Determination of esophageal probe insertion length based on standing and sitting height

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MEKJAVIĆ, IGOR B., AND MONIKA E. REMPEL. *Determination of esophageal probe insertion length based on standing and sitting height.* J. Appl. Physiol. 69(1): 376–379, 1990.—The present study derives simple formulas for the prediction of optimal insertion length of an esophageal temperature-sensitive probe from the measurements of either standing or sitting height. The formulas assume that the optimal site for an esophageal temperature probe is in the region of the esophagus bounded by the left ventricle and aorta, corresponding to the level of the eighth and ninth thoracic vertebrae (T_8 and T_9, respectively). An esophageal probe was constructed of polyethylene tubing containing 1-cm segments of alternating radiopaque and nonradiopaque tubing in the distal 20 cm of the probe. The probe was inserted through a nostril into the esophagus of 20 subjects (12 males and 8 females) of various heights (range 163–194.6 cm) and weights (range 52.2–100.8 kg), and lateral chest radiograms were obtained for determination of the insertion length of the probe (L) required to situate the probe in the retrocardiac esophagus. Analysis of the radiograms demonstrated that, at the level of the intervertebral disc between T_8 and T_9, the probe was below the tracheal bifurcation and close to the left ventricle. The distance from the nasal flare to this level showed a good correlation with the subject's stretched stature ($r^2 = 0.71$) and sitting height ($r^2 = 0.86$). The following equations were derived to predict the placement of the esophageal probe at the T_8/T_9 level based on standing height: L (cm) = 0.228 × (standing height) − 0.194, and sitting height: L (cm) = 0.479 × (sitting height) − 4.44.

core temperature; esophageal temperature; esophageal balloons; temperature regulation; hypothermia; hyperthermia

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ESOPHAGEAL PROBES are regularly used in human physiological experimentation for the assessment of core temperature with either a thermocouple or thermistor contained within the tip of the probe and for the determination of intrapulmonary pressure with an esophageal balloon. The accuracy of positioning of the latter may not be as critical as the placement of the temperature-sensitive probe. Thus esophageal balloons are usually inserted until a positive pressure is recorded in the balloon, indicating that the balloon has entered the antrum of the stomach, and subsequently retracted until a negative pressure is obtained. In contrast, in thermal physiological studies, esophageal temperature should indicate the temperature of the myocardium, and thus it should ideally be positioned at the level of the pericardial sac.

Although radiographic assessment of probe position is the most definitive method, it is often inconvenient to conduct such verification before an experiment, and in addition the equipment required is not often available in physiological laboratories. Furthermore, this method is of limited value when experimental protocols involve repeated trials with each subject, because the maximum allowable dose of radiation may soon be exceeded. A preferred method is to monitor the electrocardiographic (ECG) trace by using the esophageal probe as a positive electrode (7) and terminating further insertion once the P wave becomes biphasic in nature (1). This may be further complemented by inserting an accelerometer in the probe tip, enabling the simultaneous monitoring of heart sounds during penetration of the probe (6) and positioning the probe 12 cm deeper from the best heart sounds, as this corresponds to the thermally stable region of the myocardium (4). Probes monitoring ECG require that a metal surface be exposed, necessitating enhanced safeguards in the signal conditioning circuitry to eliminate the hazard of leakage current.

A commonly used procedure for the placement of temperature-sensitive esophageal probes is to monitor the temperature during insertion and to ensure that the probe is not positioned in the region of lowest temperature (12, 13). This may, however, be rather time consuming, because it is necessary to allow the temperature to stabilize, especially if penetration was aided by the subject drinking water at a temperature substantially different from that of the core region. Thermal mapping of the esophagus conducted by Whitby and Dunkin (14) revealed substantial longitudinal variations in esophageal temperature, with two cold spots corresponding to regions on average 10 and 13 cm below the corniculate cartilage. Their efforts to correlate these cold spots with patient height or distance from the corniculate cartilage to the xiphisternum failed; thus their recommendation was to place the probe 20 cm beyond the corniculate cartilage to avoid the cold spots and to have the measuring tip in the thermally stable lower third of the esophagus.

However, as retrocardiac esophageal temperature is considered indicative of cardiac temperature (3), the optimal site for the placement of a probe for core temperature measurement would be the region corresponding to the level of the eighth and ninth thoracic vertebrae, where the esophagus is in close proximity to the lower border of the left atrium (5) and the upper border of the left ventricle (10). The purpose of the present study was, therefore, to assess whether a simple relationship could be derived between the subject's standing or sitting height and the insertion length of the probe (L) so that it is positioned at the level of the left ventricle.

METHODS

Twenty subjects (12 males and 8 females), whose physical data are given in Table 1, participated in the present study. The subjects ranged in age from 18.9 to 34.9 yr [mean 25.4 ± 3.9 (SE) yr], in height from 163.0 to 194.6 cm (176.6 ± 9.5 cm), and in weight from 52.5 to 100.8 kg (69.8 ± 13.2 kg). The test procedure for the present study was approved by the Ethics Review Committee of Simon Fraser University, and it was thoroughly explained to each subject.

Immediately before the radiography, a specially designed and constructed probe was inserted through a nostril to a uniform depth of 50 cm beyond the nasal flare. The esophageal probe was constructed of a polyethylene tube (3.24 mm OD, 2.15 mm ID). Within this tubing, 20 segments of radiopaque and nonradiopaque tubing (1.57 mm OD, 1.14 mm ID), each segment 1 cm long, were positioned alternately at the distal end of the probe. The lateral chest radiograms were obtained with the subjects inspiring to near maximum. The radiograms were examined to determine the level of the tracheal bifurcation and the upper and lower borders of the inferior mediastinum for each subject. Finally, because the level of the eighth and ninth thoracic vertebrae (T_8 and T_9, respectively) corresponds to the level of the ventricles, considered to be the optimal position of the probe, the distance of the probe to T_8/T_9 was determined with the aid of the radiopaque markers and regressed against the subject's standing and sitting height.

TABLE 1. *Subjects' physical characteristics*

Subj No.	Age, yr	Weight, kg	Stretched Stature, cm	Sitting Height, cm
		Females		
1	21.3	55.2	168.9	86.4
2	28.7	65.0	168.0	90.8
3	20.5	57.5	166.4	87.7
4	23.6	53.6	168.9	89.5
5	24.5	62.6	174.6	90.0
6	24.6	54.2	163.0	84.8
7	24.8	52.5	167.4	86.3
8	24.8	59.7	163.3	86.8
		Males		
9	24.4	78.0	184.3	97.7
10	26.7	75.6	183.4	96.8
11	34.9	84.3	186.6	95.9
12	18.9	64.5	175.7	92.3
13	22.8	100.8	194.6	97.3
14	28.1	83.7	193.4	103.7
15	22.6	72.4	174.9	93.6
16	27.9	88.8	184.8	98.4
17	22.4	75.4	184.4	96.9
18	30.2	76.2	180.7	93.9
19	24.5	66.8	171.9	93.6
20	31.7	69.7	176.6	94.2
Group mean	25.4	69.8	176.6	92.8
±SD	3.9	13.2	9.5	5.0
Range	16.0	48.3	31.6	18.9
Minimum	18.9	52.5	163.0	84.8
Maximum	34.9	100.8	194.6	103.7

TABLE 2. *Levels of tracheal bifurcation, borders of mediastinum, and length of esophageal probe from nasal flare to intervertebral disc between T_8 and T_9*

Subj No.	Tracheal Bifurcation	Borders of Inferior Mediastinum		Probe Length to T_8/T_9, cm
		Upper	Lower	
		Females		
1	T_6	T_7	T_{10}	35.1
2	T_6/T_7	T_6	T_{10}	38.6
3	T_6	T_6	T_{11}	39.1
4	T_7/T_8	T_5	T_{11}	38.1
5	T_7	T_5	T_{10}	40.1
6	T_7	T_6	T_{11}	35.1
7	T_6/T_7	T_5	T_{11}	36.5
8	T_5	T_6	T_{11}	37.5
		Males		
9	T_6	T_6	T_{11}	42.2
10	T_5	T_6	T_{11}	43.2
11	T_7	T_7	T_{12}	41.2
12	T_6	T_6	T_{11}	39.1
13	T_5/T_6	T_6	T_{11}	42.7
14	T_7	T_7	T_{11}	43.7
15	T_6	T_5	T_{10}	41.2
16	T_6	T_6	T_{11}	42.7
17	T_5/T_6	T_6	T_{11}	41.7
18	T_5/T_6	T_6	T_{11}	40.1
19	T_6	T_6	T_{11}	41.7
20	T_7	T_7	T_{11}	40.1

RESULTS

With the aid of the radiograms, the position of the tracheal bifurcation and the upper and lower borders of the inferior mediastinum were determined relative to the vertebral column; thus the positions of these anatomic structures are given as vertebral numbers in Table 2. As evidenced from Table 2, the level of the tracheal bifurcation varied from T_5 to T_8 in the present subject group. Similarly, a range was observed for the borders of the inferior mediastinum. Thus the upper border varied between T_5 and T_7, and the lower border varied between T_{10} and T_{11}.

To position the esophageal probe for measurement of core temperature, the region of the inferior mediastinum corresponding to the intervertebral disk between T_8 and T_9 appeared to be the optimal location. It corresponded to the level of the left ventricle, and it was sufficiently distant from the tracheal bifurcation that temperature recordings from this site would be less affected by ventilation. Table 2 indicates the distance from the nasal flare to T_8/T_9 for each subject. A subsequent correlation of both standing and sitting height with L to the level of T_8/T_9, depicted in Fig. 1, indicates a good correlation for both of these variables, with the correlation being much higher for the latter.

The derived regression equations, which allow the

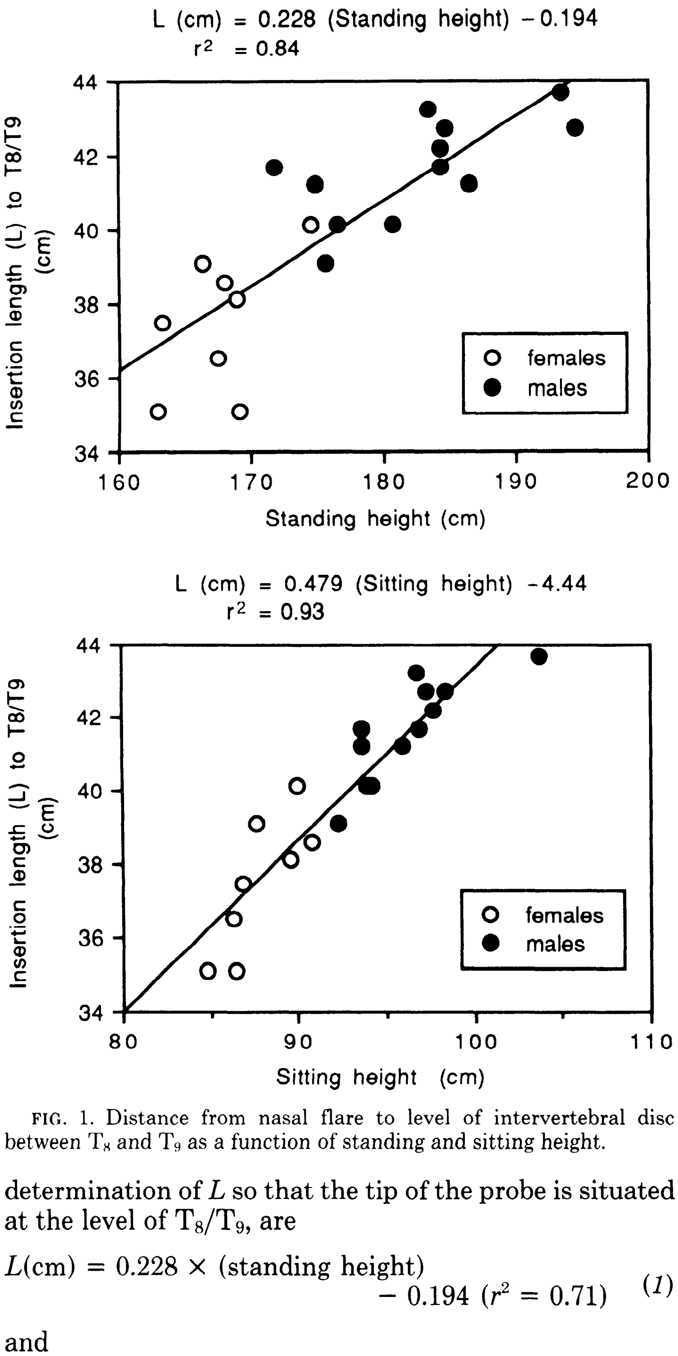

FIG. 1. Distance from nasal flare to level of intervertebral disc between T_8 and T_9 as a function of standing and sitting height.

determination of L so that the tip of the probe is situated at the level of T_8/T_9, are

$$L(\text{cm}) = 0.228 \times (\text{standing height}) - 0.194 \ (r^2 = 0.71) \quad (1)$$

and

$$L(\text{cm}) = 0.479 \times (\text{sitting height}) - 4.44 \ (r^2 = 0.86) \quad (2)$$

DISCUSSION

The results of the present study indicate that stretched stature and sitting height may be used to calculate the optimal L of a temperature-sensitive esophageal probe. Standardization of probe placement is essential in thermal physiological studies because the temperature gradients are reportedly quite substantial in the esophagus (2, 9). Furthermore, under conditions of either dynamic cooling or heating, the temperature response time may vary at different levels of the esophagus (2). Consequently, comparison of results from different studies becomes difficult if L is not identical. The lack of more stringent standardization of probe placement to date appears to result from the complexity of the available techniques for determination of probe placement. The equations derived in the present study offer a simple but accurate approximation of L. However, as with any new technique, knowledge of its limitations is perhaps more critical than is knowledge of only its benefits. Thus the following discussion focuses on several issues that should be taken into consideration when adopting the proposed anthropometrically derived equations for predicting L.

The position of the myocardium with respect to T_8/T_9 may vary substantially more among individuals than is evident in the present subject population. In obese individuals, there will be a tendency for a left axis shift of the myocardium, whereas tall individuals have a tendency for a right axis shift. This variation in myocardial position may also explain the variation reported for the upper and lower borders of the inferior mediastinum presented in Table 2.

Analysis of the radiograms confirmed the findings of other studies (1, 5, 7) that the range between T_5 and T_{10} is likely to offer a thermally stable region, as it was bounded by the myocardium ventrally and by the aorta dorsolaterally. The esophagus is close to the trachea and bronchii at the upper border of the inferior mediastinum, which may lead to cooling of this region (8, 9, 11), especially during high ventilation rates (2). Thus, in this region, the measured temperature may not necessarily be indicative of the myocardial or blood temperature (3). The esophagus is closest to the myocardium at approximately T_8 (5). The choice of T_8/T_9 as the optimal site for a temperature-sensitive esophageal probe was therefore dictated by its distance from the major conducting airways and its proximity to the left ventricle and aorta. Despite the upward shift of the pericardial sac and diaphragm that occurs during expiration, the level of T_8/T_9 retains its advantage as a site distal to the tracheal bifurcation and close to the left ventricle and aorta.

Because the present regression equations are based on the location of the probe with respect to the vertebrae, the effect of gravitational loading on the intervertebral disks may give rise to some error of estimation. The present measurements were always made during a 4-hr period before noon; thus the compression of the intervertebral discs would have been minimal. The regression equation derived for standing height agrees with the observations of Wenger and Roberts (12), who verified radiographically that L equal to 25% of the subject's standing height would correspond to a region of local maximum temperature situated posterior to the lower border of the left atrium.

A major cause for concern is the possibility of the probe bending or looping in the esophagus. Of the 20 subjects tested in the present study, only one subject had the probe loop at T_{10}. In connection with this, it should be noted that the probe used was thin and extremely compliant and in all probability more prone to bending or looping than most commercially available esophageal probes, which are usually thicker and stiffer. During the initial insertion of the probe, the subjects were requested to drink water through a straw to minimize the possibility of the gag reflex, to avoid the probe entering the trachea, and also to ease the swallowing of the probe. Once the probe had been inserted three-quarters of its length, some subjects did not need to sip water to aid penetration. However, with more compliant probes, such as the one used in the present study, the action of swallowing water may actually prevent any looping.

In summary, the present study has derived regression equations, based on radiographic analysis and anthropometric measurements, to position an esophageal probe at the T_8/T_9 level. A comparison of the coefficients of regression suggests that greater accuracy is possible by utilizing the sitting, as opposed to the standing, height in the determination of L.

The authors thank Drs. E. A. Osbery and S. B. Young for their assistance in the analysis of the radiograms and the technical staff of Brooke Radiology Associates (Burnaby, British Columbia, Canada) for their help and cooperation.

This work was supported by the Natural Sciences and Engineering Research Council (NSERC) of Canada. M. E. Rempel was recipient of a NSERC undergraduate scholarship.

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Received 24 March 1989; accepted in final form 15 February 1990.

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