Manometric mapping of normal esophagus and definition of the transition zone

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Background: The normal esophagus has not been manometrically mapped. The transition zone between esophageal smooth and skeletal muscles has also not been defined manometrically. Aims: To manometrically map the normal esophagus and to define the transition zone. Methods: Thirty normal adults [23 men; mean age 34.8 (10.4) years] underwent manometry using a water-perfused system. The lower esophageal sphincter (LES) was studied by station pull-through, and esophageal body musculature was evaluated at 1-cm intervals with five wet swallows at each level. The transition zone was identified as an area where the waveforms did not resemble typical skeletal or smooth muscle wave-forms. Results: The basal mid-expiratory LES pressure was 18.7 (7.2) mmHg, and its length was 3.6 (1.2) cm. Based on our findings, we defined the transition zone as an area where either the amplitude of contraction was <10 mmHg or, if the amplitude was 40-50 mmHg, the rate of change of pressure from baseline to peak of the wave was <50 mmHg/s. The lengths of the skeletal, transition and smooth muscle zones were 2.8 (1.2), 4.0 (1.7) and 12.5 (2.7) cm, respectively. The amplitude and dp/dt of contraction and transmission velocity were lowest in the transition zone (p<0.05). Conclusions: We have manometrically mapped the normal esophageal muscle zones; the parameters obtained may be used as reference values. The manometric criteria for the transition zone have also been defined. [Indian J Gastroenterol 1998; 17: 55-57]

Key words: Esophageal motility, esophageal muscle zones

The muscular anatomy of the human esophagus includes smooth and striated muscle.1 About 5% of the upper esophagus is exclusively constituted by striated muscle. The lower two-thirds is made up exclusively of smooth muscle. The intervening portion, the transition zone, is made up of a combination of striated and smooth muscles. This zone is believed to constitute a physiological barrier to smooth transmission of a peristaltic wave from the skeletal to smooth muscle zones. On manometry, the amplitude of contraction in the region of the aortic arch is lower than in the lower esophageal body.2 Humphries and Castell1 and Dodds3 documented a pressure trough which corresponds to the transition zone. However, no criteria were laid down for definition of the transition zone on manometry. Recently, Pehmni et al4 described a mid-esophageal pressure trough, defined by them as amplitude of contraction less than one-third of distal esophageal pressure; this trough probably corresponds to the transition zone.

There are no published data on esophageal manometric mapping. We performed esophageal manometry in healthy volunteers to map the various muscle zones and to define the transition zone.

Methods
Thirty healthy subjects in the age range 18-65 years, who were not on any medication, were studied. Their height and weight were measured, and history of alcohol intake and smoking was recorded. All subjects gave informed valid consent and the study was approved by the institution's ethics committee.

Procedure
Manometry was performed with the patient in the supine position, using a low-compliance water-perfusion system. Data were recorded in an online computer and analyzed using dedicated software (Albyn Medical, Scotland). The catheter was a 4-port tube, each with an internal diameter of 0.8 mm; ports were 5 cm apart, and oriented at 90°. Water was perfused at 0.5 mL/min/port. At this flow rate, the assembly recorded changes in pressure at >200 mmHg per second. The data were recorded at 16 MHz. The catheter was passed transnasally till all the ports were in the stomach; the position was identified by the pattern of respiratory variation.

The lower esophageal sphincter (LES) was assessed by station pull-through technique and relaxation was assessed by giving five 5-mL water swallows. Body motility was studied by withdrawing the catheter at 1-cm intervals and giving five wet swallows at each level. This pull-through was continued till the high-pressure zone of the upper esophageal sphincter was identified in the most proximal port. The mid-expiratory LES pressure was expressed as the average of pressures in the four recording ports with respect to basal gastric pressure. The residual pressure after a swallow was expressed with reference to gastric pressure.

The smooth muscle and skeletal muscle zones were identified using previously established criteria.6 The transition zone was identified as an area where the wave-forms were not typical of skeletal or smooth muscle zones. The
amplitude, duration and rate of change of pressure from baseline to peak (dp/dt) of each contraction wave were analyzed; only transmitted waves, i.e., those with amplitude >30 mmHg were analyzed. At each level, the average of 5 swallows was obtained. Abnormal waves were analyzed in the smooth muscle zones using previously defined criteria.

Since the transition zone was less than 5 cm in length, velocity through it could not be measured using the catheter with ports 5 cm apart. Hence, 8 subjects underwent repeat manometry with an indwelling catheter with ports 2 cm apart. The velocity of transmission was calculated for every 5-cm segment of the esophagus for the smooth and skeletal muscle zones, and for every 2-cm segment in the transition zone.

Statistical analysis
Values are expressed as mean (SD). Parameters in the different zones were compared using Student's t-test for unpaired data.

Results
Thirty subjects (23 men; mean age 34.8 (10.4) years, range 18-65) underwent esophageal manometry. Their height and weight were 159 (9.3) cm and 49.9 (7.8) kg respectively. There were 5 smokers and 6 subjects consumed alcohol.

Manometry parameters
The average intragastric pressure was 13.0 (3.6) mmHg. The LES was situated at a mean distance of 42.8 (2.2) cm from the nares. Its mid-expiratory basal pressure was 18.8 (7.2) mmHg with a relaxation pressure of 1.6 (0.1) mmHg. The average LES length was 3.6 (1.2) cm, with 1.9 (0.4) cm situated intrabdominally.

The total esophageal length was 19.1 (2.2) cm. Based on the manometry parameters within the transition zone (identified as above) we defined it as an area between the smooth and skeletal muscle zones, where either the amplitude of contraction was <40 mmHg or, if the amplitude was between 40 and 50 mmHg, dp/dt was <50 mmHg/s. The lengths of the skeletal, transition and smooth muscle zones were 2.8 (1.2), 4.0 (1.7) and 12.5 (2.7) cm, respectively.

The skeletal muscle zone could not be identified in two subjects because manometric tracing 1 cm distal to the upper esophageal sphincter resembled the transition zone. In the rest, the skeletal muscle zone was at least 1 cm long. Nineteen of 28 subjects had skeletal muscle zone longer than 2 cm. The transition zone could not be defined in two subjects due to resemblance between this zone and the smooth muscle zone tracings. The smooth muscle zone extended for at least 8 cm above the LES in all subjects. Fifteen subjects had smooth muscle zone extending to 14 cm above the LES.

The esophageal body parameters in the different muscle zones are shown in Table 1. The dp/dt of the upstroke of the wave and the amplitude of contraction were least in the transition zone (p=0.0005) as compared to the skeletal and smooth muscle zones. Parameters of LES and body motility were similar in both sexes, and did not change with age of the individual.

The velocity of peristalsis in different muscle zones is shown in Table 2. There was a drop in the velocity as the peristaltic wave was transmitted through the transition zone in all the subjects.

The smooth muscle zone did not reveal any abnormal waves in 5 subjects. Twenty two subjects had at least one wave with amplitude <30 mmHg ('nonsensical waves'); nine subjects had one peristaltic wave with amplitude >180 mmHg. Peristaltic waves with duration >5 s were seen in 3 subjects. None of subjects had waves of amplitude >180 mmHg or duration >5 seconds in the transition or skeletal muscle zones.

Discussion
We have quantified the range of esophageal manometric parameters and lengths of various muscular zones in normal subjects. The LES pressure was 18.7 (7.3) mmHg in the mid-expiratory phase. There was no change in the LES pressure with age or sex. Richter et al. established normal esophageal manometry values in Western subjects. Their mean LES pressure varied with the phase of respiration, and was 15.2 (10.7) mmHg and 24.4 (10.1) mmHg in the end-expiratory and mid-expiratory phases, respectively.

Our subjects had a mean amplitude and duration of

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Table 1: Esophageal body motility parameters

<table>
<thead>
<tr>
<th>Zone</th>
<th>Amplitude (mmHg)</th>
<th>Duration (s)</th>
<th>dp/dt (mmHg/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skeletal</td>
<td>70.4 (11.8)</td>
<td>2.3 (0.9)</td>
<td>100.4 (47.3)</td>
</tr>
<tr>
<td>Transition</td>
<td>37.0 (8.9)*</td>
<td>2.2 (0.5)</td>
<td>27.8 (8.0)*</td>
</tr>
<tr>
<td>Smooth</td>
<td>84.7 (19.3)</td>
<td>3.2 (0.2)</td>
<td>82.8 (19.7)</td>
</tr>
<tr>
<td>3 cm above LES</td>
<td>10.0 (2.5)</td>
<td>3.3 (0.6)</td>
<td>10.3 (46.7)</td>
</tr>
<tr>
<td>8 cm above LES</td>
<td>81.7 (26.1)</td>
<td>3.1 (0.5)</td>
<td>79.1 (25.1)</td>
</tr>
</tbody>
</table>

Values as mean (SD) and range
*p<0.05 as compared to the other zones

Table 2: Velocity of transmission in various esophageal body muscle zones

<table>
<thead>
<tr>
<th>Site</th>
<th>Skeletal to transition zone</th>
<th>Transition to smooth muscle</th>
<th>13 cm to 8 cm above LES</th>
<th>8 cm to 3 cm above LES</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>28</td>
<td>8</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Velocity (cm/s)</td>
<td>2.7 (0.9)</td>
<td>1.4 (0.6)*</td>
<td>2.8 (1.1)*</td>
<td>4.0 (0.7)*</td>
</tr>
<tr>
<td>Values as mean (SD)</td>
<td>*p&lt;0.05</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

Manometric mapping of normal esophagus
contraction of 70.4 (11.6) mmHg and 2.3 (0.9) s respectively in the skeletal muscle zone, and 84.7 (19.3) mmHg and 3.2 (0.5) s in the smooth muscle zone. These values were similar to those documented in studies from the West. The duration of contraction paralleled the amplitude, increasing distally along the esophagus, with maximum pressures recorded 3-4 cm above the LES. There was no difference in the body motility indices with age and sex.

Humphries and Castell demonstrated a trough of pressure in the upper esophagus on esophageal manometry in five normal subjects and associated this area with the transition zone; the amplitude and dp/dt of contraction were 35.0 (6.4) mmHg and 26.6 (4.5) mmHg/s in this zone. The criteria we chose to identify the transition zone were obtained by mapping the esophagus at 1-cm intervals; wave patterns in this zone could not be identified as typical of smooth or skeletal muscles. Our subjects had an exclusively smooth muscle zone for at least 8 cm above the LES, and hence the transition zone should be looked for in an area at least 8 cm above the LES. In an earlier study, at 13 cm above the LES, a mid-esophageal pressure trough could be identified in nine of 34 subjects with normal manometry.

The mean length of the transition zone in the present study was 4.0 (1.7) cm. A similar observation was made by Meyer et al on histological examination of post mortem specimens; the 50:50 point at which the muscle layer appeared half skeletal and half smooth occurred 4.7 (0.6) cm from the upper border of the criopharynx.

Dodds et al demonstrated an area of low pressure on manometry which corresponded to a site of retention of bolus on video-fluoroscopy. Mei Jung et al studied esophageal peristalsis using a computer-simulated model. They showed incomplete clearance of bolus fluid in a region at the level of the aortic arch and suggested that this was due to gradual change in the musculature from striped to smooth. In our study, the velocity of transmission was slowest in the transition zone. The transition zone thus seems to constitute a physiological barrier to transmission of peristaltic waves from the skeletal to smooth muscle zones.

The transition zone could not be demonstrated in two of our subjects due to lack of differentiation of the waves in the three zones. In two other subjects the skeletal muscle zone could not be identified manometrically. Meyer et al could not identify an all-striped muscle zone in 2 of 11 cadavers. It is possible that the subjects in our study had a similar muscular anatomy. Since some individuals may not have an all-striped muscle zone, waves in the proximal esophagus resembling those in the transition zone should be interpreted with care to avoid misinterpretation as abnormal.

Abnormal waves were detected in 22 subjects in the smooth muscle zone; however, they constituted less than 10% of all waves in these subjects.

Thus, we have manometrically mapped the normal esophagus. The values established should provide a reference for future studies in normal and disease states. We have also provided a manometric definition of the transition zone.

References

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