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ARAŞTIRMA / RESEARCH

Widening of sternoclavicular joint distances in blunt chest trauma

Künt göğüs travmasında sternoklaviküler eklem mesafelerinin genişlemesi

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Abstract

Purpose: Blunt chest trauma has high mortality and morbidity rates. The aim of this study was to evaluate the relationship between trauma findings and sternoclavicular joint (SCJ) distances in patients with blunt chest trauma.
Materials and Methods: Between May 2019- September 2019, Thorax Computed Tomography (CT) images of 102 patients (78 males, 24 females, aged 19-88 years) with blunt chest trauma were evaluated retrospectively. Rib fractures, costal cartilage fractures and other signs of trauma were evaluated. SCJ distances were measured at the inferior, mid, and superior segments in the coronal reformatted CT images. Post-traumatic SCJ expansion was evaluated in patients with rib and costal cartilage fractures. Additionally, SCJ and the presence of other post-traumatic signs were compared. An inter-observer reliability analysis with Intraclass correlation coefficient (ICC) scores with 95% CIs were calculated.
Results: In the presence of fractures of 1st to 4th ribs a statistically significant widening of superior and mid segments of the ipsilateral SCJs were detected. A 2-mm or greater difference of widening of the superior segment of the ipsilateral SCJ compared to the contralateral joint was found statistically significant for hemothorax, pneumothorax, and wall emphysema. The inter-observer agreement was excellent for the measurements of the SCJ on coronal plane, having an ICC score ranging from 0.921 to 0.961 (95% CI).
Conclusion: The expansion of the ipsilateral SCJ distances in rib fractures in the upper part of the chest wall shows that SCJ performs an important role in the absorption of energy to the chest wall.
Keywords:. Computed tomography, sternoclavicular joint, rib fractures, thoracic injuries

Öz

Amaç: Bu çalışmanın amacı, künt göğüs travması olan hastalarda travma bulguları ile sternoklaviküler eklem (SKE) mesafeleri arasındaki ilişkiyi değerlendirmektir.
Gereç ve Yöntem: Mayıs 2019 - Eylül 2019 tarihleri arasında künt göğüs travması olan 19-88 yaş arası 102 hastanın (78 erkek, 24 kadın) Toraks Bilgisayarlı tomografi (BT) görüntüleri retrospektif olarak değerlendirildi. Kosta kırığı, kostal kartilaj kırıkları ve diğer travma bulguları değerlendirildi. SKE mesafeleri, koronal reformat BT görüntülerinde alt, orta ve üst segmentlerde ölçüldü. Kostal ve kostal kartilaj kırıkları olan hastalarda travma sonrası SKE genişlemesi değerlendirildi. Ek olarak, SKE ve diğer travma sonrası bulguların varlığı karşılaştırıldı.
Bulgular: 1-4. kosta kırığı varlığında, ipsilateral SKE'nin üst ve orta kesimlerinde istatistiksel olarak anlamlı bir genişleme saptandı. Hemotoraks, pnömotoraks ve duvar amfizemi için, ipsilateral SKE'nin üst kesimindeki 2 mm veya daha fazla genişlemesi kontralateral eklem ile karşılaştırıldığında istatistiksel olarak anlamlı bulundu. SKE'nin koronal düzlemde ölçümleri için gözlemciler arası uyum, 0.921 ile 0.961 (%95 CI) arasında değişen bir ICC skoru ile mükemmel olarak bulundu.
Sonuç: Göğüs duvarının üst kısmındaki kaburga kırıklarında ipsilateral SKE mesafelerinin genişlemesi, SKE'nin travmada göğüs duvarına gelen enerjinin emiliminde önemli bir rol oynadığını göstermektedir.
Anahtar kelimeler: Bilgisayarlı tomografi, sternoklaviküler eklem, kosta kırıkları, torasik yaralanmalar

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INTRODUCTION

Trauma related death is the 10th most common cause of death worldwide [1]. Blunt chest trauma is the second most common cause of morbidity and mortality after head trauma in trauma victims [2]. Mortality reaches up to 60% in patients with chest trauma in the United States of America and Europe. High-energy trauma is traumas (traffic accident, falling from height, etc.) characterized by multiple organ injuries that develop after exposure to high levels of energy. Blunt chest trauma is common in the young age groups, and it has been reported that 25% of deaths in patients with multitrauma are due to chest trauma [3]. Rib fracture is the most common trauma sign in chest trauma [4]. Rib fracture has been reported in 32% to 42% of chest trauma victims [5]. The incidence of hemothorax and pneumothorax rises with increasing number of fractured ribs [6]. The incidence of costal cartilage fracture has been reported 19.9% [7]. Costal cartilage fractures, together with rib fractures, may cause chest wall instability.

The sternoclavicular joint (SCJ) is composed of fibrous and hyaline cartilage and located between the axial skeleton and the upper extremity. The ligamentous part of the joint is formed by the anterior and posterior sternoclavicular ligaments, costoclavicular ligament, and interclavicular ligament [8, 9]. The normal anatomic features and variations of SCJ were reported by studies where the joint was examined using Computed Tomography (CT) [10, 11].

The aim of the present study was to assess the trauma related alterations of SCJ distances in patients with chest trauma. In trauma, we think that SCJ performs an important role in stabilization in the prevention of upper thoracic region injury along with costal cartilage, and this study will contribute to the English literature.

MATERIALS AND METHODS

This study, whose approval was granted by Medical Ethics Committee of Pamukkale University, was carried out in accordance with the Helsinki Declaration regulation and guidelines (Date: 01.21.2020, Number: PAU 60116787-020/31192). The post-traumatic CT images of 1415 patients with trauma aged 18-91 years who were examined at Denizli State Hospital Radiodiagnostic Department between May 2019 and September 2019 were retrospectively reviewed. 1313 patients, those with thoracic rotoscoliosis(n=11), previous bypass surgery(n=51), sternocostal anomaly or dislocation(n=1), oncological conditions(n=47), metabolic bone disease(n=4), patients with SCJ effusion(n=2), non-optimal positioning of the patient during CT scans(n=118) and not exposed to high-energy trauma(n=1079) were excluded. The thoracic CT images of 102 patients with blunt chest trauma aged 19-88 years (78 males, 24 females; median age 55 years; mean age 52.77 ±16.20 years) were retrospectively reviewed by two radiologists, one (V.C.) with 10 years of experience and the other (S.T.) with 4 years of experience.

Computed tomography procedure

Computed tomography examination was performed using a 16 detector row multislice helical CT device (16 MDCT CT scanner, Toshiba Alexion, JAPAN). All thoracic CT examinations were performed at suspended inspiration, with the patients lying in supine position. CT examination was planned over the scanogram image, to scan a region between the neck and the upper pole of the kidney. The imaging parameters were as follows: tube voltage 120 kV, tube current 70 mAs, slice thickness 2.0 mm, rotation time 750 ms, and “pitch” 0.938. All patients axial CT images were examined in mediastinal (WW:350, WL:50), parenchymal (WW:-600, WL:1600), and bone (WW:2500,WL:480) windows on the work station. Coronal reformatted CT images of the thorax are reconstructed at 2,5 mm slice thickness and coronal images were examined in bone (WW:2500,WL:480) window.

Image analysis

The trauma signs (pneumothorax, hemothorax, pneumomediastinum, lung contusion, mediastinal vascular injury, subcutaneous emphysema, sternum fracture, clavicula fracture, scapula fracture, rib fracture, and costal cartilage fracture) were studied on the thorax CT examinations of patients who presented to the emergency department after high energy trauma between May 2019 and September 2019. In patients without clavicula fractures, SCJ distances were measured at the inferior, mid, and superior segments in the thoracic CT images reformatted on coronal plane. SCJ distances and asymmetry between both joints were evaluated in patients with rib and costal cartilage fractures. Additionally, joint distances and the presence of other post-traumatic signs (pneumothorax, hemothorax, scapula fracture, abdominal organ injury etc.) were compared.

Statistical analysis

Data analysis was performed on a personal computer using statistical software (SPSS 21 for Windows, Chicago, IL). Descriptive statistics were shown as mean ± Standard deviation in continuous variables and as % in categorical variables. Chi-square test was performed for categorical variables. Comparison of SCJ distances on coronal planes was performed with t test. $p< 0.05$ was considered statistically significant. An inter-observer reliability analysis with the Kappa statistic was performed to determine consistency among raters. Intraclass correlation coefficient (ICC) scores with 95% CIs were calculated.

RESULTS

Signs of trauma detected in patients with blunt chest trauma were presented in Table 1. An excellent inter-observer agreement was found for the assessment of trauma signs. The patients in the study group were according to their age, and there were 19 patients between the ages of 19-35 years, 23 patients between the ages of 36-51 years, 23 patients between the ages of 52-59 years, 23 patients between the ages of 60-70 years and 14 patients over the age of 71 years. No statistical differences were found compared to the signs of trauma according to age groups.

In the study group there was a total of 256 rib fractures at the right side and 268 rib fractures at the left side. An excellent inter-observer agreement was found for evaluation of rib and costal cartilage fractures (Table 2) (Figure 1a, Figure 1b). In patients with chest trauma, fractures were most commonly observed in 5-8th ribs and in the 1st, 6th and 7th costal cartilages. There was a costal cartilage fracture in 43 of 102 patients with blunt chest trauma and fractures were found in a total of 40 costal cartilages at the right side and 33 costal cartilages at the left side. The prevalence of costal cartilage fracture was calculated 3.03% among 1415 trauma patients.

Table 1. Signs of trauma in patients with blunt chest trauma

	Positive(n)						**Negative(n)**		
Signs of Trauma	Right		Left		Bilaterally				Kappa values
	R1	R2	R1	R2	R1	R2	R1	R2	
Pneumothorax	30	30	16	16	5	5	51	51	1.00
Hemothorax	27	27	25	25	3	3	47	47	1.00
Contusion	24	23	21	20	7	7	50	52	0.96
Wall emphysema	10	10	8	9	1	1	83	82	0.96
Scapula fracture	10	10	12	12	1	1	79	79	1.00
	R1			R2			R1	R2	Kappa
Pneumomediastinum	2			2			100	100	1.00
Sternum fracture	3			3			99	99	1.00
Vertebral fracture	18			18			84	84	1.00
Intracranial hemorrhage	18			18			84	84	1.00
Hepatic laceration	5			5			97	97	1.00
Splenic laceration	5			5			97	97	1.00

n= number of patients, R1= Radiologist 1, R2= Radiologist 2.

Table 2. Localization of the rib and costal cartilage fracture in the study group

	Right		**Left**		
Rib fracture	R1(n)	R2(n)	R1(n)	R2(n)	**Kappa**
1-4 ribs	33	31	27	27	0.954
5-8 ribs	48	46	44	44	0.964
9-12 ribs	11	11	22	22	1.000
Costal cartilage fracture					
1-5 cartilage	13	13	11	11	1.000
6-10 cartilage	16	15	14	13	0.929

n= number of patients, R1= Radiologist 1, R2= Radiologist 2

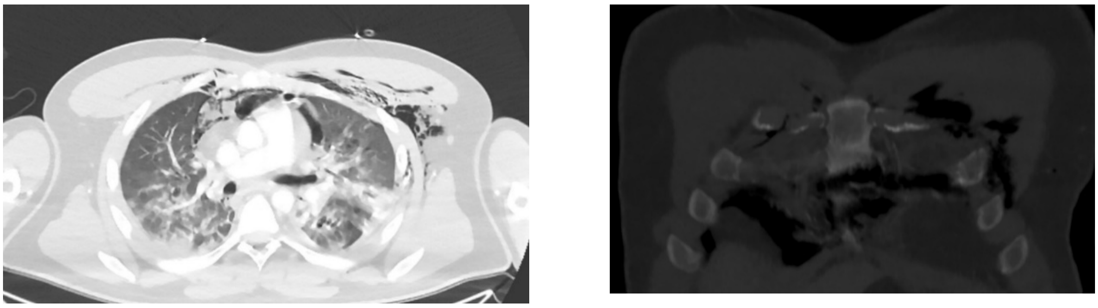

Figure 1. Blunt chest trauma signs. a) Axial CT image in the parenchyma window. A 39-year-old male patient who has pneumomediastinum, chest wall emphysema, pulmonary contusion. Costal cartilage fracture is observed on the right. b) Coronal reformatted CT image in the bone window. Fracture in the right 3rd costal cartilage.

Table 3. Relationship between SCJ enlargement with rib and costal cartilage fracture

			>2 mm widenig of the sternoclavicular joint					
			Right(p=)			**Left(p=)**		
		Ribs	Superior	Mid	Inferior	Superior	Mid	Inferior
Rib fracture	Right	1-4	0.005	0.024	0.090	0.437	0.009	0.563
		5-8	0.052	0.002	0.027	0.153	0.047	0.493
		9-12	0.597	0.187	0.545	0.104	0.287	0.205
	Left	1-4	0.502	0.440	0.225	0.017	0.05	0.077
		5-8	0.394	0.167	0.092	0.181	0.025	0.117
		9-12	0.278	0.089	0.183	0.153	0.149	0.580
Costal cartilage fracture	Right	1-5	0.529	0.434	0.119	0.588	0.728	0.412
		6-10	0.310	0.531	0.522	0.034	0.573	0.570
	Left	1-5	0.597	0.187	0.235	0.301	0.597	0.101
		6-10	0.413	0.142	0.311	0.466	0.587	0.454

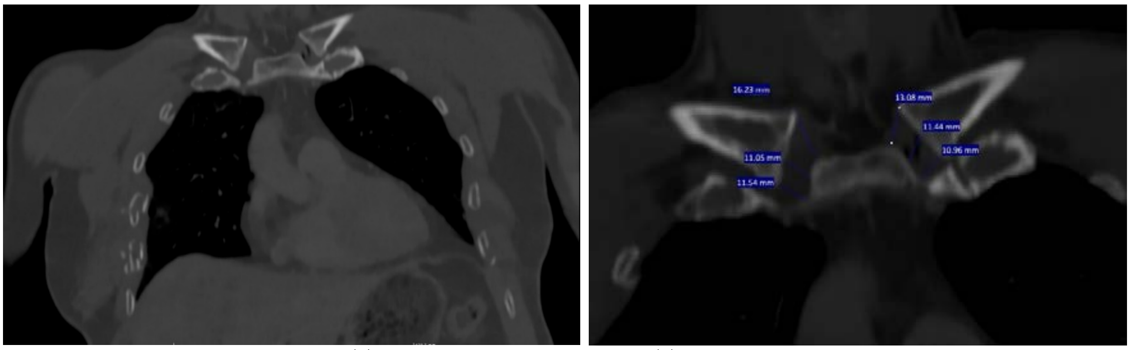

Figure 2. a) Coronal reformatted CT image in the bone window. The right SCJ is enlarged compared with the left side with multiple rib fractures seen on the right. Gas is present within the left SCJ. b) Coronal reformatted CT image in the bone window shows relative expansion of the right superior part of SCJ compared with the left side.

The inter-observer agreement was excellent for the measurements of SCJ on coronal plane, having an ICC score ranging from 0.921 to 0.961 (95% CI). When there was a fracture of the 1-4th ribs, there was a statistically significant widening of the superior and mid segments of ipsilateral SCJ (Table 3) (Figure 2a, Figure 2b). For the 5-8th rib fractures, there was a widening in the mid segment of the ipsilateral SCJ and a significant widening in the inferior segment of the right SCJ. No significant difference was found for SCJ widening in the 9-12th rib fractures. A significant widening in the superior segment of the left SCJ was detected in fractures of the 6-10th ribs. However, no significant difference was found between SCJ widening in other costal cartilage fractures. A 2-mm or greater difference of widening of the superior segment of the ipsilateral SCJ compared to the contralateral joint was found statistically significant for hemothorax (p=0.040), pneumothorax (p=0.028), and wall emphysema (p=0.005).

No significant difference was found for the mid and superior segments of SCJ in case of the presence of hemothorax, pneumothorax or lung contusion. No significant difference was found between joint distances for scapula fracture, humerus fracture, and cervical and thoracic vertebra fracture. SCJ distances showed no significant difference in the presence of abdominal organ injury accompanying severe chest trauma.

DISCUSSION

According to a World Health Organization report dated 2008, trauma is the 5th leading cause of death worldwide. The worldwide mortality rate related to blunt trauma has been reported to be 9% [12]. CT is the most rapid and reliable imaging technique for detecting signs of trauma during the management of trauma patients in the emergency department. It was reported that at least one injury existed in 61.4% of CT scans of trauma victims in emergency departments, with the most common injuries being lung contusion and rib fractures [13]. Signs of trauma such as pneumothorax, hemothorax, lung contusion, and solid organ injuries are detected in a majority of patients with severe chest trauma [14,15]. We detected pneumothorax in 50%, hemothorax in 46%, and pulmonary parenchymal contusion in about a half of our patients suffering from chest trauma.

Rib fractures, were reported to be the most common injuries in patients with blunt chest trauma [16]. Rib fractures have been reported in 10% of patients with chest trauma [17]. Isolated rib fractures have been reported between 6% and 13.1% in various series [17-19]. The most commonly broken ribs are 4th to 9th ribs. Fracture of the upper ribs (particularly 1st and 2nd ribs) indicate severe chest trauma. In such cases great vessel injuries or other signs of trauma may be observed owing to the location of the upper ribs. The most commonly broken ribs in our study were 5th to 8th ribs. All patients in the chest trauma group had rib fractures, with a total number of 256 at the right side and 268 at the left side. Fractures involving 9th to 12th ribs may be accompanied by upper abdominal organ injury.[6,7] We detected fractures of 9th to 12th ribs at the right side in 11 patients with blunt chest trauma and at the left side in 22 patients, and 5% of patients also had hepatic or splenic laceration.

Costal cartilage fractures are usually seen with multiple rib fractures. This leads to chest wall instability, increasing morbidity and mortality. The first costal cartilage is a synchondrosis joint, which may accompany the fractures of the first and second ribs. The location of costal cartilage fractures and the potential organ co-injuries are important. Tracheobronchial tree injuries and main vascular injuries may co-occur with the fractures of 1st to 3rd costal cartilages; upper abdominal organ injury may co-exist with the fractures of 6th and 7th costal cartilages [20]. We found costal cartilage fractures in 43 patients. There was a total of 40 costal cartilage fractures on the right side and 33 on the left side. We revealed a costal cartilage fracture prevalence of 3.03% among 1415 trauma patients. Nummela et al. reported a costal cartilage fracture prevalence of 7.8% in 1461 patients presenting with trauma [7]. We believe that the lower prevalence in our study likely resulted from a more common use of CT for trauma victims at the emergency departments in our country. Similar to what Nummela et al [7] reported, the most commonly broken cartilages were the first, sixth, and seventh costal cartilages.

Plain radiographs cannot provide adequate detail except for SCJ fractures. There are a number of studies where the anatomic details of the joint cartilage were provided for SCJ assessment [21]. However, the use of magnetic resonance imaging (MRI) for the assessment of SCJ has a limited practical use owing to respiratory and vascular pulsatile artifacts. Ultrasonography has also been reported to be used in some authors to evaluate SCJ effusion, infection and inflammatory processes [22]. In clinical practice CT is the modality that is used to evaluate SCJ. Studies that have examined SCJ degeneration in CT among volunteers and cadavers have shown an increase in the prevalence of degenerative signs with aging [23,24]. In a study where SCJ distances were examined with CT it was reported that there may be an asymmetry up to 5.7 mm between both joints [10]. However, the work done by

De Maeseneer et al.[11] revealed no significant difference between the joint distances of both SCJ. That study was performed retrospectively through carotid CT angiography images, where patients were kept in neutral position during image acquisition [11]. Additionally, that study reported that joint distance might show a slight decrease with aging, with degenerative signs showing an equal distribution on the sternal and clavicular surfaces.

Sternum appears as two symmetrical sternal bands at the 9th week of embryological development and starts to take the shape of mature sternum with ossification centers at midline during 5th to 6th fetal months. SCJ conjoins without a visible border to form the fibrocartilaginous disc at the second month of fetal life. Costal cartilages are of hyaline type, which conjoin with the cartilage of the sternal primordium and connects to the ribs in a similar way with epiphyseal plaques of the bones[25].

We, based on the work done by De Massener et al.[11] and embryological evidence, think that SCJ distances are symmetrical in healthy adults. We believe that energy applied to chest wall due to trauma is absorbed by SCJ and costal cartilages, and if the incoming energy cannot be absorbed this will results in fractures and other signs of trauma. We defined the inter-sternoclavicular joint distance difference as 2 mm or greater in blunt chest trauma. In order to prevent measurement error, we omitted joint distance values below 1 mm or 2 mm. According to that classification, we detected a widening of 2 mm or greater at the superior and mid segments of the ipsilateral SCJ in the case of fractured 1st to 4th ribs in the study group of patients. There was widening of the mid segment of the ipsilateral SCJ and a significant widening of the inferior segment of the right SCJ in the case of 5^{th} to 8^{th} rib fractures. Apart from these findings, we detected a 2-mm or greater difference between the superior segment of the ipsilateral SCJ and its symmetrical counterpart when there was hemothorax, pneumothorax, and chest wall emphysema. No significant difference was found in SCJ distances in the presence of other signs of trauma.

In our study, left sided SCJ expansion was observed in patients with right and left side 5^{th}-8^{th} rib fractures. In most of the patients in our study, their position at the time of the trauma and the direction of the trauma were unknown. We thought that the left SCJ expansion in these patients could be due to the fact that the majority of patients with blunt chest trauma in the study group were in the driver position and the trauma was inflicted from the left side. However, in patients with right 6^{th}-10^{th} costal cartilage fractures, the left SCJ widening was found to be a coincidence.

This study was planned as an interobserver study, where the patients' CT images were evaluated by two radiologists who were blinded to the final reports of CT studies. There was an excellent inter-observer agreement for detection of signs of trauma as well as rib and cartilage fractures in CT images. For the assessment of SCJ the ICC score was found to be (%95 CI) 0.921 and 0.961.

Our study had some limitations. First, it was a retrospective study. Second, SCJ distances were not re-checked after recovery as no CT was taken in the recovery period of the patients in the severe chest trauma study group. Third, mortality and morbidity rates of these patients with severe chest trauma could not be determined as there was insufficient information about their clinical course. Fourth, there was no clinical scoring in the emergency department for the study group. Finally, no assessment of the ligamentous components of the joint was made while SCJ distances were being examined.

In conclusion, we propose to investigate the presence of mild SCJ dislocations in the presence of hemothorax, pneumothorax, rib fractures, which may be life-threatening findings in patients with blunt thorax trauma. Among patients with chest trauma, widening of the ipsilateral SCJ distances in the presence of the signs of trauma such as hemothorax and pneumothorax, and particularly rib fractures in the upper parts of the chest wall is an evidence to the role of SCJ as an absorber of the energy applied to chest wall.

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