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Localizing the Contractile Deceleration Point (CDP) in Patients with Abnormal Esophageal Pressure Topography

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Abstract

Background—The contractile deceleration point (CDP) is an important landmark for interpreting esophageal pressure topography (EPT) plots. Previous analysis in normal subjects confirmed that the CDP could be localized using an algorithm that found the time during peristalsis at which a maximal length of the distal esophagus was contracting concurrently (tML method). This study aimed to test the tML method for localizing CDP in patients with abnormal motility.

Methods—High resolution manometry studies of 75 patients with normal and disordered peristalsis were analyzed. Two experts, JEP and YX, used the original tangent-intersection method to score CDP coordinates for the first two swallows of each study. Alternative computerized algorithms tested against the expert were: a) the tML method, b & c) the intercept between the leading edge of the 30-mmHg isobaric contour and a line 2.0 cm (or 10% of esophageal length) proximal to the esophagogastric junction (EGJ) at rest, or d) the ‘tML-3cm’ method which added the stipulation that the CDP be within 3 cm of the EGJ.

Results—All tested algorithms were highly correlated with the expert. However, the tML- 3cm method was better in the sense that it eliminated outliers (>1 s discrepancy with the expert) that occurred with the other methods usually attributable to weak distal peristalsis.

Conclusions & Inferences—Optimal automated CDP localization was achieved in both normal and a spectrum of abnormal motility using the tML method with the added stipulation that the CDP be restricted to within the distal 3 cm of the EGJ at rest.

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AUTHOR CONTRIBUTIONS

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COMPETING INTERESTS

No authors have any competing interest.

Keywords

contractile deceleration point; esophageal manometry; esophageal pressure topography; achalasia; distal esophageal spasm

INTRODUCTION

The contractile deceleration point (CDP) is a landmark in esophageal pressure topography (EPT) plots indicative of the transition from peristalsis to ampullary emptying (1). Visually, the CDP is localized as an inflexion point on the 30-mmHg isobaric contour where propagation velocity slows in the distal esophagus. Accurate identification of the CDP is crucial for determining the distal latency (DL), a measure of peristaltic propagation defined as the interval between upper sphincter relaxation and the CDP (2). In the Chicago Classification of esophageal motility disorders, premature contractions (a defining criterion for distal esophageal spasm and spastic achalasia) are defined by a DL of less than 4.5 s (3).

Previous studies have shown that the CDP can be identified by intuitive visualization or by manually fitting tangential lines to the initial and terminal portions of the 30-mmHg isobaric contour and noting the intersection of the lines (1). These methods can be subjective. We recently demonstrated an alternative method for localizing the CDP based on the principle that it occurs at the time that the maximal length of the distal esophagus is contracting concurrently (4). Visualizing the 30-mmHg isobaric contour surrounding the distal contraction, the leading edge slows before the trailing edge; hence, the length of the vertical intercept between the two is maximized at the CDP. We tested this algorithm in control subjects and found good correlation with manual methods for localizing the CDP. Since the methodology is dependent on finding the time of maximal length of concurrent contraction, we abbreviate it the tML method (4). However, the tML method has not been tested in patients with abnormal peristalsis, circumstances in which the morphology of EPT plots can be highly atypical. Thus, the aim of this study was to test the tML method for localizing CDP in patients with esophageal motor disorders.

METHODS

Subjects

EPT studies of 75 patients (27 males, mean age 55 years, range 23-86 years) with an array of normal and disordered peristalsis were analyzed. Patients with absent peristalsis or prior gastric or esophageal surgery were excluded. Patients were selected with the criterion that they exhibited at least two test swallows with abnormal contractions by Chicago Classification criteria (3). The study protocol was approved by the Northwestern University Institutional Review Board and informed consent was obtained from each subject.

High resolution manometry protocol

High resolution manometry studies were done with a 4.2 mm outer diameter solid-state assembly with 36 circumferential sensors spaced at 1-cm intervals (Given Imaging, Los Angeles, CA). Before recording, transducers were calibrated at 0 and 300 mmHg using externally applied pressure. Studies were done in a supine position after at least a 6-hr fast. The manometry assembly was placed transnasally and positioned to record from the hypopharynx to the stomach. The catheter was fixed in place by taping it to the nose. The manometric protocol included ten 5-ml water swallows.

EPT data analysis protocol

The CDP coordinates for each patient were determined manually by two experts, JEP and YX, using the original tangent-intersection method for the first two swallows (Figure 1). Thereafter, data from the same test swallows were exported from ManoView™ (Given Imaging, Los Angeles, CA) to MATLAB™ (The MathWorks Inc., Natick, MA) to test alternative algorithms for localizing the CDP. Algorithms tested against the expert were: 1) the tML method, 2) the intercept between the leading edge of the 30-mmHg isobaric contour and a line 2.0 cm proximal to the esophagogastric junction (EGJ) at rest ('fixed length intercept 2.0 cm') method, 'fixed length intercept 10% esophageal length (EL)' method, and 3) the tML method with the added stipulation that the CDP must be within 3 cm of the EGJ at rest ('tML-3cm') method.

CDP localization with tML method

A spatial pressure variation plot was calculated to identify the positions of proximal though (P) and distal though (D) (if present) (4, 5) (Figure 1). If point 'D' could not be localized, the distal limit was taken as the proximal margin of the EGJ after the termination of the contraction. A fixed threshold of 30 mmHg was then used to control the search process between the P and D both in time (s) and length (cm) to find the maximal contracting segment length. Finally, the CDP coordinates were determined as the intercept between the leading edge of the 30-mmHg isobaric contour and the time of maximal contracting segment length.

Statistical analysis

Data for CDP time coordinates were expressed as mean ($\pm$ SD) and range or median, 5th and 95th percentiles. Wilcoxon rank sum test was used to compare the CDP time coordinates obtained from different methods. Pearson's correlation coefficient was also calculated to assess the correlation between the expert and alternative CDP calculations.

RESULTS

A comparison of the CDP time coordinates obtained with each method for all 150 test swallows (75 patients) is shown in Table 1. All methods tested were highly correlated with the expert value ($P < 0.001$). In terms of outliers, the tML method had 10 swallows exhibiting a discrepancy of greater than 1.0 s (range 1.0-3.9 s) in CDP timing compared to the expert (see Table 1). These were attributed to repetitive contractions in the distal esophagus or to discrepancies in localization of the superior margin of the LES. Restricting the localization of potential CDP coordinates to the 3 cm segment proximal to the EGJ (tML-3cm) reduced the mean discrepancy between methods from 0.16 s to 0.09 s and in swallows with a localization error > 1.0 s to 0.2 s.

An example of an EPT plot in which the tML-3cm method improved significantly on the tML method is illustrated in Figure 2 wherein there is a relatively hypotensive peristaltic contraction in proximity to the EGJ, the region in which peristalsis is usually of greatest amplitude. Consequently, the tML method localized the CDP to the second contractile segment (S2) whereas the tML-3cm method in essence mandates that it be within the third contractile segment (S3).

DISCUSSION

A series of recent observations have attached increasing physiological and pathophysiological significance to the CDP on EPT plots. A study utilizing 3D-HRM concluded that the CDP demarcated the transition from the tubular esophagus to the effaced

LES (6). Another recent study suggested that the latency of the distal esophageal contraction, defined by the CDP, was a more relevant criterion for spasm than contractile velocity (7). Yet another recent study demonstrated the feasibility of localizing the CDP based on the principle that it occurs at the time that the maximal length of the distal esophagus was contracting concurrently because the leading edge of the contraction slows at the CDP before the trailing edge slows, still being localized in the peristaltic segment (4). The major finding of this study was that accurate automated localization of the CDP was achieved using the time of maximal length (tML) method with the added stipulation that potential CDP coordinates be restricted to within the distal 3 cm of the EGJ at rest.

The original method used to localize the CDP was by pattern recognition or by manually fitting tangential lines to the initial and terminal portions of the 30-mmHg isobaric contour on an EPT plots (1). These methods are subjective, with their accuracy somewhat dependent on the user's experience. The algorithm proposed from this analysis uses the intercept between the leading edge of the 30-mmHg isobaric contour and the time at which a maximal length of the third contractile segment (8) is concurrently contracting (tML-3cm method) as an alternative. The rationale for this is that because the leading edge of peristalsis terminates before the trailing edge, the maximal length of esophagus will be contracting concurrently when the leading edge slows, eg the CDP. Key to the reproducibility of this calculation is specifying the pressure threshold and spatial limits to be considered in the calculation. Selection of the 30-mmHg isobaric contour as a pressure threshold is arbitrary based on the precedent that this threshold has been used frequently as a criterion for temporal landmarks of esophageal contractility (3). Selection of spatial limits for the CDP is more difficult, especially when faced with the extreme variability in EPT pressure morphology encountered in clinical populations. Whereas the tML method sufficed in normal subjects, this tended to be confounded in patients with hypotensive distal contractions as illustrated in Figure 2. Hence, the added criterion is that the CDP must be localized within 3 cm of the upper margin of the EGJ at rest. This necessarily confines it to S3 which is conceptually where it should occur (6).

In conclusion, we developed and tested an automated analysis algorithm suitable for localizing the CDP in clinical EPT studies characterized by a spectrum of contractile abnormalities. The algorithm was based on finding the time at which the maximal length of esophagus is contracting concurrently and stipulated that the CDP must localize within three cm of the EGJ. We speculate that this methodology will both help standardize and reduce the variability among observers in diagnoses using the Chicago Classification of EPT.

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Abbreviations

(CDP)	contractile deceleration point
(EPT)	esophageal pressure topography
(EGJ)	esophago-gastric junction
(DL)	distal latency
(tML)	time of maximal length

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Figure 1.

Methodology for localization of the contractile deceleration point (CDP) position with the tML method. The upper left panel illustrates a typical EPT plot with the 30-mmHg isobaric contour identified by the white line. The corresponding spatial pressure variation plot to the right depicts the greatest contractile pressure at each axial position along the esophagus. This plot is used for localization of proximal (P) and distal (D) pressure troughs (red dotted lines) between which the CDP must be localized. The dotted vertical black lines show the length of the contracting segment, with the solid line depicting the maxima of this function, thereby localizing the CDP (pink circle) with the tML method. For comparison, the CDP is also identified manually by fitting 2 tangential lines (white dotted lines in left panel) to the initial and terminal portions of the 30-mmHg isobaric contours and noting the intersection of the lines. The lower panel illustrates vertical contractile length (VCL) as a function of time for the data in upper left panel.

Figure 2.

An example of how the tML-3cm method improves upon the tML method in an EPT plot characterized by relatively hypotensive peristalsis proximal to the EGJ. The panel to the left depicts the swallow in Manoview™ with the expert localization of the CDP (red dot) by the tangent intercept method. The panel to the right shows the corresponding MATLAB™ plot with the tML method of localization (6.1s) and the tML- 3cm method (10.1s). Panel C illustrates vertical contractile length (VCL) as a function of time for the data in Panel B.

A comparison of CDP times among experts and alternative algorithms developed in MATLAB™ for 75 patients. Models tested were time of maximal contraction length (tML), the fixed length intercept (FLI) between the 30-mmHg isobaric contour and a horizontal line 2 cm proximal to the EGJ at rest, the FLI using a line 10% of the total esophageal length (EL) proximal to the EGJ at rest, and the tML method with the added stipulation that the CDP localize within 3 cm of the EGJ at rest. The number of swallows with >1s discrepancy from the expert and each tested method were least with the tML-3cm algorithm.

Table 1

	CDP localization method					
	Expert 1	Expert 2	tML	FLI 2.0 cm	FLI 10% EL	tML-3cm
Mean ± SD (s)	7.2±1.4	7.3±1.4	7.1±1.4	7.2±1.3	7.2±1.4	7.2±1.4
Min, max (s)	3.1, 12.3	3.2, 12.0	3.0, 11.7	3.0, 11.2	3.0, 11.2	3.0, 11.7
Swallows with >1s discrepancy from expert value (n)	---	8	10	19	18	0
Correlation with expert interpretation	---	R=0.86 P<0.001	R=0.91 P<0.001	R=0.87 P<0.001	R=0.86 P<0.001	R=0.96 P<0.001