Clinical Location of the Fourth and Fifth Intercostal Spaces as a
Percent of the Length of the Sternum

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ABSTRACT

Objectives

To verify accurate placement of the precordial ECG leads by identifying the 4th and 5th intercostal spaces as a function of the length of the sternum. This should decrease the percentage of lead misplacement leading to misdiagnoses.

Methods

The population consisted of patients, and healthy volunteers. The proposed method compared palpation of the 4th and 5th intercostal spaces to a percentile of the sternal length. Location of the 4th and 5th intercostal space using a simple device was evaluated to assist in proper placement of the precordial leads to obtain accurate diagnosis.

Results

The location of the 4th and 5th intercostal space is related to the length of the sternum. It is 77% of the sternal length that measures 15cm for the 4th intercostal space. The position of the V1 and V2 electrodes decreases to 57% when the sternal length is 26cm. Similar data was obtained to locate the 5th intercostal space with proper position of V4-V6 electrodes. Tables are provided to facilitate this process. An instrument was designed to measure the 4th and 5th intercostal space as a function of the sternal length.

Conclusions

The location of the 4th and 5th intercostal space is identified based on the length of the sternum.

Keywords

Sternal Notch, Xiphoid Process, 4th and 5th Intercostal spaces, Electrode placement

The standardization of precordial leads was published in 1938 and has been consistently observed since then.¹ Leads V1 and V2 are placed in the 4th intercostal space to the right and left of the sternum respectively and V4- V6 are located in the 5th intercostal space. The epidemic of obesity has markedly increased the difficulty in locating the precise positions of the precordial leads.² It has been reported that the proper precordial lead positions by trained ECG technicians was identified in only 40-50% of men and in 15-20% of women. ³

Several approaches have been suggested to increase the accuracy of precordial lead placement. One approach advocates placing one's hand up against the base of the neck to identify the 2nd interspace⁴ and another uses a precordial lead grid.⁵ More recently, an electrode locator has been proposed to determine the correct precordial lead placement.⁶ None of these approaches have been widely adopted and the traditional approach of attempting to feel the 4th and 5th interspaces by palpitation of the chest wall is the predominant method to localize the precordial leads.

The present study provides data to indicate that the proper ECG precordial lead positions can be determined from the length of the sternum measured from the sternal notch to the tip of the xiphoid process. (SN-XP) In a recent report from our center, the location of the 4th interspace was measured in 55 adults by CT images. ⁷ The sternal notch to the fourth interspace was found to be a mean of 67% of the length of the sternal notch to the xiphoid process with an overall correlation of $r=0.600$ ($p<.001$). There is a trend to a higher percent of the distance from the sternal notch to the 4th and the 5th intercostal spaces when there is a shorter sternal length (Tables 1 and 2). The

length of the sternum can be readily measured even in obese individuals. If there is a concern of the precise location of the end of the xiphoid process, a flat pillow can be placed below the patient's back at the level of the xiphoid process to raise the sternum to assist in locating this point. Although the relation of the 4th and 5th interspaces relative to sternum has been documented by CT scan⁷ it should be confirmed by clinical measurement in patients. Therefore, this study was undertaken.

Methods

The study was approved by the Human Subjects Committee. All patients signed an informed consent. A trained ECG technician (PB) and a cardiologist (FM) blindly performed the measurements on 13 adult volunteers, as well as on 18 patients (Table 1).

The first measurement consisted of the technician determining the distance from the sternal notch to the xiphoid process. The location of the 4th intercostal space was determined by palpation. When this was located a removable marker was placed on the sternum. The distance from the sternal notch to this point was measured and the percentage of the distance from the sternal notch to the 4th intercostal space relative to the length of sternum was calculated. The physician then independently repeated this process without knowledge of the technicians' data.

If the measurement of the sternal length or the distance of the sternal notch to the 4th intercostal space was different by ≥ 2 cm between the investigators, the measurement was made jointly and the final values were determined by consensus.

All statistical calculations were done using SPSS¹¹. Reliability was assessed using intraclass correlation. This statistic quantifies the agreement between the technician and the cardiologist in this study. The intraclass correlation was 0.90 initially and 0.94 when significant disparities were identified and those patients re-measured. External validity was assessed by calculating the relationship clinically between distance of the 4th intercostal space distance to the sternal notch and the length of the sternum measured as distance from the xiphoid process to the sternal notch. These data were compared to the same relationship obtained in the previous study in which measurements were made by CT scan.

Results

The data from the CT study⁷ were modified by adding half the width of the 4th intercostal space to the distance from the sternal notch to the 4th intercostal space to correspond to the procedure used clinically. The relationship between these distances is plotted in Figure 1 and the predicted values are listed in the second column of Table 1. The linear function depicted in the caption of Figure 1 can be used to predict the distance from the sternal notch to the 4th intercostal space. As can be seen from column 4 and column 5 of Table 1, the percentage of the distance from the sternal notch to the xiphoid process relative to the distance from the sternal notch to the 4th intercostal space decreases as the SN to XP distance increases, such that a single percentage does not represent the relationship between the two distances. This also occurs with the raw data implying that a single parameter proportional model with just "percentage" is probably not accurate. A two parameter

linear model with a proportional component and an additional constant obtained. That is the model in the caption of Figure 1.

The relation of the distance from the sternal notch to the middle of the 4th and 5th interspaces from the clinical data is shown in Figure 2 and in Tables 1 and 2. Linear models for those relationships are also shown in the caption of Figure 2 and predicted values in Tables 1 and 2. The mean distance from the sternal notch to the middle of the 4th interspace was 65% of the length of the sternum in patients with a sternal length of 20cm and a similar measurement for the 5th interspace was 78%. The 4th interspace is the correct location of V1 and V2 electrodes and the 5th interspace identifies the correct location of V4-V6.

Discussion

Electrocardiology is a standard method to determine the presence of ischemic heart disease as well as to suspect abnormalities of the right and left ventricles. Additionally, recording of precordial electrocardiograms can suggest the presence of atrial enlargement as well as right and left ventricular hypotrophy. Anterior myocardial infarction can be suspected by the presence of Q waves in the anterior precordial leads or by poor progression of the height of the QRS complexes across the precordium.⁸ This diagnosis may be incorrect if the precordial leads are improperly placed.^{9,10} The proposed method in this study can accurately locate the precordial ECG positions as a function of the sternal length. Facilitation of the location of the V1 and V2 electrode placement using a simple device (Figures 1-4) can facilitate the proper position of the V1 and V2 electrodes to enhance the diagnostic value of the ECG. As noted in Tables 1 and 2, the location of the V1 and V2 electrodes is a function of the length of the sternum. The

correct location of the V1 and V2 electrodes are a smaller percent of the total sternal length with increasing length of the sternum. Tables 1 and 2 are adjusted for this offset and the predicted values can be used as a table to determine the 4th and 5th intercostal distances from the sternal notch.

Conclusion

An approach to the location of the 4th and 5th intercostal spaces is proposed based on a linear function of the length of the sternum.

The increased amount of soft tissue on obese individuals can make finding the 4th intercostal space difficult. Our approach using the above method should be particularly useful in obese individuals.

References

1. Joint recommendations of the American Heart Association and Cardiac Society of Great Britain and Ireland: Standardization of precordial leads. American Heart Journal 1938;15:107-108
2. García-Niebla J, Llontop-García P, Valle-Racero JI, et al. Technical mistakes during the acquisition of the electrocardiogram. Annals of Non Invasive Electrocardiology 2009;14:389-403
3. Wenger W, Kligfield P. Variability of precordial electrode placement during routine electrocardiography. Journal of Electrocardiology 1996;29:179-184
4. Lehmann MH, Katona AM. Proposed bedside maneuver to facilitate accurate anatomic orientation for correct positioning of ECG precordial leads in V1 and V2: A pilot study. The Journal of Emergency Medicine 2012;43:584-592
5. Kerwin AJ, Mclean R, Tegelaar H. A method for the accurate placement of chest electrodes in the taking of serial electrocardiographic tracings. Canadian Medical Association Journal 1960;82:258-261
6. Rautaharju PM, Wolf HK, Eiffler WJ, et al. A simple procedure for positioning precordial ECG and VCG Electrode using an electrode locator. Journal of Electrocardiology 1976; 9:35-40
7. Day K, Oliva I, Krupinski E, Marcus F, et al. Identification of the 4th intercostal space using sternal notch to xiphoid length for accurate electrocardiogram lead placement. Journal of Electrocardiology 2015; 48: 1058-1061
8. Zema MJ, Luminais SK, Chiaramida S, et al. Electrocardiographic poor R wave progression. III the normal variant. Journal of Electrocardiology 1980;13:135-142

9. Ilg KJ, Lehmann MH. Importance of recognizing pseudo-septal infarction due to electrocardiographic lead misplacement. American Journal of Medicine 2012;125:23-27
10. Bond RR, Finlay DD, Nugent CD, et al. The effects of electrode misplacement on clinicians' interpretation of the standard 12-lead electrocardiogram. European Journal of Internal Medicine 2012;23:610-615
11. IBM Corp. Released 2015. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp.

Figure 1. CT measurement of the 4th IC

$$\hat{Y} = 5.615 + 0.385(X), r = 0.629$$

The solid line represents the line of best fit, or regression line, for clinically predicting the distance to the 4th intercostal space using the distance between the sternal notch and xiphoid process by CT scan. It is expressed mathematically by the expression above, where "X" is the distance between the sternal notch and xiphoid process, " $\hat{Y}$ " is the predicted distance from the sternal notch to the 4th intercostal space, and "r" is the correlation between these two distances.

Figure 2 Clinical measurement of the 4th and 5th IC

The (solid) lines of best fit are represented by the linear functions below:

$$4^{\text{th}} \text{ IC: } \hat{Y} = 7.761 + 0.269(X), r=0.426$$

$$5^{\text{th}} \text{ IC: } \hat{Y} = 7.859 + 0.394(X), r=0.573$$

The dashed lines represent the 95% confidence bands around the lines of best fit by clinical measurement.

An example is provided in the diagram. If the length of the sternum measured from the sternal notch to the xiphoid process is 21.5cm, the distance from the sternal notch to the 4th IC space is 13.5cm (lower part of the graph) while the distance from the sternal notch to the 5th IC space is 16.3cm. (Data from figures 5 & 6)

Figure 3

This photo shows the measuring device on the chest of a man with the upper bar placed at the sternal notch and the lower bar at the tip of the xiphoid process.

Figure 4

A photo of the measuring device consisting of a smaller plastic tube inserted in a larger diameter tube. When the end of the device with the larger diameter tubing is placed at the sternal notch (left bar) and the opposite end with the smaller diameter tubing is placed at the xiphoid, the length of the sternum is shown as a number in cm. Adjacent to this number is the distance from the sternal notch to the 4th intercostal space and separate numerical values are present for the 5th intercostal space. (See figures 5 & 6) These data are calculated based on the percent of the length of the sternum.

Figure 5

A photo of the side of the measuring device showing the length of the sternum in cm. (upper row of numbers) The adjacent numbers on the smaller tube show the distance to the 4th intercostal space in cm, as computed from a percentage of the sternal length.

Figure 6

A photo of the other side of the measuring device showing the length of the sternum in cm. (lower row of numbers) The adjacent numbers on the smaller tube show the distance to the 5th intercostal space in cm, as computed from a percentage of the sternal length.

Table 1

Mean Distance from Sternal Notch to the Center of the 4th Intercostal Space by CT scan and Clinically and the Percentage of this Measurement Related to the Length of the Sternum

Sternal Length: Distance from SN to XP (cm)	N=55 Distance from SN to Center of 4th IC by CT scan (cm)	N=31 Distance from SN to Center of 4th IC clinically (cm)	N=55 Percentage of the 4th IC calculated from the Length of Sternum by CT scan
15	11.4	11.8	76%
16	11.8	12.1	74%
17	12.2	12.3	72%
18	12.5	12.6	69%
19	12.9	12.9	68%
20	13.3	13.1	66%
21	14	13.4	67%
22	14.1	13.7	64%
23	14.5	13.9	63%
24	14.9	14.2	62%
25	15.2	14.5	60%
26	15.5	14.8	59%

Abbreviations:

Intercostal Space **IC**

Sternal Notch **SN**

Xyphoid Process **XP**

The CT scans were performed in 55 adult patients. (7)The clinical measurements were made in 13 volunteers and in 18 patients in the supine position.

Table 2

Mean Distance from Sternal Notch to 5th Intercostal Space Measured Clinically and the Percentage of this Measurement to the Length of the Sternum

Distance from SN to XP (cm)	Distance from SN to Center of 5th IC (cm)	Percentage of 5th IC to length of Sternum
15	13.8	92%
16	14.2	89%
17	14.6	86%
18	14.9	83%
19	15.4	81%
20	15.7	78%
21	16.1	77%
22	16.5	75%
23	16.9	73%
24	17.3	72%
25	17.2	69%
26	18	69%

Abbreviations:

Intercostal Space **IC**

Sternal Notch **SN**

Xyphoid Process **XP**