The Accuracy of Chest Wall Thickness: To Improve Success Rate of Emergency Needle Thoracostomy

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Background: *40% of needle thoracostomy were failed in emergency situation. The Advanced Trauma Life Support was recommended to apply 5-cm of needle into the 2nd intercostal space (ICS) about the midclavicular line (MCL) for immediate treatment of tension pneumothorax. 9.9-35% of normal chest wall thickness (CWT) from the previous studies were more than 5 cm.*

Objective*: To analyze the average of Thai patient CWT at the 2nd ICS in MCL.*

Material and Method*: Prospective data collection of the patients who underwent a chest computed tomography scans during the period between April and September 2009. CTW was measured at the 2nd ICS in the MCL in distant for standard procedure, shortest distant and injured distant.*

Results*: The mean CWT patients were 35.2±11.9 mm for the right side and 34.7±11.7 mm for the left side. The mean of shortest distant was 30.9 mm. The mean CWT was significantly higher in patients with high body-mass index (BMI).*

Conclusion: *The standard 5-cm needle may be not passed into the thoracic cavity in 11.3 % of studied population. CWT was showed significant correlation with BMI. 44.5% of patients with BMI more than 30 kg/m^2 had CWT more than 5 cm.*

Keywords: *Needle thoracostomy, Chest wall thickness, Pneumothorax*

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The emergency needle thoracostomy is a life-saving procedure for chest decompression in many emergency conditions especially in tension pneumothorax[1-3]. According to the Advanced Trauma Life Support® (ATLS®) recommendation, inserted a large caliber of 5 cm-long needle into the 2nd intercostal space (ICS) about midclavicular line (MCL) is a proper emergency management of tension pneumothorax[4-9,15]. Regarding to previous studies, about 38% of emergency needle thoracostomy were failed in emergency condition[4-6]. In some case reports, insufficient length of the needle might be a caused of failure in emergency needle thoracostomy. Although, most authors did not recommend using longer instrument because of potentially complications such as mediastinal vessels injury or pulmonary laceration[12-14].

The evidenced base of chest wall thickness (CWT) which more than 5 cm were about 9.9-35.4% of overall Western-patients in many previous studies[4-9, 15]. However, no previous study about CWT of the Asian population was performed. The widely use of chest CT in medical practice can also be used to measure chest wall thickness without additional risk to patients, study on CWT in Asian population with chest CT is so interesting.

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Material and Method

The primary objective is to analyze the average CWT at the 2nd ICS in MCL in Thai patients. The secondary objective is to identify the proper needle size and technique for needle thoracostomy.

A prospective review of Chest-CT scans was performed at Siriraj Hospital, the largest hospital in Thailand with more than 2,000,000 OPD visits per year and more than 2,200 patient beds. Permission from ethics committee of the faculty of Medicine at Siriraj Hospital was granted for this study. The data is collected from patients who were 18 years old or more, scheduled for Chest-CT during the period from April 1st until September 30th, 2009. Information includes age, gender, height, body weight, as well as indication for

Chest-CT. Patients who had diseases of the chest wall (breast mass, chest wall tumor, congenital anomalies, or pleural disease), chest wall trauma were excluded from this study. All of Chest-CT images were collected on the Siriraj Picture Archive and Communication System (Si-PACS). The Chest-CT images that do not meet the quality standard or are incomplete data were also excluded from this study. The right and left CWT were measured on the both side of 2nd ICS (just above the 3rd rib) about MCL of the patients. The MCL was first identified and then traced downwards to locate just above the 3rd rib by 1.25 mm thickness CT imaging. From the puncture site, direct distant (or direct puncture distant) and shortest distant to enter the pleural cavity and angulations between the direct and the shortest distant were recorded. The shortest distant from puncture site to mediastinum (distant to injury) and angulation with direct distant were noted. The CWT of the 5th ICS was recorded as well.

The collected data were analyzed by using SPSS version 17. Spearman and Pearson's correlation coefficient was used to determine data relationship. Unpaired T-test was used to determine significant differences when *p*-value <0.05.

Results

172 patients were included in this study, 79 (45.9%) were men and 93 (54.1%) were women. The median age was 51 years (IQR 18-88). The median height was 161 cm (IQR 137-181), median body weight was 56 kg (IQR 29-141), and overview of the mean CWT was presented in Table 1. The mean CWT was significantly lower in male patients (*p*-value <0.001) than female patients for both right and left sides. However, the difference between the right and left sides is not significant for both male (*p*-value of 1.52) and female patients (*p*-value of 1.01). The chest wall thickness in both male and female patients are highly correlated with BMI (correlation coefficient of 0.800 and 0.785 for the right and left side respectively) and BW (correlation coefficient of 0.651 and 0.632 for right and left side respectively), but no significant correlation between patient's age and CWT (Table 2 and Fig. 1). From the, the mean chest wall thickness, both male and female, increase in line with the change in BMI for both left and right sides (Table 3 and 4). The correlation of potential failure of 5 cm needle to reach pleural cavity and BMI is shown (Table 5).

Table 1. An overview of mean chest wall thickness at right and left side for male and female

	Right (mm)	Left (mm)
Male	31.0±11.5	30.3±10.9
Female	38.8±11.2	38.3±11.1
Total	35.2±11.9	34.7±11.7

The study revealed that the direct puncture at the 2nd ICS in MCL was not the shortest distant to access the pleural cavity, due to the acute angle of anatomy of pleural cavity at lateral aspect. Medial angulation at around 20 degree may result in reduction of chest wall thickness by approximately 4 to 5 mm. For the distant from punctured site to mediastinum ≤5 cm in 1.7% (0.6% of the right side and 2.9% of the left side), all of the patients at risk have BMI <22 kg/m^2 and mean angulation to injury are 47.2% for the right side and 45.9% for the left side (Table 6-8). Additional measures of the 5th ICS in anterior to midaxillary line were revealed a significant reduction of thickness of chest wall (Table 9).

Discussion

The needle thoracostomy is relatively simple and less time consuming procedure, hence, this procedure is used in many parts of medical practice, especially for chest decompression before placement of tube thoracostomy in tension pneumothorax. Nevertheless, not everyone routinely performs this procedure. The study of physiology and personnel skill training of medical practitioners, including emergency medical service teams, in the future will be helpful to reduce failure rate. In the case that the needle thoracostomy is performed without rush of air, which could be a result of technical problems or the tension pneumothorax is not existed. The study of CWT and proper use of instruments can also improve success rate and minimize complication.

According to the ATLS® guidelines, the 5 cm needle is recommended and considered safe from this study. Because of chest wall thickness ≥5 cm, only 9.9% for the right and 12.2% for the left side and according to the 0.5% and 2.9 % potential mediastinal injury for right and left side respectively. Attention may be paid to patients who were underweight or BMI <18.5 kg/m^2, due to potential for injury.

The 3.75 cm (or 1.5 inches) catheter may not penetrate chest wall in 37.2% and 18.6 % of the studied patients who have chest wall thickness 4.5 cm. This may result in 8.2% failure to decompress after needle removal and 4.5 cm sheath was left in place (kinking and displacement are not included).

In case of obese patients with BMI more than 30 kg/m^2, the 5 cm needle may not penetrate pleural cavity in 54.5% The anterolateral approach may improve success rate, according to mean CWT around 2.3 cm, but risk for cardiac, mediastinal and diaphragmatic injuries cannot be clearly evaluated because patient's respiration causes movement of the diaphragm, variable distant from chest wall to intrathoracic organ. In such cases, medial angulation of around 20 degrees may improve success rate without significant increase of potential injury risk.

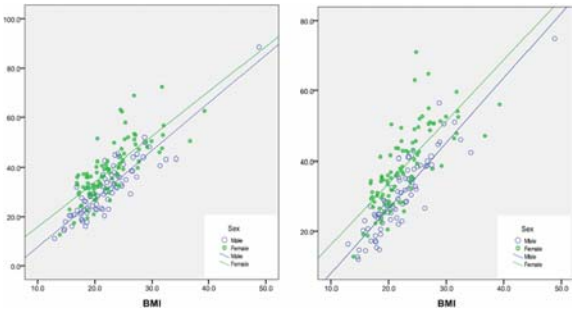

Fig. 1 Correlation between BMI and chest wall thickness.

Although chest CT may be considered as the best method for chest wall measurement and show significant correlation with cadaver study[8], there are still some limitations. Precision of the punctured site is required. According to the anatomy of the pleural cavity, acute angle at lateral aspect of the pleural cavity may significantly increase chest wall thickness when the punctured site was displaced laterally. The next limitation is related to arm position. In order to avoid artifacts, patients who underwent CT chest will be placed in elevated arm position. From the previous study, chest wall thickness was significantly increased

Table 2. BMI (Underweight = BMI <18.5 kg/m^2, Normal 18.5-24.9, Overweight 25.0-30.0 kg/m^2, Obese >30.0 kg/m^2)

	n	Percent	Male	Female
1. Underweight	34	19.8%	20	14
2. Normal	100	58.1%	43	57
3. Overweight	27	15.7%	12	15
4. Obese	11	64.0%	4	7
Total	172	100.0%	79	93

Table 3. Male chest wall thickness, classified by BMI

	Right			Left		
	Direct(cm)	Shortest(cm)	Angle	Direct(cm)	Shortest(cm)	Angle
1. Underweight	20.4±5.0	18.3±4.4	21.6±6.8	19.2±4.7	16.9±4.1	20.5±6.4
2. Normal	30.8±6.9	27.1±5.8	21.7±5.1	30.3±5.9	26.6±5.4	19.9±5.42
3. Overweight	41.7±6.6	36.6±5.9	22.5±7.4	41.5±7.3	36.1±6.2	18.4±3.8
4. Obese	53.9±23.1	45.6±16.6	24.0±3.3	53.5±14.7	45.1±12.7	22.8±5.4
Total	31.0±11.4	27.3±9.5	21.9±5.8	30.4±10.9	26.5±9.3	19.9±5.5

Table 4. Female chest wall thickness, classified by BMI

	Right			Left		
	Direct(cm)	Shortest(cm)	Angle	Direct(cm)	Shortest(cm)	Angle
1. Underweight	28.6±7.4	24.9±6.9	23.0±7.2	26.7±6.3	23.7±6.3	19.2±6.5
2. Normal	36.1±8.2	32.1±7.5	19.9±5.9	36.5±9.2	32.0±8.3	21.1±4.9
3. Overweight	50.5±6.7	45.4±7.3	17.7±6.0	49.8±6.5	44.9±7.2	16.9±5.5
4. Obese	55.3±9.4	48.6±10.3	18.3±7.6	51.9±5.1	45.3±5.6	18.1±3.4
Total	38.8±11.2	34.4±10.4	19.9±6.4	38.3±11.1	33.8±10.2	19.9±5.3

in arm down position in female patients and the right chest of male patients[9]. The elevated arm position makes it difficult to locate the puncture site precisely and may cause error in measurements. Another consideration is patient condition. When chest CT was performed, patient was conscious and in full inspiration, which is different from trauma situation where patients may not cooperate well and injured distant and thickness of the chest wall may change.

Table 5. Chest wall measurement ≥5cm in subgroups by BMI

	N	Right	Left
Underweight	34	0.0%	0.0%
Normal	100	3.0%	3.0%
Overweight	27	33.3%	44.4%
Obese	11	54.5%	54.5%
Total	172	9.9%	12.2%
	172	11.3%	

Conclusion

The standard 5 cm-needle may be not passed into the thoracic cavity in 11.3 % (9.9% of right side and 12.2% of left side) of studied population. An improper use of 3.75-cm needle may cause insufficient length in 37.2%. About 8.2 % of patients, who success with needle decompression, may fail when needle was removed and 4.5 cm sheath was left in place. Retained needle or stabling device may be helpful in this situation. Chest wall thickness had significant correlation with BMI and 45.5% of patients with BMI at > 30 kg/m^2 had thickness ≥5 cm. Needle projection

Table 6. Potential failure rate of needle usage for needle thoracostomy

	Right			Left			Total
	Male	Female	Total	Male	Female	Total	%
1.5-inch needle	24.0	48.4	37.2	26.6	46.2	37.2	37.2
4.5 cm sheath	7.6	26.9	18	7.6	29	19.2	18.6
5 cm needle	1.3	17.2	9.9	5.1	18.3	12.2	11.3

Table 7. Potential injuries in male patients

	N	Minimum	Maximum	Mean	Std. Deviation
Right injured distant	79	49.6	116.2	77.125	10.2603
Angle of injury	79	32.0	61.0	47.210	6.6270
Left injured distant	79	53.2	118.8	77.711	12.8155
Angle of injury	79	31.0	63.0	45.940	6.6840

Table 8. Potential injuries in female patients

	N	Minimum	Maximum	Mean	Std. Deviation
Right injured distant	93	54.6	110.0	77.773	11.4131
Angle of injury	93	18.0	63.0	43.230	7.8230
Left injured distant	93	47.3	110.5	74.597	12.6371
Angle of injury	93	23.0	60.0	41.410	7.5990

Table 9. Chest wall thickness at the 5th intercostals space, anteriror to midaxillary line

	Minimum	Maximum	Mean	Std. Deviation
Right anterolateral thickness	6.6	73.9	23.343	10.0140
Left anterolateral thickness	1.8	72.7	23.497	10.2843

with medial angulation around 20 degrees may increase success rates without significant potential injuries. Anterolateral approach may be an alternative in case of obese patients but the risks are not well studied.

What is already known on this topic?

According to the ATLS® guidelines, the 5 cm needle is recommended for chest decompression by needle thoracostomy technique.

What this study add?

In average patients, needle thoracostomy with standard 5cm-needle is a safety procedure for chest decompression in a tension pneumothorax condition. Few of the patients with high level of BMI, especially more than 30 kg/m^2 have to use extra-long needle which more than 5 cm for needle thoracostomy.

Acknowledgment

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Potential conflicts of interest

None.

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การประเมินความหนาของผนังทรวงอกเพื่อเพิ่มประสิทธิภาพในการทำการเจาะระบายลมในช่องอกด้วยเข็มในภาวะฉุกเฉิน

จตุพร ศิริกุล, บรรเจิด ประดิษฐ์สุขถาวร, จิตรลัดดา วะศินรัตน์

ภูมิหลัง: การทำ needle thoracostomy ในภาวะฉุกเฉินมีโอกาสประสบความล้มเหลวได้ร้อยละ 40 จากคำแนะนำของ The Advanced Trauma Life Support® แนะนำให้ใช้เข็มความยาวขนาด 5 ซม. ในการเจาะช่องอกที่ช่องระหว่างกระดูกซี่โครงช่องที่ 2 ในระดับกึ่งกลางของกระดูกไหปลาร้าในผู้ป่วยที่มีภาวะ tension pneumothorax โดยพบว่า ร้อยละ 9.9-35 ของกลุ่มประชากรในการศึกษาก่อนหน้านี้มีความหนาของผนังทรวงอกหนามากกว่า 5 ซม.

วัตถุประสงค์: ศึกษาหาค่าความหนาของผนังทรวงอกของคนไทยในบริเวณช่องระหว่างกระดูกซี่โครงช่องที่ 2 ในระดับกึ่งกลางของกระดูกไหปลาร้า

วัสดุและวิธีการ: การศึกษาดำเนินการโดยการเก็บข้อมูลผู้ป่วยแบบไปข้างหน้าในผู้ป่วยที่จะต้องถ่ายภาพรังสีแบบคอมพิวเตอร์ของหน้าอกโดยข้อบ่งชี้ต่าง ๆ ในช่วงเดือนเมษายนถึงเดือนกันยายน พ.ศ. 2552 โดยจะวัดความหนาของผนังทรวงอกในบริเวณช่องระหว่างกระดูกซี่โครงช่องที่ 2 ในระดับกึ่งกลางของกระดูกไหปลาร้าในระยะมาตราฐานของการทำหัตถการ และในระยะที่บางที่สุดของผนังทรวงอก

ผลการศึกษา: ค่าเฉลี่ยของความหนาของผนังทรวงอกเท่ากับ 35.2±11.9 มม. ในหน้าอกด้านขวา และ 34.7±11.7 มม. ในหน้าอกด้านซ้ายโดยพบว่าค่าเฉลี่ยของระยะที่บางที่สุดของความหนาของผนังทรวงอกเท่ากับ 30.9 มม. และความหนาของผนังทรวงอกของผู้ป่วยมีความหนามากขึ้นสัมพันธ์กับดัชนีมวลกายที่มากขึ้นอย่างมีมีนัยสัมพันธ์ทางสถิติ

สรุป: การใช้เข็มความยาวขนาด 5 ซม. มีโอกาสที่จะแทงไม่เข้าช่องอกประมาณร้อยละ 11.3 ของประชากรที่ศึกษาโดยที่ความหนาของผนังทรวงอกจะสัมพันธ์กับดัชนีมวลกายอย่างมีมีนัยสัมพันธ์ทางสถิติและพบว่าผู้ป่วย ที่มีดัชนีมวลกายที่มากกว่า 30 กก./ตร.ม. จะมีความหนาของผนังทรวงอกที่มากกว่า 5 ซม. ถึงร้อยละ 44.5