Power of oesophageal peristalsis can be controlled voluntarily

R M Valori, M T Hallisey, J Dunn

Abstract
The hypothesis that oesophageal peristalsis can be modified voluntarily was explored. Six healthy male volunteers and eight female patients with angina like chest pain underwent oesophageal manometry. Each was asked to take a series of swallows, and to vary their size, in random order, by taking either a big gulp or a little swallow. None of the subjects experienced difficulty in doing so. In both groups the amplitude of oesophageal contractions were significantly greater after big gulps than little swallows (p<0.01) and this was true for wet (62.0 ± 68.9 mmHg) and dry swallows (52.3 ± 43.3 mmHg). For the patients' wet swallows the mean values were 73.0 and 56.0 mmHg. Thus, the amplitude of oesophageal peristalsis can be controlled voluntarily. This effect may account for some of the within subject variation in the amplitude of oesophageal contractions. During oesophageal manometry subjects should be encouraged to standardise the size of their swallows whenever possible. Patients with symptoms related to abnormal oesophageal peristalsis such as dysphagia, heartburn, and chest pain may benefit from biofeedback training.

It is now accepted that changes in the amplitude of oesophageal peristaltic contractions can cause symptoms.14 Low amplitude contractions can cause dysphagia1 and may lead to ineffective clearance of acid from the oesophagus2 and thus to symptoms of oesophageal reflux and oesophagitis. High amplitude contractions, so-called 'nutcracker' oesophagus, can cause angina like chest pain.3 Hence, modification of the power of oesophageal contractions may be therapeutically useful. This study explored the possibility that the amplitude of oesophageal peristalsis could be altered voluntarily.

Methods

SUBJECTS

Healthy volunteers
These were subjects with no history of chest pain, dyspepsia, or other gastrointestinal symptoms.

Patients
These were patients with angina like chest pain but without evidence of ischaemic heart disease (excluded with exercise electrocardiogram or coronary angiography, or both). Before manometry for investigation of chest pain, each subject was asked if she would perform an additional 20 wet swallows. The exact nature of the swallows was not explained until routine manometry was completed.

OESOPHAGEAL MANOMETRY

Oesophageal manometry was performed with either a perfused tube (healthy volunteers) or transducers in situ (patients).

Perfused tube manometry
A 5 mm diameter, multilumen manometry catheter, with three perfusion ports spaced 5 cm apart, was perfused with low compliance pneumatic system (Arndorfer Medical Specialities, Greendale, Wisconsin, USA). Signals from externally placed transducers were recorded using a Synectics polygraph system (Synectics, 215 Willow Road, Enfield, EN1 3BT). The amplitude, duration, and propagation velocity of contractions were analysed by an observer, blind to the order of randomised swallows, using an upper gastrointestinal motility software program (Synectics).

Transducers in situ
A 2 mm diameter cable with three miniature transducers mounted 5 cm apart (Gaeltec Ltd, Dunvegan, Isle of Skye, Scotland IV55 8GU) was connected to a lectromed polygraph system (Ormed Ltd, 32 Hydeway, Welwyn Garden City, Herts AL7 3AW) and the pressure changes were recorded on heat sensitive paper. The recordings were analysed manually by an observer, blind to the order of swallows, using a standard technique.

Statistics
The data were stored on a dual VAX 3600 system (WMRCRCTU) and analysed using the BMDP statistical package.1 Exploratory data analysis showed that the data had no significant skew or
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TABLE I. Analysis of variance statistics for amplitude of peristalsis

<table>
<thead>
<tr>
<th>Volunteers</th>
<th>p</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet Dry (Type-T)</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Little big (gulp)</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>TG</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Channel C</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>TC</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>GC</td>
<td>0.0280</td>
<td>0.0280</td>
</tr>
<tr>
<td>TGC</td>
<td>0.984</td>
<td>0.984</td>
</tr>
<tr>
<td>Patients (wet swallow only)</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Little big (gulp)</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Channel</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>GC</td>
<td>0.0124</td>
<td>0.0124</td>
</tr>
<tr>
<td>Patient x control (wet swallow only)</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Patient x control</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Little big (gulp)</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Case x gulp</td>
<td>0.2602</td>
<td>0.2602</td>
</tr>
</tbody>
</table>

Table summarises the amplitude data for the healthy volunteers. Each mean (SD) represents 20 swallows. C1, C2, and C3 refer to channels 1, 2, and 3.

### Results

**HEALTHY VOLUNTEERS**

Six men (age range 30–38, mean = 34 years) each performed 40 wet and 40 dry swallows in random order. The mean amplitude of contractions for wet and dry swallows for each subject is summarised in Table II. The amplitude of wet swallows was significantly greater than that for dry swallows (p<0.01) and contractions in the lower oesophagus were stronger (<0.01). The big gulps produced more powerful oesophageal contractions than the little swallows (p<0.01). There was no difference in the magnitude of the effect of swallow type between wet and dry swallows (p=0.12). There was a significant interaction between swallow type and channel (p=0.028) and plotting the values suggested that the upper oesophagus was more sensitive to the effect of swallow type. There were no differences in the duration or propagation velocity of contractions.

**PATIENTS**

Eight female patients (age range 34–58, mean = 51 years) with angina like chest pain performed 20 wet swallows. Table III summarises the amplitude data for the patients. The changes were similar to those for the volunteers' wet swallows. The amplitude of contractions was greater in the distal oesophagus (p<0.01), and big gulps pro-

TABLE II. Summary of amplitude data for the healthy volunteers. Each mean (SD) represents 20 swallows. C1, C2, and C3 refer to channels 1, 2, and 3.
duced more powerful contractions than little
swallows (p<0.01). There was a similar interac-
tion between swallow type and channel
(p=0.012). The change in amplitude (in response
to different swallow type) was greater in the
patient group than in the volunteer group but the
difference was not significant (p=0.30). By
increasing the swallow effort, one patient
increased the mean amplitude of 10 swallows
distal two channels) from 142 to 202 mmHg.
This change would have reclassified the patient
from the normal into the 'nutcracker' range
(mean amplitude in distal two channels
>180 mmHg). There were no differences in the
duration or propagation velocity of contrac-
tions.

While measurements of the baseline manomo-
metry in the patients was not part of the original
protocol, it is of interest to compare the baseline
amplitude with the amplitude of the modified
swallows. The means for all three methods of
swallowing (little swallow, baseline, and big
gulp) are summarised in Table IV. Two way
analysis of variance showed a significant differ-
ence between baseline swallows and big gulps
(p<0.01). The overall difference between little
swallows and baseline swallows was not signifi-
cant (p=0.16), but when differences in separate
channels were examined, baseline swallows in
channel 2 were significantly stronger (p=0.028).
The baseline amplitude (distal two channels) of
the patient with possible nutcracker oesophagus
was 148 mmHg.

VARIATION
The variation in amplitude for different swallow
types in the patients' swallows and the volun-
tee's dry swallows was very similar except for
one patient in whom one ratio was greater than
4:1 in two channels (in favour of a big gulp).
However, for the volunteers' wet swallows eight
of 18 channels (three times six subjects) showed
ratios greater than 2:6 in favour of big gulps and
one of 18 in favour of little swallows. Thus, big
gulps in the volunteers produced significantly
less variation in the amplitude of peristalsis.
Finally, as might be expected, the variation of all
swallows was much greater than that of indi-
vidual swallow types.

Discussion
Much importance has been placed upon the
characteristics of the oesophageal pressure wave
in the investigation of function and pathology of
the oesophagus.23 Abnormalities of amplitude are
thought to cause symptoms.23 This study has
shown that the amplitude of oesophageal
peristalsis can be modified by changing the effort
used in swallowing. This finding may affect the
method and interpretation of oesophageal manomo-
metry in the future and may also have therapeutic
implications for the control of oesophageal
symptoms.

The manometric differences between big
gulps and little swallows were apparent for both
wet and dry swallows, as well as for both
volunteers and patients. There was no difference
in magnitude of effect between wet and dry.
While the change was not significant, the patients
increased the amplitude of their swallows more
consistently than did the volunteers. This dif-
fERENCE between patients and volunteers could be
due to posture, to probe size, or to the subject. It
may be easier to modify swallow size while sitting
upright or with a smaller foreign body in the
pharynx. Alternatively, patients, who in this
study were older and all women, may be more
proflcient at changing their swallow size.

There has been one previous report of the effects
of swallowing effort on oesophageal
peristalsis.18 An increase in the amplitude of
oesophageal peristalsis was recorded with
stronger swallows but the change failed to reach
statistical significance. In that study, the effect
of effort was only examined on dry swallows, and
comparisons were made between maximum and
average effort. When we compared baseline
amplitudes (average effort) in our patient group
with those of maximum (big gulp) and minimum
(little swallow) effort, most values (54%) lay
between these two means. Thus, failure to
compare maximum with minimum effort, use of
dry swallows, or chance may explain the dif-
fERENCE between the two studies.

Differences in the oesophageal response to wet
and dry swallows have been attributed to a bolus
effect with wet swallows.18 It could be argued
that in the present study swallowing air with the
more powerful swallows caused a bolus effect
which lead to an increase in the amplitude of
peristalsis. While this may have occurred with
the dry swallows it is unlikely to have done so
with the wet swallows. Previous studies have
shown that larger volumes of water (20 ml) do
not significantly alter the amplitude of contrac-
tions.3 Therefore, unless quite large volumes
of air were swallowed the amplitude of wet swallows

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**Table III** Summary of amplitude data for the patients. Each mean (SD) represents 10 swallows. C1, C2, and C3 refer to
channels 1, 2, and 3.

<table>
<thead>
<tr>
<th>Patients</th>
<th>Little</th>
<th>Big</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C1</td>
<td>C2</td>
</tr>
<tr>
<td>1</td>
<td>15-8</td>
<td>25-6</td>
</tr>
<tr>
<td></td>
<td>(4-9)</td>
<td>(4-3)</td>
</tr>
<tr>
<td>2</td>
<td>12-5</td>
<td>42-4</td>
</tr>
<tr>
<td></td>
<td>(5-0)</td>
<td>(18-1)</td>
</tr>
<tr>
<td>3</td>
<td>35-6</td>
<td>28-2</td>
</tr>
<tr>
<td></td>
<td>(12-7)</td>
<td>(12-3)</td>
</tr>
<tr>
<td>4</td>
<td>119-0</td>
<td>41-6</td>
</tr>
<tr>
<td></td>
<td>(61-3)</td>
<td>(72-3)</td>
</tr>
<tr>
<td>5</td>
<td>63-7</td>
<td>102-4</td>
</tr>
<tr>
<td></td>
<td>(19-1)</td>
<td>(30-1)</td>
</tr>
<tr>
<td>6</td>
<td>24-8</td>
<td>52-3</td>
</tr>
<tr>
<td></td>
<td>(6-3)</td>
<td>(17-1)</td>
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<td>7</td>
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<td>38-5</td>
</tr>
<tr>
<td></td>
<td>(15-2)</td>
<td>(24-8)</td>
</tr>
<tr>
<td>8</td>
<td>29-8</td>
<td>58-6</td>
</tr>
<tr>
<td></td>
<td>(12-1)</td>
<td>(19-8)</td>
</tr>
<tr>
<td>Means</td>
<td>41-7</td>
<td>58-7</td>
</tr>
<tr>
<td>Grand means</td>
<td>56-0</td>
<td></td>
</tr>
</tbody>
</table>

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**Table IV** Mean amplitude (in mmHg) of 10 wet swallows
(5 ml water) in each channel for little swallows, baseline
manometry, and big gulps.

<table>
<thead>
<tr>
<th>Channel</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Little  swallows</td>
<td>41-7</td>
<td>58-7</td>
<td>67-7</td>
</tr>
<tr>
<td>Baseline</td>
<td>43-3</td>
<td>67-5</td>
<td>70-1</td>
</tr>
<tr>
<td>Big gulps</td>
<td>51-7</td>
<td>78-8</td>
<td>88-8</td>
</tr>
</tbody>
</table>
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should not have been affected by air. The subjects were specifically asked to try to avoid swallowing air and after the study all confirmed that they had not been aware of swallowing air with the larger swallows. Furthermore, only one subject noticed an excess of wind after the study (a volunteer in whom the difference in amplitude was the fifth largest of six). To explore this possibility further it would be necessary to measure intestinal gas during and after a study, with and without powerful swallows. It could also be argued that little swallows lead to more ‘double swallows’ and that these may have led to the reduced amplitude in this group. We did not monitor swallowing, but neither subjects nor observers were aware of an excess of double swallows in either group.

The control of oesophageal peristalsis is thought to involve vagal, intramural, and myogenic mechanisms. Furthermore, the amplitude of peristalsis seems to be dependent upon cholinergic activity. If there is no bolus effect, the increase in amplitude shown in this study could have been mediated directly by pharyngo-oesophageal intramural pathways or indirectly by either pharyngeal or cortical stimulation of the vagus. It would make sense for the oesophagus to have warning of how powerfully it needs to contract to ensure clearance with one swallow.

Because of intrasubject variation in the amplitude of peristalsis it is recommended that the amplitude of peristalsis should be estimated from the mean of 10 swallows. Some of this variation may be due to varying the effort employed in swallowing. In our data there was a significant difference in the variation of little swallows and of big gulps for the volunteers’ wet swallows but not, with one exception, for the patients’ swallows. Therefore, we cannot recommend that investigators ask their patients to maximise or minimise their swallowing effort to reduce variation. However, the variation of all swallows was much greater than of little swallows or of big gulps alone, so, it would seem advisable to ask subjects to try to keep the effort of swallowing constant.

There is controversy about the importance of the nutcracker oesophagus. In our study, the mean amplitude of 10 wet swallows in one patient with atypical chest pain increased into the nutcracker range when the patient was asked to increase the force of her swallows. As a group, patients probably find oesophageal intubation more stressful than subjects who volunteer. This added stress may lead to more forceful swallows and spuriously high estimations of amplitude. Thus, high amplitude contractions in some of these patients may be a stress related artefact.

The finding, on further manometry, of normal peristaltic pressure in up to 47% of patients with the nutcracker oesophagus supports the hypothesis of a stress related artefact occurring during the first study.

The most important clinical application of this study is the potential for treating symptoms using biofeedback control of oesophageal peristalsis. If the nutcracker oesophagus and low amplitude peristalsis are important factors in the genesis of chest pain, heartburn and dysphagia, then conscious control of the amplitude of peristalsis should be useful for treatment of these symptoms. It is easy for a subject to observe his own oesophageal contractions, therefore the amplitude of contractions should be amenable to biofeedback control. Further studies designed to explore this treatment model are now warranted.

We thank Dr R Nagle for allowing us to study his patients, Mr D Farrar and Dr R Cockel for loan of manometry equipment. Dr Krys Kelly for statistical advice, and Miss Joanne Worthington for typing the manuscript.

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