Development and validation of a lipase nasogastric tube position test

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ABSTRACT

Background: Nasogastric tube position should be checked every day by either aspirate pH or chest radiography to prevent fatal misplaced feeding into the lungs. Many patients do not have acidic gastric aspirates and require daily chest radiographs. We developed and validated a lipase test that was compatible with non-acidic gastric aspirates.

Methods: We conducted evaluations of diagnostic test accuracy at a teaching hospital in development and validation stages. Development: We collected gastric and lung aspirates from 34 consecutive patients. We measured pH and human gastric lipase activity in the laboratory. These data helped us develop the lipase test. Ingenza Ltd (Roslin, Scotland) created tributyrin-coated pH test paper, which human gastric lipase converted into butyric acid, thus correcting false negatives. Validation: We tested nasogastric feeding tube aspirates from 36 consecutive patients with pH and lipase tests, using chest radiography or trial by use as the reference standard.

Results: Development: We demonstrated human gastric lipase activity in the non-acidic stomach aspirates. Validation: The accuracy of the lipase test (sensitivity 97.2%, specificity 100%) was significantly better than pH (sensitivity 65.7%, specificity 100%, p<0.05).

Conclusions: When nasogastric tube stomach aspirates were not acidic and pH was falsely negative, the lipase test showed a true positive and was significantly more accurate.

INTRODUCTION

Nasogastric tubes are commonly used to assist enteral nutrition.¹ The National Patient Safety Agency issued guidelines recommending that aspirate pH is tested before every feed and at least once every day to check nasogastric tube position and prevent harm from feeding into the lungs through a mis-placed nasogastric tube. An acidic result (pH<5.5) indicates that the nasogastric tube is correctly positioned in the stomach and feeding is safe. If the result is not acidic (pH>5.5), a chest radiograph is indicated to check that the nasogastric tube is positioned in the stomach and not in the lungs.² ³

No other tests other than pH and chest radiography are reliable and currently recommended.⁴ However, up to 42% of hospital inpatients receive antacid medications that render the results of pH test paper falsely negative.⁵

The ideal solution would be a test that was accurate despite non-acidic gastric aspirates, safe, point-of-care and non-ionising. Other authors have reported some success with pH and magnetic-tipped nasogastric tube styles.⁶ ⁷ The use of gastric enzymes in nasogastric tube position tests has been mooted, but no evaluations of clinically viable prototypes have been published.⁸

Human gastric lipase is an endogenous gastric enzyme, which starts the digestion of dietary triglyceride in the human stomach.⁹ Chief cells secrete human gastric lipase
entirely from the gastric fundus.\textsuperscript{10, 11} It is not known for
certain if human lipase activity is present in the lungs. Human gastric lipase is relatively stable and its production,
unlike the secretion of hydrochloric acid from gastric parietal cells, is not affected by antacid medications.\textsuperscript{12, 13} Production of human gastric lipase is well
developed at birth\textsuperscript{14} and is stimulated by pentagastrin
and a high-fat diet\textsuperscript{15} and reduces with age, but does not
diminish completely.\textsuperscript{11} One barrier to a single reagent
test is that human gastric lipase is inactivated by acidic
stomach contents and therefore is unsuitable as a means
of determining nasogastric tube position on its own. It
has been suggested that a combined test for pH incorpor-
orating a gastric enzyme may be significantly more
accurate than each in isolation.\textsuperscript{7} The objective of this
study was to develop and validate a nasogastric tube posi-
tion test that was compatible with non-acidic gastric
aspirates by utilising human gastric lipase to lower the
pH of gastric aspirates on pH test paper.

\section*{METHODS}

\section*{Study design}

We present two prospective studies. The development
phase explored human gastric lipase activity from
stomach and lung aspirates in the laboratory. The valid-
ation phase was a diagnostic test study that trialled the
lipase test versus pH to determine nasogastric tube posi-
tion reported in accordance with STARD guidelines.\textsuperscript{16}

\section*{Setting}

This research project was conducted in the UK at a single
tertiary-referral acute London teaching hospital between
2011 and 2012. Favourable opinions were obtained from
the UK National Health Service research ethics commit-
tees (Refs: 10/H0706/45 and 10/H0724/76).

\section*{Development phase}

Recruitment consisted of consecutive adult patients
undergoing major upper-gastrointestinal surgery involv-
ing one-lung ventilation, a procedure that ensured
accurate collection of stomach and lung aspirates.
Patients known to have no gastric fundus (eg, previous
gastrectomy) were excluded because human gastric
lipase is exclusively produced by the fundus.\textsuperscript{11} All other
patients who gave valid consent to participate were
included. After the patient was anaesthetised, the con-
sultant anaesthetist inserted a nasogastric tube. The con-
sultant surgeon checked whether the tip of the
nasogastric tube was correctly positioned in the stomach
by palpation after gaining access to the abdominal cavity
through a laparotomy incision and before mobilising
any organs. This direct confirmation of nasogastric tube
position represented the reference standard. After this
confirmation, stomach aspirates were taken. In addition,
the consultant anaesthetist took lung aspirates under
direct vision by aspirating from the newly reinfated lung
near the end of the operation. We immediately labelled
the samples with anonymous codes and froze them to
\(-80^\circ\text{C}\) ready for transport to the off-site laboratory. A
biochemist thawed the samples and tested pH and
human gastric lipase activity at the off-site laboratory.
The analysis was blinded. pH was measured by wetting
the pH test paper with an aspirate and waiting for 1 min
(Merck, New Jersey, USA, Ref: 1095840001). Human
gastric lipase activity was measured using the 718 STAT
Titrino (Metrohm, Herisau, Switzerland) using methods
that have already been described.\textsuperscript{13} A pH of \(5.5\) indicated
correct and \(>5.5\) indicated incorrect nasogastric
tube position. Any human gastric lipase activity indicated
correct nasogastric tube position and no activity indi-
cated incorrect nasogastric tube position.

\section*{Design of lipase test}

The results of the development phase informed the cre-
ation of the lipase test. A biochemist coated pH test
paper (Merck, New Jersey, USA, Ref: 1095840001) with
tributyrin (Ingenza Ltd, Roslin, Scotland). This substrate
produces an alcohol and butyric acid when metabolised
by human gastric lipase. We hypothesised that active
human gastric lipase in non-acidic nasogastric tube
stomach aspirates would create enough butyric acid to
change the pH on the lipase test paper to \(\leq 5.5\), thus cor-
correcting false-negative results.

\section*{Validation phase}

The accuracy of the lipase test was determined in the
validation phase. Recruitment consisted of consecutive
adult patients treated clinically with a nasogastric
feeding tube. Patients known to have no gastric fundus
(eg, previous gastrectomy) were excluded. All other
patients who gave valid consent to participate were
included. The reference standard test consisted of chest
radiography or trial by use if chest radiography was not
indicated. Consultant radiologists interpreted all chest
radiographs while blinded to the index test results.
Criteria for correct nasogastric tube position on the
chest radiograph included a straight vertical course near
the midline passing through the carina and not follow-
ing a bronchus with the tip below the diaphragm on
the same side as the gastric bubble. An aspirate from the
nasogastric tube was taken within 30 min of the chest
radiograph and there was no sign of nasogastric tube dis-
placement such as change in tube length in the inter-
vening time. If there were signs that the nasogastric tube
may have been displaced, for example, patient pulling
the tube, sticky plaster not securing the tube, length of
tube at nares changed, then repeat aspirate tests and
radiography were performed after the tube was reseted.
Trial by use was used because the research ethics com-
mittee deemed it inappropriate to obtain additional
chest radiographs for the purpose of this study. Patients
who had trial by use already had the position of their
nasogastric tube satisfactorily confirmed earlier by pH,
chest radiography or direct confirmation during an
operation. All patients were followed up after their first
feed after entering the study had been administered and again at discharge from the hospital to ensure that no misplaced nasogastric tube feeding into the lung had occurred during their admission (ie, aspiration pneumonia). We tested the aspirate with the standard 0–6 pH test paper with 0.5 increments and also with 2–9 pH paper with 0.5 increments by wetting the test paper with aspirate (BDH, VWR International Ltd, Leicester, UK, Ref: 31505; and Merck, New Jersey, USA, Ref: 1095840001). We also simultaneously tested the aspirate with the lipase test in the same way. Two study authors (OA and MH) independently assessed the results of the test papers, while blinded to the results of the reference standard tests. The test papers were read at 1 min. A pH of ≤5.5 indicated correct and >5.5 indicated incorrect nasogastric tube position.

Statistics
In the development and validation phases, we compared the accuracy of pH and lipase tests in the same participants with paired analyses.17 We required at least 10 patients for the development phase.18 For the validation phase, we estimated that n=52 was required to rule out a clinically significant difference using pilot data (first 20 patients, pH test paper accuracy was 65%, lipase test accuracy was 100%, but 95% was used in the calculation, α=0.05, power=80%).19 Planned interim analysis at the end of the originally allotted study time period showed a significant difference, and therefore recruitment was not extended beyond 36 patients.

RESULTS
Development phase
Participants
We recruited 36 consecutive patients who underwent upper-gastrointestinal surgery between 2011 and 2012. Two patients were not included in the analysis, because one patient withdrew consent and another patient had an inoperable tumour and the position of their nasogastric tube could not be confirmed during the operation. Therefore, data from 34 patients were included in the analysis, 23 men and 11 women. The median age of participants was 68 years (range 44–82). We obtained gastric aspirates from 32 patients (2 patients had dry gastric aspirates) and lung aspirates from 23 patients (11 patients had dry lung aspirates). Twenty-two patients (65%) were taking antacid medication (12 were taking omeprazole, 7 were taking lansoprazole and 3 were taking esomeprazole). We excluded no data from the analysis. There were no indeterminate or outlier results.

Stomach samples
The pH of the 32 stomach samples ranged from 1 to 8.5 with a mean of 4.4. 19 (59%) of the stomach samples had a pH of 5.5 or less, which would indicate correct placement of a nasogastric tube. Human gastric lipase activity was present in 21 (66%) of the stomach samples and all of the samples between pH 3 and 8. Human gastric lipase activity was not present in samples that were more acidic than pH 3 and was also not present in a single alkaline sample at pH 8.5. This was the most alkaline sample and human gastric lipase activity was present in samples at pH 8. Crucially, 31 (97%) of the stomach samples had either a pH of 5.5 or less and/or human gastric lipase activity. Therefore, this indicated that a combined pH and human gastric lipase test could be more accurate than pH alone.

Lung samples
The pH of the 23 lung samples ranged from 6 to 8.5 with a mean of 6.9. None of the lung samples had a pH of 5.5 or less, which could have resulted in misplaced nasogastric tube feeding into the lung on pH criteria. Human gastric lipase activity was present in none of the lung samples, which was essential to the viability of a human gastric lipase-based test.

Validation phase
Participants
We approached 46 consecutive ward patients who were treated clinically with nasogastric tubes between 2011 and 2012. One patient could not be recruited because they had a previous gastrectomy. Nine of the recruited patients were not included in the analysis because their nasogastric tube aspirates were dry. Therefore, data from 36 patients were included in the analysis, which included 27 men and 18 women. The median age of the participants was 67 years (range 22–88). In total, 38 patients (84%) were taking antacid medication (17 were taking omeprazole, 20 were taking lansoprazole and 1 was taking esomeprazole).

Diagnostic accuracy
Table 1 shows a summary of the results. All measurements were made twice, independently, by two assessors (OA and MB) and were always in agreement with one

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Diagnostic accuracy results from the validation phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH (%)</td>
<td>Lipase test (%)</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>65.7</td>
</tr>
<tr>
<td>Specificity</td>
<td>100</td>
</tr>
<tr>
<td>Positive predictive value</td>
<td>100</td>
</tr>
<tr>
<td>Negative predictive value</td>
<td>7.7</td>
</tr>
</tbody>
</table>

+, Indicates correct nasogastric tube placement; −, indicates incorrect nasogastric tube placement.
another. We excluded no data from the analysis. There were no indeterminate or outlier results. Overall, the accuracy of the lipase test was significantly greater than pH (extended McNemar’s test $\chi^2=11$ with 2 df, $p<0.05$). The sensitivity of the lipase test was significantly greater than pH ($\chi^2=9.091$ with 1 df, $p<0.05$). The 95% confidence interval for the difference between the sensitivities was 17.3% to 47.5%.17

**DISCUSSION**

In the development study, we determined pH and human gastric lipase activity in stomach and lung aspirates. We found human gastric lipase activity in the stomach when the pH was not acidic (pH>5.5), which confirmed that a combined pH and lipase test might be viable and more accurate than each in isolation. We then incorporated tributyrin, a substrate to human gastric lipase, onto pH test paper. Tributyrin is metabolised by human gastric lipase to form butyric acid. This acid lowers pH and corrects false-negative results from gastric aspirates that are not acidic. We also showed that there is no human gastric lipase activity in lung aspirates, another new and crucial finding, because if there were any human gastric lipase activity in the lung, the lipase test could produce catastrophic false positives. In the second study, we examined the lipase test on aspirates from ward patients with nasogastric feeding tubes and demonstrated that it had significantly improved accuracy at determining nasogastric tube position when compared with pH.

We addressed an important unmet need in this translational research project with a novel innovative solution that can be clinically implemented and result in tangible benefits to patients, healthcare workers and organisations. We used robust methods and reported these in accordance with the STARD, QUADAS-2 and QAREL quality checklists for studies of diagnostic tests.16 20 21 In the validation phase, we included a spectrum of participants that is representative of the patients who will receive the test in practice. Very few patients were excluded from the study and we detailed the reasons in each case. The reference standard tests used in both studies were likely to classify the position of the nasogastric tube correctly and the index tests were performed very close to the time of the reference standard tests. The index test did not form part of the reference standard tests. No patients were lost to follow-up. In the validation phase, assessment of the index tests was independent, blinded and random with good inter-rater reliability and with the same clinical data as would be available were the test performed in practice. There were no interpretable, indeterminate and intermediate results or withdrawals after entering the study.

We could not include patients who were unable to give valid consent. This included some patients in the acute phases of a stroke. We did include patients with stroke who could give valid consent. Therefore, we believe that the potential spectrum bias introduced by not including patients who cannot give valid consent does not affect the generalisability of the results. It was deemed unethical to perform additional research chest radiographs on patients who did not require them clinically by an independent research ethics committee, as trial by use as described in the methods provided an equivalent reference standard to chest radiography and more accurately represented clinical practice. The lipase test and all aspirate nasogastric tube position checks could produce a false positive result if fresh gastric contents were aspirated from the lungs. This diagnosis might be missed in patients with clinically silent aspiration pneumonia such as those in a coma. Therefore, we support the use of chest radiographs in patients at risk of silent aspiration pneumonia to check both nasogastric tube position and for radiological signs of the diagnosis.

Up to 42% of hospital inpatients receive antacid medications that render the results of pH test paper falsely negative.5 According to the guidelines, these patients require a chest radiograph every day. Daily chest radiography is undesirable due to radiation, cost, time and inconvenience and is inaccessible once the patient leaves the hospital. The ideal solution would be a test that was accurate despite non-acidic gastric aspirates, safe, point-of-care, intuitive and non-ionising. Other authors have reported success with pH and magnetic-tipped nasogastric tube styles.6 7 These have not been widely adopted because they are operator dependent, requiring training of specialist teams that do not represent the majority of end-users. The lipase test is a viable daily nasogastric tube position check for patients in hospital and in the community. Patients with no functioning gastric fundus to secrete human gastric lipase will not benefit. The lipase test will reduce reliance on chest radiographs. A reduction in reliance on chest radiographs is desirable to minimise the delay to start feeding, exposure to radiation, cost, burden on services and misinterpretation. The National Patient Safety Agency received reports of 32 deaths and 80 severe harms associated with feeding into the lungs through misplaced nasogastric tubes between 2002 and 2010.2 3 Misinterpretation of chest radiographs was the most common reason for harmful misplaced nasogastric tube feeding into the lungs.1 22

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