocrine pancreatic insufficiency and are interfered with by some drugs, diarrhoea, pH, and gastrointestinal operations, which lower their specificity. In general these indirect pancreatic function tests are unreliable for clinical practice in early chronic pancreatitis1–3 and the search continues for a sensitive as well as a practical test to definitely prove or exclude exocrine pancreatic insufficiency.

Recently pancreatic elastase 1 was isolated and further characterised as a human and pancreas specific enzyme that is not degraded during intestinal transport and which is five to sixfold enriched in faeces compared with duodenal juice.10–12 Furthermore, a highly sensitive enzyme linked immunosorbent assay (ELISA) for human faecal and duodenal elastase 1 determination using two specific monoclonal antibodies is commercially available.10–11 Early clinical studies gave promising results in patients with exocrine pancreatic insufficiency for determination of faecal elastase 1 concentration in comparison with the fluorescein dilute test13–14 and in a few patients compared with the secretin-caerulein test as well.15–16

The aim of the present study was to evaluate (a) the sensitivity and specificity of faecal elastase 1 determination in a sufficient number of patients with exocrine pancreatic insufficiency in comparison with the ‘gold standard’ of pancreatic function testing, the secretin-caerulein test; (b) to characterise the sensitivity of the test according to a subclassification of patients with mild, moderate, and severe exocrine pancreatic insufficiency; (c) to compare these results with the
determination of faecal chymotrypsin activity; 
(d) to perform various correlation studies to
further characterise clinically important vari-
bles; and (e) to determine the practicability
and clinical handling of faecal elastase 1 ana-
lysis with regard to individual day to day
variations, problems of sample storage, and
temperature dependency of sample analysis.

Methods

CLASSIFICATION OF PATIENTS

Seventy-nine consecutive patients with clini-
cally suspected chronic pancreatitis were
referred to our clinic for the secretin-caerulein
test. Morphological criteria according to the
Cambridge classification17 18 were assessed by
ultrasonography, abdominal computed tomog-
raphy, or endoscopic retrograde pancreatog-
raphy (ERP) to confirm or exclude chronic
pancreatitis.

Thirty-five patients had a normal secretin-
caerulein test and no morphological signs of
chronic pancreatitis. The following non-
pancreatic gastrointestinal diseases were
confirmed by further diagnostic investigations:
erosive gastroduodenitis or gastric or duodenal
ulcer (n=15), coeliac disease (n=3), gastro-
esophageal reflux (n=2), Crohn’s disease
(n=2), cholecystitis (n=1), gastric cancer
(n=1), and functional diarrhoea (n=11).

Forty-four patients had a pathological
secretin-caerulein test together with morpho-
logical criteria as defined in the Cambridge
classification.17 18 According to the results of
the secretin-caerulein test these patients with
chronic pancreatitis were subclassified18 into
mild (I; n=8) (pathological secretion of one to
three enzymes, normal volume and bicarbon-
ate secretion, no steatorrhoea), moderate (II;
n=14) (pathological secretion of enzymes as
well as pathological volume and bicarbonate,
no steatorrhoea), and severe (III) exocrine
pancreatic insufficiency (n=22) (as II plus ste-
atorrhoea >7 g/day). Subclassification was
performed according to functional criteria of
the secretin-caerulein test only; morphological
data were not used for this categorisation.

Faecal elastase concentration and faecal
chymotrypsin activity were determined in all
79 patients and furthermore in 50 healthy
controls with no pathological clinical and
laboratory findings. Table I shows the patients’
characteristics of the several groups investi-
gated in detail.

TABLE I  Characteristics of patients

<table>
<thead>
<tr>
<th>Healthy controls</th>
<th>Chronic pancreatitis with exocrine pancreatic insufficiency</th>
<th>Other gastrointestinal diseases</th>
</tr>
</thead>
<tbody>
<tr>
<td>No of patients</td>
<td>I (mild) II (moderate) III (severe)</td>
<td></td>
</tr>
<tr>
<td>Age (mean (SEM))</td>
<td>27.4 (0.8) 35.6 (5.3) 44.6 (3.5) 47.2 (1.6) 52.0 (2.5)</td>
<td>22/0 35/2 22/13</td>
</tr>
<tr>
<td>Sex (male/female)</td>
<td>26/24</td>
<td></td>
</tr>
<tr>
<td>Body weight (mean (SEM)) (% BROCA)</td>
<td>90-0 (2-1) 95-9 (6-9) 88-9 (3-2) 78-9 (1-8) 92-5 (2-4)</td>
<td></td>
</tr>
<tr>
<td>Abdominal pain (yes/no)</td>
<td>0/50 4/4 10/4 16/8 0/35</td>
<td></td>
</tr>
<tr>
<td>Steatorrhoea (yes/no)</td>
<td>0/50 0/8 0/14 22/0 7/28</td>
<td></td>
</tr>
<tr>
<td>Diabetes mellitus (yes/no)</td>
<td>0/50 2/6 7/1 11/11 0/35</td>
<td></td>
</tr>
<tr>
<td>Pancreatic calcification (yes/no)</td>
<td>0/50 4/4 10/4 20/2 0/35</td>
<td></td>
</tr>
</tbody>
</table>

SECRETIN-CAERULEIN TEST

After an overnight fast patients were intubated
in the morning at 8 am with a gastroduodenal
tube, which was placed up to the ligament of
Treitz. After 15 minutes’ collection of basal
secreted duodenal juice, 1 U secretin/kg bw/t/h
was continuously given intravenously for two
hours and 30 ng caerulein/kg bw/t/h was
simultaneously given intravenously during the
second hour. Pancreatic juice was collected in
15 minute aliquots, and volume, pH,
bicarbonate, amylase, trypsin, lipase, and
elastase were measured by commercial test kits
(amylase, lipase, trypsin, from Boehringer/
Mannheim, Germany). The lower normal
limits are two SD below the mean values:
volume <150 ml/first hour, bicarbonate <10
mmol/first hour, amylase <15×10^3 U/second
hour, lipase <90×10^3 U/second hour, trypsin
<6×10^3 U/second hour, and elastase <16×10^3
µg/second hour.

FAECAL ELASTASE

Faecal elastase was measured using two
monoclonal antibodies specific for human
pancreatic elastase 1, which bind to two
distinct epitopes of this enzyme10 11 (test
kit from Schebo Tech, 35435 Wettenberg,
Germany). The lower detection limit of the
elastase 1 assay is below 1 ng/ml.11 The
intraassay variance is 5-8%, and the interassay
variance is 7-7%.11 Stool (100 mg) was finally
diluted 1:500 and faecal elastase 1 concentra-
tion (µg/g stool) was calculated photometri-
cally (OD 405 mm) in comparison with a
standard solution.10 11

FAECAL CHYMOTRYSIN

Faecal chymotrypsin activity (U/g stool) was
calculated by photometric estimation with a
test kit from Boehringer Mannheim (Germany).20
Values were expressed as U/g stool and values <3 U/g stool were regarded as
pathological.

FAECAL FAT ANALYSIS

Faecal fat excretion was measured by the
established method of van de Kamer et al11
with the patients consuming 90 g fat per day
during the three day sample collection period.
Steatorrhoea was defined as faecal fat excretion
of more than 7 g fat per day as a mean of a 72
hour collection period.
CORRELATION STUDIES
Various correlation studies were performed – namely, duodenal elastase concentration versus duodenal volume, bicarbonate, amylase, lipase, and trypsin as found in the secretin-caerulein test; faecal elastase concentration versus duodenal volume, bicarbonate, amylase, lipase, trypsin, and elastase; faecal elastase versus faecal chymotrypsin; and faecal elastase versus faecal fat excretion. For comparison the same correlations were calculated for faecal chymotrypsin.

DAY TO DAY VARIATIONS
Day to day variations for faecal elastase concentrations and faecal chymotrypsin activities were calculated by daily stool analysis on 10 consecutive days in eight patients. Individual and mean coefficients of variance were determined.

TEMPERATURE DEPENDENCY
To calculate the temperature dependency of faecal elastase and chymotrypsin analysis over a storage period of one week, the homogenised stool samples of 11 persons were taken, stored at room temperature (+22 °C), +4 °C or −25 °C for one week. Differences between temperatures were calculated and the results expressed as percentage variation.

STATISTICAL ANALYSIS
The between group statistical differences were calculated with the Mann-Whitney U test, and regression analysis was performed with the Spearman rank test. Sensitivity and specificity of faecal elastase and faecal chymotrypsin were compared with the results of the secretin-caerulein test. Values are expressed as mean (SEM).

Results
Figure 1 depicts individual results of faecal elastase concentration (μg/g) and faecal chymotrypsin activity (U/g). Faecal elastase concentrations (μg/g) in patients with chronic pancreatitis were significantly lower (I: 208.3 (88.2) (p<0.01); II: 28.0 (8.2) (p<0.001); III: 12.5 (5.6) (p<0.001)) compared with healthy controls (601.9 (38.2)) or patients with non-pancreatic gastrointestinal diseases (545.9 (61.8)). By contrast faecal chymotrypsin activity (U/g) was not significantly reduced in patients with mild pancreatic insufficiency (9.3 (3.6); p=0.08) compared with healthy controls (15.1 (1.2)) and patients with other gastrointestinal diseases (10.2 (1.3)). Although patients with moderate (5.2 (1.2); p<0.001) and severe (1.7 (0.6); p<0.001) exocrine pancreatic insufficiency had significantly lower faecal chymotrypsin activities, several patients were above the cut off value of 3 U/g, which was not the situation for faecal elastase concentration in these groups (Fig 1).

Table II shows the sensitivity and specificity of faecal elastase concentrations with a cut off of 100 μg/g stool and 200 μg/g stool and faecal chymotrypsin activity with a cut off of 3 U/g. Faecal elastase concentrations below 200 μg/g stoolshow a total of 93% both for sensitivity and specificity, whereas sensitivity for moderate and severe exocrine pancreatic insufficiency is 100% and for mild insufficiency 63%. By comparison with mild and moderate insufficiency the sensitivity of faecal chymotrypsin amounted to 25% and 50% respectively (Table II).

Linear regression analysis showed significant correlations between duodenal as well as faecal elastase concentrations and duodenal trypsin, lipase, amylase, total volume, and bicarbonate

![Figure 1](image-url)

**Figure 1**: Faecal elastase concentration (μg/g stool) (upper panel) and faecal chymotrypsin activity (U/g stool) (lower panel) in normal healthy controls (N), patients with mild (I), moderate (II), and severe (III) exocrine pancreatic insufficiency according to the secretin-caerulein test, and patients with other gastrointestinal diseases (GI) of non-pancreatic origin. Significance *p* N.

<table>
<thead>
<tr>
<th>Exocrine pancreatic insufficiency</th>
<th>Elastase cut off</th>
<th>Chymotrypsin cut off</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>&lt;100 μg/g (%)</td>
<td>&lt;200 μg/g (%)</td>
</tr>
<tr>
<td>Sensitivity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>50</td>
<td>63</td>
</tr>
<tr>
<td>II</td>
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<td>III</td>
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<td>total</td>
<td>86</td>
<td>93</td>
</tr>
<tr>
<td>Specificity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>98</td>
<td>93</td>
</tr>
</tbody>
</table>

I=mild; II=moderate; III=severe; total=total exocrine pancreatic insufficiency as estimated by the secretin-caerulein test.
Faecal elastase in exocrine pancreatic insufficiency

according to the results of the secretin-caerulein test (Figs 2 and 3). Similar analyses showed much lower correlations for faecal chymotrypsin with duodenal trypsin (0.626; p<0.001), lipase (0.605; p<0.001), amylase (0.635; p<0.001), volume (0.392; p<0.001), and bicarbonate (0.590; p<0.001). Furthermore, significant correlations were found for faecal elastase/faecal chymotrypsin (0.724; p<0.001) and faecal elastase/duodenal elastase (0.773; p<0.001), but there was no significant correlation between faecal elastase and faecal fat excretion (r=-0.336). Repeated daily measurements of elastase concentrations in eight persons on 10 consecutive days showed coefficients of variance between 9% and 21% with a mean value of 15% (Table III). By comparison the coefficients of variance for faecal chymotrypsin ranged between 11% and 46% with a mean value of 30% (Table III).

After one week's storage at different temperatures the faecal elastase concentrations of stool samples from 11 persons varied by mean 6-6% between -25°C and room temperature, 4-13% between -25°C and +4°C, and 2-51% between +4°C and room temperature. The results for faecal chymotrypsin were 27.52%, 10.37%, and 17.15% after storage of the stool samples for one week.

Discussion

Elastase 1 is a proteolytic pancreas specific enzyme with a molecular weight of about 28 kDa with a special affinity to the carboxyl group of alanine, valine and leucine.\(^{10,13}\) It was first described in 1975 by Mallory and Travis\(^{13}\) as protease F, and further characterised as an elastolytic pancreatic enzyme by Largmann et al.\(^{24}\) Under physiological conditions elastase 1 concentration in pancreatic juice is between 170 and 360 µg/ml, which is about 6% of all secreted pancreatic enzymes.\(^{25}\) During intestinal passage elastase 1 is mainly bound to bile salts and it was shown that elastase 1 – by contrast with other pancreatic enzymes – is not degraded during passage through the gut, whereas it is concentrated about five to sixfold in human faeces compared with pancreatic juice.\(^{10,12,25}\)

Recently published studies comparing faecal elastase 1 concentration with the fluorescein dilaurate test and faecal chymotrypsin activity in patients with chronic pancreatitis disclosed a comparable sensitivity of faecal elastase 1.
with the fluorescein dilaurate test, whereas determination of faecal chymotrypsin activity was less sensitive.\textsuperscript{13, 14} In all 11 patients with exocrine pancreatic insufficiency confirmed by the secretin-cholecystokinin test, Stein et al\textsuperscript{15} found faecal elastase 1 concentrations <150 µg/g stool, whereas 21 patients without exocrine pancreatic insufficiency had concentrations above 250 µg/g. Katschinski et al\textsuperscript{16} reported a sensitivity and specificity of faecal elastase 1 determination (cut off <400 µg/g) for pancreatic insufficiency of 91% in 23 patients with 11 patients having exocrine pancreatic insufficiency as assessed by a direct tube test. In 204 children with cystic fibrosis, Terbrack et al\textsuperscript{20} found a sensitivity of 89.5% and a specificity of 99% for faecal elastase 1 concentration with a cut off of <200 µg/g stool. These data were confirmed by other investigators, who found faecal elastase 1 concentrations below 15 µg/g in all patients studied with confirmed cystic fibrosis.\textsuperscript{15}

Our data confirm those already published indicating that faecal elastase 1 determination is a sensitive and specific test for the detection of decreased exocrine pancreatic function. Furthermore, the present study is the first to present data on the basis of a large cohort of patients with various well defined degrees of exocrine pancreatic insufficiency as measured by the secretin-caerulein test as the ‘gold standard’ of pancreatic function testing. Our data extend the suggestions of previous investigators by showing (a) that faecal elastase 1 determination with a cut off <200 µg/g is highly sensitive (93%) and specific (93%) for the detection of exocrine pancreatic insufficiency; (b) subclassification according to the results of the secretin-caerulein test and faecal fat excretion show excellent sensitivity for moderate (100%) and severe (100%) and sufficient but limited sensitivity for mild (63%) exocrine pancreatic insufficiency; (c) overall sensitivity of faecal elastase 1 (93%) is much higher than that of faecal chymotrypsin (64%); (d) elastase 1 shows a very similar excretion pattern to the other pancreatic enzymes and faecal elastase 1 concentration is highly significantly correlated with duodenal enzyme and volume output; (e) faecal elastase 1 analysis proved to be of high clinical practicability with low individual day to day variability and excellent stability under various storage conditions.

Faecal elastase 1 concentrations <100 µg/g are found in mild and moderate as well as
Faecal elastase in exocrine pancreatic insufficiency

### TABLE III

<table>
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<th>Day</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
<th>P6</th>
<th>P7</th>
<th>P8</th>
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<tbody>
<tr>
<td>Faecal elastase (μg/g)</td>
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<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
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<td>611</td>
<td>9</td>
<td>335</td>
<td>5</td>
<td>458</td>
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<td>10</td>
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<td>6</td>
<td>433</td>
<td>4</td>
<td>425</td>
<td>0</td>
</tr>
</tbody>
</table>

| CV (%) | 12% | 19% | 13% | 17% | 9% | 14% | 21% | 16% |

| Faecal chymotrypsin (μg/g) | | | | | | | | |
| 1 | 139 | 9 | 134 | 7 | 79 | 2 | 215 | 5 |
| 2 | 152 | 2 | 89 | 9 | 95 | 1 | 15 | 1 |
| 3 | 167 | 7 | 112 | 1 | 11 | 2 | 9 | 9 |
| 4 | 110 | 1 | 122 | 6 | 7 | 0 | 7 | 0 |
| 5 | 139 | 9 | 7 | 8 | 5 | 8 | 17 | 5 |
| 6 | 146 | 9 | 9 | 7 | 2 | 6 | 19 | 5 |
| 7 | 163 | 6 | 9 | 5 | 11 | 5 | 16 | 0 |
| 8 | 144 | 4 | 9 | 5 | 10 | 1 | 15 | 8 |
| 9 | 139 | 6 | 5 | 6 | 16 | 0 | 17 | 0 |
| 10 | 155 | 2 | 25 | 2 | 11 | 1 | 18 | 1 |

| Mean | 145 | 1 | 14 | 4 | 9 | 9 | 7 | 0 |
| SD | 1 | 6 | 5 | 3 | 5 | 0 | 5 | 8 |
| CV | 14 | 6 | 9 | 9 | 15 | 9 | 16 | 5 |

CV=Coefficient of variance (mean for faecal elastase 19%; mean for faecal chymotrypsin 30%).

severe exocrine pancreatic insufficiency and are therefore not characteristic for severe cases only. On the other hand, the sensitivity in mild cases is limited, with a cut off <200 μg/g as three out of eight patients had elastase 1 concentrations above that concentration. Nevertheless, a sensitivity of 63% in these mild cases is much higher compared with other indirect pancreatic function tests available, and a sensitivity of 100% in moderate exocrine pancreatic insufficiency is not reported for any other tubeless test either.1 3 8

In a well documented meta-analysis, overall sensitivity for mild and moderate chronic pancreatitis assessed by the secretin-caerulein test was 39% for the fluorescein dilute test, 46% for the NBT-PABA test, and 49% for faecal chymotrypsin determination, whereas sensitivities for severe cases were 79%, 71% and 85% respectively.1 3 8

The presented results differ from data by Amann et al27 who found normal (>200 μg/g) faecal elastase 1 concentrations in four out of seven patients with mild to moderate exocrine pancreatic insufficiency. This low sensitivity might be due to the different subclassification criteria in this study: whereas Amann et al27 subclassified their 13 patients according to a combined parameter score with morphological (calcifications, ERP, surgery) and functional (secretin test) criteria, subclassification in the present study was performed according to functional criteria1 19 only, although morphological criteria17 18 had to be present to confirm the diagnosis. Evaluation of a novel function test should be based on the best established functional variable as subclassification standard, which is the secretin-caerulein test.

Significant correlations between faecal as well as duodenal elastase 1 concentrations and duodenal lipase, amylase, trypsin, and bicarbonate were found, which proves that secretion patterns of elastase are similar to those of other pancreatic enzymes. Furthermore, faecal elastase 1 was highly significantly correlated to duodenal elastase 1 concentrations, which clearly confirms the suggestions of other investigators that measurement of faecal elastase 1 is representative of pancreatic elastase 1 secretion.10 25

This study disclosed very low individual day to day variations of faecal elastase 1 concentrations, confirming results of studies in children with cystic fibrosis.26 Faecal elastase 1 determination does not require analysis of different stool samples. Single analysis of a normal 100 mg stool sample proved to be sufficient and should only be repeated in uncertain cases with faecal elastase 1 concentrations in the borderline area around 200 μg/g stool. Furthermore, faecal elastase 1 was found to be stable over a storage period of one week, even at room temperature, as also described by other investigators28 and this makes handling and even mailing of a small stool sample straightforward and easy. As monoclonal antibodies against human pancreatic elastase are used in the ELISA kit,10 11 faecal elastase 1 determination is not affected by simultaneous enzyme replacement therapy with pancreatin of animal origin.28

In conclusion, the data of the present study show the excellent sensitivity of faecal elastase 1 determination for moderate and severe exocrine pancreatic insufficiency and its limited sensitivity for mild disease. At present faecal elastase 1 determination is the most sensitive and specific tubeless pancreatic function test available, and furthermore proved to be a rapid and easy to handle routine method.

Parts of the study were published in abstract form at the European Pancreatic Club Meeting in Barcelona, Spain (Digestion 1993; 50: 332: 1482-90). The study was presented at the European Gastroenterology Week in Berlin/Germany (Gut 1995; 37: A140).

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