ÖZGÜN ARAŞTIRMA ORIGINAL RESEARCH

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LUNG CONTUSION VOLUME: DO YOU REALLY KNOW?

AKCİĞER KONTÜZYON HACMİ: GERÇEKTEN BİLİYOR MUSUNUZ?

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Öz

Amaç

Pulmoner kontüzyon, künt göğüs travmasının en yaygın komplikasyonlarından biridir. Bir hekimin pulmoner kontüzyonun boyutunu ve gerçek miktarını belirlemesi bazen çok zordur. Çalışmanın amacı bilgisayarlı tomografi görüntüleri üzerinde Cavalieri prensibi ile manuel planimetri yöntemini kullanarak doğru pulmoner kontüzyon hacmini ölçmektir.

Gereç ve Yöntem

Çalışma “Acil Tıp Kliniğine”, akciğer kontüzyonu ile başvuran 76 hasta üzerinde yapıldı. Hasta verileri retrospektif olarak tarandı ve akciğer kontüzyonu olan hastaların bilgisayarlı tomografi görüntüleri akciğer kontüzyon hacmini hesaplamak için incelendi. Tüm akciğer kesitlerinde ölçüm yapıldıktan sonra, sistemik randomize örnekleme ile 6-8-10 kesitte akciğer kontüzyon hacmi hesaplandı. Kontüzyon hacmi iki bağımsız gözlemci tarafından manuel planimetri yöntemi kullanılarak hesaplandı.

Bulgular

Tüm kesit ölçümlerinden elde edilen ortalama kontüzyon hacmi %34.23 ± 17.56 idi. Kontüzyon hacmi 6 kesit ölçümünde %27,98±15,05, 8 kesitte %30,66±16,07 ve 10 kesitte %32,47±16,97 idi. Bland Altman grafiklerini incelediğimizde 10 kesitten elde edilen ortalama farkın 6 ve 8 kesit ölçümlerine göre daha küçük olduğu ve güven aralığının daha dar olduğu görülmektedir. Dolayısıyla 10 kesit ölçümünün yaklaşık %95 doğruluk oranı ile tüm akciğer kontüzyon ölçümlerine en yakın değerlendirmeyi verdiğini söyleyebiliriz.

Sonuç

Akciğer kontüzyon hacmi, BT'de tüm akciğer alanı ölçümü olmaksızın sistematik rastgele örnekleme ile manuel planimetri yöntemi kullanılarak yüksek gözlemciler arası ve gözlemci içi uyum ile objektif olarak değerlendirilebilir.

Anahtar Kelimeler: Akciğer kontüzyonu, Bilgisayarlı tomografi, Kontüzyon hacmi, Planimetri yöntemi, Travma

Abstract

Objective

Pulmonary contusion is one of the most common complication of blunt chest trauma. It is sometimes very difficult for a physician to determine the extent and real amount of pulmonary contusion. The aim of the study was to measure the accurate pulmonary contusion volume on computed tomography images by using the manual planimetry method with the Cavalieri principle.

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Material and Method
The study was performed on 76 patients who were admitted to the Emergency Medicine Clinic with lung contusion. Patient data were retrospectively screened and computed-tomography images of patients with lung contusion were examined to calculate lung contusion volume. After measurement in all lung sections, lung contusion volume was calculated in 6-8-10 sections by systemic randomized sampling. The volume of the contusion was calculated by two independent observers using the manual planimetry method.

Results
The mean volume of contusion obtained from all cross-section measurements was 34.23 ± 17.56%. In 6 sections measurement, contusion volume was 27.98±15.05%, in 8 sections 30.66±16.07% and in 10 sections 32.47±16.97%. When we examined the Bland Altman graphs, it is seen that the mean difference obtained from the 10 sections is smaller than the 6 and 8 sections measurements and the confidence interval is narrower. Therefore, we can say that the 10 sections measurement gives the closest evaluation to all lung contusion measurements with about 95% accuracy ratio.

Conclusion
Lung contusion volume can be objectively evaluated using the manual planimetry method with systematic random sampling without whole lung area measurement on CT with high interobserver and intraobserver agreement.

Keywords: Computed tomography, Contusion volume, Lung contusion, Planimetry method, Trauma

Introduction

Pulmonary contusion is one of the most common complication of blunt chest trauma, which is diagnosed in approximately one-third of acute trauma patients in the emergency service (1-3). This type of trauma can cause hypoxia-hypoxemia and lead to the requirement of ventilatory support as well as admission to the intensive care unit (ICU) (4).

A pulmonary contusion can lead to significant morbidity and mortality outcomes of acute lung injury, acute respiratory distress syndrome (ARDS), and ventilator-associated pneumonia.1 Chest radiography and computed tomography (CT) are used for radiological imaging. However, CT is superior to chest radiography with higher sensitivity for the detection of pulmonary contusion (5). CT findings of contusion include consolidation and ground-glass opacification. Patients' clinical outcomes generally correlate with the volume of pulmonary contusion involvement on CT scanning (6).

It is sometimes very difficult for a physician to determine the extent and real amount of pulmonary contusion. Computer-generated three-dimensional (3D) reconstruction of the injured lung is often used for volume detection. Radiology consultation may be needed to determine the amount of contusion. Radiology consultation most often reports that there is a small, moderate, or large area of contusion, or single, more than one lobe, or bilateral contusion without any numerical or nearly exact volume of contusion. Although the clinical status of the patient is the most important part of the decision process, we think that the amount of pulmonary contusion is very important to decide on ICU admission or the service follow-up period.

This study aimed to measure the accurate volume of pulmonary contusion on CT images using the manual planimetry method with the Cavalieri principle by a physician, without any three-dimensional reconstruction computer programs.

Materıal and Method

The study was performed on 76 patients who were admitted to the Emergency Medicine Clinic with isolated thoracic trauma and lung contusion between January and June 2019. Patient data were retrospectively screened from the Hospital Information Management System (HIMS; ProbelR). Ethics committee approval was obtained (Manisa Celal Bayar University Medical Faculty Health Sciences Ethics Committee Approval Accept number: 11/ 11/ 2020/ 20.478.486). The study protocol conforms to the ethical guidelines of the 1975 Declaration of Helsinki as reflected in a priori approval by the institution's human research committee.

CT images of patients with lung contusion, which were taken at the admission time to the emergency service, were examined to calculate the lung contusion volume.

The contusion volume was calculated by two independent observers using the manual planimetry method. The procedures were repeated 10 days later by each observer. The observers were blinded to the estimation results of their first measurement, results of the other observer, and name of the patients. Using a hand-held mouse, the rater marked-up around the area of total lung and contusion within the slice (7).

The lung contusion volume was estimated by multiplication of the obtained sectional surface areas with the section thickness (7, 8).

$V = t \times \Sigma AV = t \times \Sigma A$

t: the section thickness of consecutive sections

Σ A: the total sectional area of the contusion in consecutive sections

The coefficient error (CE) of planimetric volume estimations was calculated using the formula described in the literature (9).

In the tomography sections, an evaluation was performed from the area where the lung started to the end of the lowest section. The section where the apex of the lung began to be seen on tomography was determined as the first section. Measurements were made up to the lowest cross-section of the lung in sections of 0.5 cm. Apical to basal whole lung areas as well as contusion areas were marked with a mouse. All areas of the lung were measured from apex to baseline. Pulmonary contusion areas were marked with a mouse. Total lung areas were multiplied by section thickness, and total lung volume was determined. Total contusion volume was calculated by multiplying total contusion areas by cross-section thickness. The total contusion volume was divided by the total lung volume, and the total contusion percentage was calculated. After the first section of the lung apex was seen on tomography, a systematic random sampling was made, and the fifth section was numbered as “1” in all patients. To determine the effect of the number of sections on the accuracy rate, each fourth, sixth, and eighth sections were evaluated separately.

For total 6 sections calculation: 5th–13th–21st–29th–37th–45th

For total 8 sections calculation: 5th–11th–17th–23rd–29th–35th–41st–47th

For total 10 sections calculation: 5th–9th–13th–17th–21st–25th–29th–33rd–37th–41st sections were measured (Fig. 1).

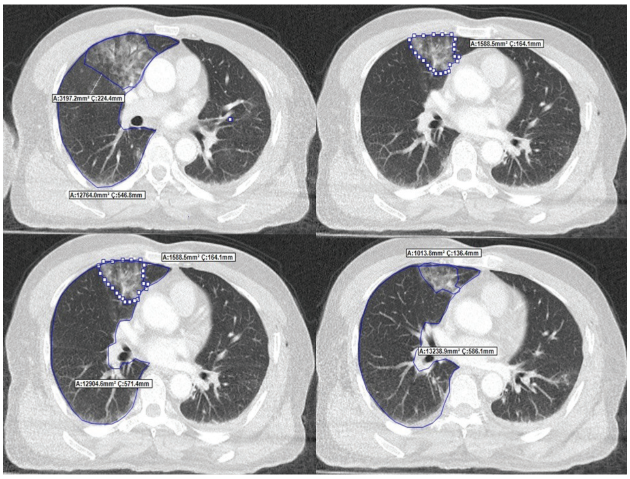

Figure 1
Measurement of lung contusion on the tomography sections with the planimetry method.

The percentage of contusion in different section numbers was calculated as well as the ratio to total lung volume.

NCSS (Number Cruncher Statistics System) 2007 (Kaysville, Utah, USA) program was used for statistical analysis. Descriptive methods (mean, standard deviation, median, frequency, rate, minimum, maximum) were used when evaluating the study variables. Quantitative assessment of normal distribution compatibility was tested using the Shapiro-Wilk test and box pilot graphics. We used Intraclass correlation coefficients (ICC) agreement levels (10) and Bland Altmann plot for the evaluation of contusion measurement agreements. $p < 0.05$ was considered as significant.

Results

The contusion volume was calculated by two independent observers on data from 76 CT images. The mean total time required by the two observers to obtain lung contusion volume using the manual planimetry method was 6.17 ± 3.10 min (range, 4.51–10.3 min). There was no significant difference between the first and second measurements of the first observer ($p > 0.293$) as well as the second observer ($p > 0.278$). There was no significant difference between the first and second observers regarding contusion volume ($p > 0.33$). The mean CE was 1.45 ± 0.52% (min–max, 0.56–3.22) for all the estimations.

Table 1 Lung contusion volume

Contusion area	N	Min-Max	Mean±SD	Median
Whole sections contusion volume%	76	8,20-74,20	34,23±17,56	30,8
6 sections measurement %	76	5,99-62,39	27,98±15,05	25,2
8 sections measurement %	76	7,60-66,79	30,66±16,07	27,1
10 sections measurement %	76	7,97-70,34	32,47±16,97	29,1

The mean volume of contusion obtained from all cross-section measurements was 34.23 ± 17.56. In 6, 8, and 10 sections measurements, contusion volume was 27.98 ± 15.05, 30.66 ± 16.07, and 32.47 ± 16.97, respectively (Table 1). When the accuracy rate of contusion measurements made in 6, 8, and 10 sections was examined according to the volume of contusion performed in all sections, it was observed that the difference was 19%, 11%, and 5.8%, respectively.

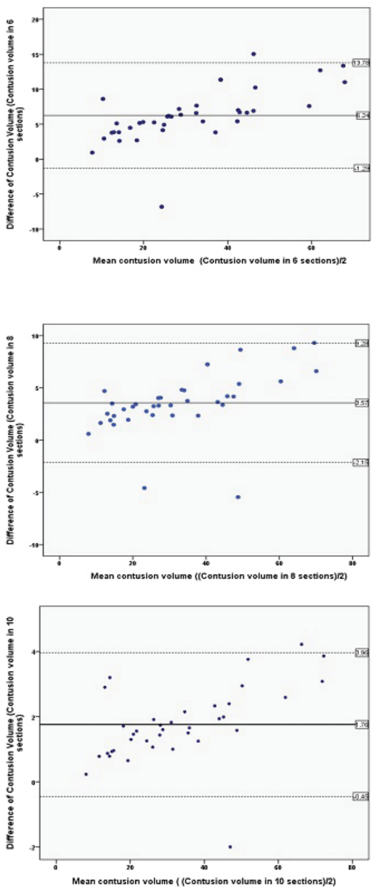

Figure 2
The Bland Altman graphs for 6-8-10 sections.

We observed that there were statistical agreements between whole lung contusion volume measurement and the six, eight, and ten sections measurements (ICC = 0.903; p < 0.001).

The difference of mean was 1.76 units and limits of agreement were −0.45 and 3.96 for the Bland Altman plot, where the horizontal line demonstrates the mean of all lung contusion measurements and 10 sections of volume measurements, and the vertical line demonstrates the difference between measurements. As a result, the value obtained from 10 sections measurement was 1.76 units smaller than all lung measurements, while that for the 8 and 6 sections measurements were 3.57 units and 6.24 units smaller than the whole section's volume measurement (Table 2).

When we examined the Bland Altman graphs, it is seen that the mean difference obtained from the 10 sections is smaller than that obtained from the 6 and 8 sections measurements, and the confidence interval is narrower (Fig. 2). Therefore, we can say that the 10 sections measurement gives the closest evaluation to all lung contusion measurements with approximately 95% accuracy ratio.

Discussion

Sectional radiological images are used for volume estimation in the Cavalieri principle. The cut surface areas of sections are multiplied by the section thickness to estimate the volume. Point counting and planimetry are methods for volume calculation using the cut surface area based on the Cavalieri principle. Planimetry involves manually tracing the boundaries of objects on sections. The sum of measured areas of sections obtained by planimetry is multiplied by the section thickness, and the volume of the structure is estimated (11, 12).

Table 2 Distribution of the Ranges of Contusion Volumes for Bland Altman

Contusion volume %	Difference mean±SD	%95 CI lower –upper limit
Whole sections-6 sections	6.24±3.84	-1.29-13.78
Whole sections-8 sections	3.37±2,92	-2,15-9.28
Whole sections-10 sections	1.76±1,13	0.45-3.96

Pulmonary contusion is an important risk factor for pulmonary dysfunction, which results from intrapulmonary hemorrhage and alveolar edema. It has been shown that more than 20% of lung contusion volume increases the risk of ARDS and length of intensive care unit follow-up period (1, 4, 13, 14). When the anatomic extent of the contused lung increases, the degree of hypoxemia increases (6). There are also studies in the literature opposing this view. According to a study, there was no correlation between number of rib fractures and pulmonary contusion, and between pulmonary contusion and the development of ARDS. And also, the mortality with pulmonary contusion was 8.2% as opposed to a mortality of 5.1% in patients without pulmonary contusion (15). In this study, it is seen that contusion measurements were made with the semi-automated method in about 8% of patients. CT is very sensitive for detecting pulmonary contusion; as the contusion volume increases, there is a correlation with clinical outcomes (3, 16, 17).

Accurate quantification of pulmonary contusion is a problem for physicians. Computerized three-dimensional reconstruction of the contused lung on chest CT and computer programs are used to measure contusion volume (13). Accurate quantification of lung contusion volume may guide to understand the patients' risk for hypoxia, hypoxemia, pneumonia and adult respiratory distress syndrome and the need for mechanical ventilation. Considering our results, there was no statistical difference between interreader and intrareader variation results. We think that the manual planimetry method has reproducibility in the quantification of pulmonary contusion volume. It is an accurate, easy, quick, and replicable method to calculate the amount of lung contusion on CT scan imaging.

The Cavalieri method is the most used stereological method to estimate the volume of structures using tomographic and histological slices (18) Eric et al. (19) showed that the Cavalieri principle or 3D breast reconstruction has a similar accuracy for breast volume estimation. The volume measurements were not done in a single tomographic slice. We performed volume measurements in whole lung and contusion areas.

The planimetry method was used in liver tumor volume estimation because of its speed (20). These methods are based on the geometric properties of three-dimensional structures without causing bias. They provide reliable, efficient, reproducible, fast, and quantitative data for volumetric measurements.

As shown in the literature, after the pathological areas are determined and marked, measurements are performed in each section using a computer program with a 3D-reconstruction technique (1, 21). Therefore, financial resources are needed to have a 3D-reconstruction computer software program. Unlike this program, a physician can measure the pathological and normal areas on tomography sections by the manual planimetry method with systematic random sampling and determine the ratio of the contusion volume. In this way, which is faster to do as you gain experience, there is no need to measure all lung areas.

All tomography sections are measured by the manual planimetric method, and all the obtained results are summed up. The total volume is calculated by multiplying by the section thickness. In our study, we measured a smaller number of sections by systematic random sampling, and we achieved 95% accuracy by making fewer measurements.

Trauma scoring systems are changing and being updated according to studies and consensus reports. In the recent thoracic trauma scores used today, lung contusion is scored according to the anatomical location and the number of lobes in which it is located. However, in these scoring systems, the amount of contusion is determined only according to lobar involvement without a numerical value. In the recent thoracic trauma scoring systems, diffuse pulmonary contusion in one lobe, where the risk of complications and respiratory distress is higher, scores less than contusion in small areas in two lobes (14). Lung contusion volume or ratio is not evaluated in these systems. We believe that with the use of this method of calculation, proportional and volumetric values will be used in future trauma scores rather than the location of the lung contusion and the number of lobes in which it is located. We think that with these measurements, the severity of lung contusion assesses in more detail in future trauma severity scores. In addition, we hope that significant speed and time will be gained in making the decision of intensive care hospitalization together with clinical evaluation.

This situation creates problems in patient evaluation and the use of the same academic language. In future thoracic trauma scoring systems, scoring by giving a more specific mathematical value besides the location will provide a more accurate approach to the clinical evaluation of the patients and the decisions on intensive care hospitalization. In this study, contusion rates were shown mathematically, quickly, and with high accuracy. All radiological programs with area selection and calculation could be used for measurement without any specific software program.

Considering this information, we think that the use of this method will support all units dealing with trauma, academic publications, and new trauma scores.

Hemothorax and pneumothorax are accepted as life-threatening clinical conditions, but the effect of lung contusion on mortality must be investigated in a large sample size. Accurate and easy quantification of pulmonary contusion volume may help to identify the trauma patients with high risk. In a tomographic examination, lung areas can be examined in 45 to 60 sections on average. Instead of whole sections measurement, we showed that 10 sections of lung and contusion areas measurements provide approximately 95% accuracy. With this measurement technique, contusion rates can be measured easily and quickly.

The limitation of our study was that we did not use any injury or trauma score to show the clinical status of patients. In addition, we did not investigate any relationship between these measurements and mortality. We examined the specific part of trauma and not all the trauma components. The reason why the article is written in a detailed technical expression is to ensure that everyone who works on this subject can repeat it without making mistakes in the direction of the method. We attempted to investigate the method of volumetric pulmonary contusion measurement.

In conclusion, lung contusion volume can be objectively evaluated using the manual planimetry method with systematic random sampling without whole lung area measurement on CT with high interobserver and intraobserver agreement.

Conflict of Interest Statement
The authors have no conflicts of interest to declare.

Ethical Approval
Ethical approval was obtained from Manisa Celal Bayar University Medical Faculty Health Sciences Ethics Committee (approval accept number: 11/11/2020/20.478.486). The study was conducted in line with the principles of the Helsinki Declaration.

Consent to Participate and Publish
No need due to retrospective design.

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Availability of Data and Materials
Data are available on request from the authors.

Authors Contributions
Contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work are provided equally by all authors.

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