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Diagnostic performance of multislice computed tomography to detect diaphragmatic injuries in hemodynamically stable patients. Preliminary results

Rendimiento diagnóstico de la tomografía computarizada multidetector para la identificación de heridas diafragmáticas en pacientes hemodinámicamente estables. Resultados preliminares

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Abstract

Introduction: Diaphragmatic injuries are a common finding in patients with penetrating thoracoabdominal trauma. Their diagnosis requires exploration through open or laparoscopic surgery. However, multislice computed tomography (MSCT) emerges as a useful noninvasive tool for this purpose.
Objective: To determine the diagnostic performance of MSCT for detecting diaphragmatic injuries in hemodynamically stable patients with penetrating thoracoabdominal trauma.
Materials and methods: Prospective study conducted on 119 patients treated at the Hospital Universitario del Valle, Cali, Colombia, between March 2012 and June 2015. In order to evaluate the diagnostic performance of MSCT, the results obtained through this test were compared with those reported in the reference test (open surgery). Two readings of the imaging studies were performed by 2 radiologists. Intra- and interobserver agreement on the MSCT readings were analyzed using the Fleiss' Kappa coefficient.
Results: MSCT had sensitivity and specificity of 94.4% and 46.8%, respectively. Its positive (PPV) and negative (NPV) predictive values were 44.7% and 94.8%, respectively. The positive likelihood ratio (LR+) was 1.7765, and the negative likelihood ratio (LR-) was 0.1186. Regarding interobserver agreement, Fleiss' Kappa coefficient between the first reading of both radiologists was 0.4425.
Conclusions: MSCT specificity for diagnosing diaphragmatic injuries found in this study differs considerably from that reported in the literature. Considering the sensitivity, PPV and LR- values obtained in the present study, MSCT could be an important tool for the management of these patients since conservative treatment may be used in patients whose diaphragmatic injuries are not detected with this type of scan.
Keywords: Tomography; Tomography, X-Ray Computed; Tomography, Spiral Computed; Hernia, Diaphragmatic, Traumatic; Wounds, Gunshot (MeSH).

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Resumen

Introducción. Las heridas diafragmáticas son un hallazgo común en pacientes con trauma toracoabdominal penetrante. Su diagnóstico requiere exploración mediante cirugía abierta o laparoscópica. Sin embargo, la tomografía computarizada multidetector (TCMD) surge como una herramienta no invasiva útil para este propósito.
Objetivo. Determinar el rendimiento diagnóstico de la TCMD en la identificación de heridas diafragmáticas en pacientes con trauma toracoabdominal penetrante hemodinámicamente estables.
Materiales y métodos. Estudio prospectivo realizado en 119 pacientes atendidos en el Hospital Universitario del Valle, Cali, Colombia, entre marzo de 2012 y junio de 2015. Para evaluar el rendimiento diagnóstico de la TCMD, los resultados obtenidos mediante esta prueba fueron comparados con los reportados por el test de referencia (cirugía abierta). Se realizaron 2 lecturas de los estudios de imagen por 2 radiólogos. La concordancia intra e interobservador respecto a la lectura de las TCMD se analizó mediante el coeficiente Kappa de Fleiss.
Resultados. La TCDM tuvo una sensibilidad y especificidad de 94.4% y 46.8%, respectivamente. Sus valores predictivos positivo (VPP) y negativo (VPN) fueron 44.7% y 94.8%, respectivamente. La razón de verosimilitud positiva (LR+) fue 1.7765, y la razón de verisimilitud negativa (LR-), 0.1186. Respecto a la concordancia interobservador, el coeficiente Kappa de Fleiss entre la primera lectura de ambos radiólogos fue de 0.4425.
Conclusiones. La especificidad de la TCMD para el diagnóstico de heridas diafragmáticas encontrada en el presente estudio difiere considerablemente de lo reportado en la literatura. Teniendo en cuenta la sensibilidad, el VPN y la LR- obtenidos en el presente estudio, la TCMD podría constituir una herramienta importante en el manejo de estos pacientes, ya que en aquellos en los que no se detecte herida diafragmática mediante este tipo de tomografía podría considerarse un manejo conservador.
Palabras clave: Diafragma; Traumatismos abdominales; Tomografía; Tomografía por rayos x; Tomografía computarizada por rayos x (DeCS).

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Introduction

Thoracoabdominal trauma, whether blunt or penetrating, accounts for 5.8% of all trauma cases.[1] In turn, the incidence of diaphragmatic injuries in patients with chest or abdominal trauma ranges from 4% to 6%.[2-4]

Studies conducted in developed countries show that diaphragmatic injuries are more frequent in penetrating trauma (67%) than in blunt trauma (33%)[5] and that they are an important cause of death in people under 44 years of age.[6] Such findings are similar to those found in Africa and Latin America, where the incidence of this type of penetrating trauma injury is between 43% and 83%.[7-9] In Colombia, previous studies reported that penetrating trauma, either by sharp weapons or firearms, causes diaphragmatic injuries more frequently (96%) than blunt trauma (3.7%).[10]

Mortality in patients with diaphragmatic injuries varies. Some publications have reported that, depending on the evolution of the trauma over time, it may be 11-37% for acute events and 30-66% for cases with delayed diagnosis, which is associated with intestinal obstruction due to ventral herniation.[4,11]

Having the prevention of delayed diagnoses in mind, protocols for the management of penetrating thoracoabdominal injuries indicate that an open or laparoscopic examination should be performed in all cases of left or right anterior wounds.[1,12] However, imaging is an alternative for detecting and characterizing diaphragmatic injuries that has the advantage of being a non-invasive, low-risk method.

Usually, chest x-ray is considered a routine examination in patients with thoracoabdominal trauma; however, its accuracy for identifying diaphragmatic injuries does not exceed 50% and varies depending on the severity and location (left or right side) of the trauma.[6,12]

Initial studies with single-row detector helical CT tomographs showed variable results in the identification of diaphragmatic injuries. In penetrating trauma, sensitivity and specificity were 84% and 77%, respectively,[13] while in blunt trauma, these values were 66% and 100%, respectively.[14] The variability of these results suggests that the differential performance of the helical CT diagnostic method depends on the type of trauma.

A prospective study[15] and a retrospective study,[16] both performed with 4- and 16-detector-row tomographs, found accuracy values of 77% (sensitivity: 87%, specificity: 72%) and 95% (sensitivity: 94% specificity: 95%), respectively, for the identification of diaphragmatic injuries. However, none of these studies were carried out with 64-row MSCT or using regular statistical analysis. Moreover, although it is assumed that patients were hemodynamically stable since they underwent the imaging study, no explicit reference is made to this condition.

Taking into account the above, the objective of this study was to determine the diagnostic performance of MSCT for identifying diaphragmatic injuries in hemodynamically stable patients with penetrating thoracoabdominal trauma.

Materials and methods

Study type

A prospective study was carried out.

Study population

The study population consisted of all patients with penetrating thoracoabdominal trauma and hemodynamically stable who were treated at the Hospital Universitario del Valle in Cali, Colombia, between March 2012 and June 2015.

For sample selection, patients who voluntarily agreed to undergo a non-contrast MSCT scan and those who had undergone a chest CT, a non-contrast abdominal CT scan, or an IV contrast or oral contrast computed tomography that included the upper abdomen during their hospital stay, regardless of the reason, were included.

Pregnant women and patients with a history of congenital or traumatic diaphragmatic hernia were excluded, as well as patients in whom the penetrating injury did not involve the thoracoabdominal area or were wounded on the posterior right side.

During the study period, 140 patients were considered eligible, but 21 were excluded since they did not meet the inclusion criteria because they were transferred to another healthcare center or because it was not possible to perform MSCT before surgery. The study was finally carried out in 119 patients.

Procedures

MSCT was performed using a General Electric LightSpeed VCT CT system (General Electric Healthcare, GE Medical Systems, Milwaukee, WI, USA) with 64 rows of detectors. Reconstructed submillimeter acquisitions were performed on slices <3mm thick; information was stored in the institution's picture archiving and communication system in DICOM format and in individual compact discs that were delivered to the study physicians for analysis.

Studies were read independently and blindly by a radiologist (radiologist 1) and a second-year resident of radiology (radiologist 2) who did not have access to the gold standard test result (surgery). It should be noted that when the study started in 2012, radiologist 2 was a second-year resident, but he had already been granted his degree as a radiologist by the time the study was completed.

None of the readers were informed about the patients' personal details, official MSCT reading (if applicable), or definitive diagnosis of the injury. Similarly, the treating physicians were not informed about the radiological interpretation of the results of the diaphragm examination given the blinded nature of the study design.

MSCT interpretation was performed on Apple iMac 2013 computers (Apple Inc., Cupertino, CA, USA), which had monitors with a resolution of 2560x1440 pixels and the OSIRIX Lite (Pixmeo SARL-SWISS) image processing application, which has navigation and visualization tools to adjust the window/level and zoom and render the multiplanar reconstruction. These tools were available for all images and could be used at the observer's discretion to improve interpretation.

Before starting with the research, and based on literature, it was established that the following radiological signs were positive for diaphragmatic injury:

Herniation of abdominal organs: Abdominal organs are directly visualized in the chest cavity; it is considered the most specific sign of diaphragmatic injury.

Discontinuous diaphragm sign: A directly observable defect (e.g., perforation) is identified along the wound path.

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Contiguous injury sign: It is defined as an injury to contiguous organs, which is observed on both sides of the diaphragm and involves a transdiaphragmatic wound.

Dependent viscera sign: On the left side, abdominal contents (usually stomach or intestine) lie directly on the posterior costal wall due to lack of diaphragmatic containment, while it is visualized when the upper third of the liver abuts the posterior ribs on the right side.

Collar sign: It refers to the constriction of a hollow viscera or peritoneal fat that is observed through the diaphragmatic injury.

Diaphragmatic thickening sign: It is usually caused by a hematoma, but it does not allow distinguishing between a diaphragmatic rupture or a hemorrhage produced by a lesion of adjacent structures that reaches the diaphragm and can simulate a diaphragmatic hemorrhage; therefore, it is a non-specific sign.

The presence of any of these signs defined a test as positive, and two or more of them could coexist in the same patient. The CT scan results read by the licensed radiologist (radiologist 1) were compared with surgical or laparoscopic findings to establish sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), positive likelihood ratio (LR+) and negative likelihood ratio (LR-).

The diagnostic performance of the test was also independently calculated based on the description given by the radiology resident (radiologist 2). Both readers made a second review of each study blindly with a difference of two months. For the main variables, intraobserver agreement (agreement between interpretations when evaluating images of the same patient at different times) and interobserver agreement (agreement between radiologists when interpreting the results of the same patient) were evaluated; the second reading report was used for the latter calculation.

On the other hand, Fleiss' Kappa coefficient was used to analyze intra- and interobserver agreement with respect to MSCT readings.[17] Results were classified, according to Altman[18], as very good (κ =1.0-0.81), good (κ=0.8-0.61), moderate (κ=0.6-0.41), regular (κ=0.4-0.21), and poor (κ<0.2). STATA 13.0 (Stata Corp, College Station, TX, USA) was used to perform these calculations.

Ethical considerations

The study took into account the ethical principles for medical research involving human subjects established by the Declaration of Helsinki[19] and the scientific, technical and administrative standards for health research of Resolution 8430 of 1993 of the Ministry of Health of Colombia.[20] The research was approved by the Ethics Committee of the Faculty of Health of the Universidad del Valle according to Minutes 084011 of May 3, 2011. All participants signed an informed consent form prior to their participation.

Results

Descriptive analysis of the clinical and sociodemographic characteristics of the patients

The average age of the participants was 23 years; 90.75% (n=108) were men, 48.73% (n=58) identified themselves as mestizos, and 86.55% (n=103) were from Cali. The first patient was included in the study on March 11, 2012, and the last patient on June 7, 2015.

Regarding vital signs reported upon hospital admission, average systolic blood pressure of 110 mm Hg, heart rate of 88 bpm, respiratory rate of 20 brpm, and Glasgow Coma Scale score of 15 were reported. The most frequent mechanism of injury was gunshot wound with 85.71% (multiple wounds 48.74% and single wound 36.97%). The wound was found on the left side in 55.46% of cases, on the right side in 26.86%, and it was bilateral in 17.65%. Of the study population, 6.72% had or reported a history of thoracoabdominal trauma.

During the study, only 3 deaths were reported among participants, and only 1 of these cases had a diaphragmatic injury.

MSCT performance

Based on the results of the second reading by radiologist 1, the diagnostic performance of the test was analyzed, obtaining the following results: 34 patients with positive MSCT and positive confirmatory surgery (true positive), 37 patients with negative MSCT and negative confirmatory surgery (true negative), 42 patients with positive MSCT and negative confirmatory surgery (false positive) and 2 patients with negative MSCT and positive confirmatory surgery (false negative); similarly, 4 patients were classified with non-diagnostic MSCT for various reasons, such as incomplete study or study with movement.

The performance estimates and diagnostic capacity of MSCT to identify diaphragmatic injuries in hemodynamically stable patients with penetrating thoracoabdominal wounds were determined by statistical analysis that considered the results assigned by radiologist 1 (Table 1).

Table 1. Diagnostic test performance for all findings reported by radiologist 1.

Injury	Surgery	Rad 1	TP	TN	FP	FN	PPV	NPV	Sensitivity	Specificity	AUC	LR+	LR-
Diaphragmatic injury	36	76	34	37	42	2	0.4474	0.9487	94.44%	46.84%	0.7064	1.7765	0.1186
Pleural effusion	8	92	8	27	84	0	0.0870	1.0000	100.00%	24.32%	0.6216	1.3214	0.0000
Lung contusion	12	76	11	42	65	1	0.1447	0.9767	91.67%	39.25%	0.6546	1.509	0.2123
Pneumothorax	23	71	18	43	53	5	0.2535	0.8958	78.26%	44.79%	0.6153	1.4176	0.4853
Hemoperitoneum	40	78	37	38	41	3	0.4744	0.9268	92.50%	48.10%	0.703	1.7823	0.1559
Liver injury	32	35	27	79	8	5	0.7714	0.9405	84.38%	90.80%	0.8759	9.1758	0.1721
Splenic injury	16	19	9	93	10	7	0.4737	0.9300	56.25%	90.29%	0.7327	5.7937	0.4845
Kidney injury	17	32	15	85	17	2	0.4688	0.9770	88.24%	83.33%	0.8578	5.2941	0.1412
Hollow viscus injury	33	20	14	80	6	19	0.7000	0.8081	42.42%	93.02%	0.6772	6.0808	0.6189
Fracture	7	79	6	39	73	1	0.0759	0.9750	85.71%	34.82%	0.6027	1.3151	0.4103
Pneumoperitoneum	4	29	1	87	28	3	0.0345	0.9667	25.00%	75.65%	0.5033	1.0268	0.9914

Rad 1: Radiologist 1; TP: true positives; TN: true negatives; FP: false positives; FN: false negatives; PPV: positive predictive value; NPV: negative predictive value; AUC: area under the curve; LR+: positive likelihood ratio; LR-: negative likelihood ratio.
Source: Own elaboration.

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It was established that MSCT has a diagnostic performance of 94.44% (sensitivity) to identify diaphragmatic injuries and 46.84% (specificity) to rule out their presence. When a test is positive, 44.74% of the patients are sick (PPV), but when a test is negative, 94.87% of the patients are healthy (NPV). LR+ in sick patients compared with healthy patients was 1.78, which is considered regular, whereas LR- in healthy patients compared with sick patients was 0.12, which is considered good. Therefore, despite its good sensitivity, it was generally established that MSCT has better diagnostic performance for classifying healthy individuals.

With respect to the other reported findings, MSCT has good performance for the diagnosis of healthy and sick patients with liver and kidney injury.

Agreement analysis

When evaluating agreement between the first and second reading by radiologist 1, it was found that there was agreement in 89.57% of the patients for the diagnosis of diaphragmatic injury and that the kappa coefficient between both readings was 0.7809 with a variation of 9.17%. Therefore, it was considered that the agreement ratio was good and was not random (p<0.0001) (Table 2).

Table 2. Radiologist 1 intraobserver agreement analysis for all reported findings.

Variables	% of agreement	% agreement expected	Kappa	p-value
Diaphragmatic injury	89.57%	52.38%	0.7809	<0.0001
Pleural effusion	94.12%	64.46%	0.8345	<0.0001
Lung contusion	75.63%	49.42%	0.5182	<0.0001
Pneumothorax	90.76%	52.68%	0.8047	<0.0001
Hemoperitoneum	84.03%	52.48%	0.6640	<0.0001
Liver injury	95.80%	58.13%	0.8996	<0.0001
Splenic injury	91.60%	74.31%	0.6729	<0.0001
Kidney injury	96.64%	60.68%	0.9145	<0.0001
Hollow viscus injury	88.24%	72.04%	0.5793	<0.0001
Fracture	85.71%	56.20%	0.6739	<0.0001
Pneumoperitoneum	87.39%	59.26%	0.6906	<0.0001

Source: Own elaboration.

In general, for secondary findings, agreement between the first and second reading by radiologist 1 had good and very good agreement; only pulmonary contusion (51.82%) and fracture (57.93%) had moderate agreement. On the other hand, the best percentage of agreement was associated with pleural injury (91.45%), followed by liver injury (89.96%) and pleural effusion (83.45%). None of the agreements for the secondary findings were random.

When evaluating agreement between the first and second reading by radiologist 2, it was found that there was agreement in 94.02% of the patients for the diagnosis of diaphragmatic injury and the kappa coefficient between both readings was 0.8694 with a variation of 9.23%. Therefore, it was considered that the percentage of agreement was good and was not random (p<0.0001).

Similarly, in general, for secondary findings, agreement between the first and second reading by radiologist 2 had a good agreement, except for the finding of hollow viscus injury, which had a moderate Kappa agreement (κ=0.59). None of the agreements for secondary findings were random (p<0.0001).

Finally, when evaluating interobserver agreement, i.e., between the reading by radiologist 1 and the reading by radiologist 2, the percentage of agreement was 69.91% for the main finding of diaphragmatic injury and the kappa coefficient between the first reading of both radiologists was 0.4425 with a variation of 8.01%. Therefore, a moderate agreement percentage that was not random was considered (p<0.0001). Secondary findings had good agreements with κ>0.6 in almost all the findings, except for hollow viscus injury (κ=0.4808) and pneumoperitoneum (κ=0.5545) (Table 3).

Table 3. Interobserver agreement analysis of radiologist 1 and radiologist 2 for all findings.

Variables	% of agreement	% agreement expected	Kappa	p-value
Diaphragmatic injury	69.91%	46.03%	0.4425	<0.0001
Pleural effusion	91.60%	62.16%	0.7779	<0.0001
Lung contusion	83.19%	55.24%	0.6245	<0.0001
Pneumothorax	91.60%	52.19%	0.8242	<0.0001
Hemoperitoneum	81.51%	50.65%	0.6254	<0.0001
Liver injury	93.28%	59.17%	0.8354	<0.0001
Splenic injury	94.12%	76.03%	0.7546	<0.0001
Kidney injury	93.28%	63.01%	0.8183	<0.0001
Hollow viscus injury	84.03%	69.25%	0.4808	<0.0001
Fracture	89.08%	55.09%	0.7567	<0.0001
Pneumoperitoneum	83.19%	62.28%	0.5545	<0.0001

Source: Own elaboration.

Agreements and disagreements between radiologists were described for each of the reported findings; in the case of diaphragmatic injury, for example, 41 agreements were obtained for 72 positive readings of radiologist 1 and 42 positive readings of radiologist 2.

There were 34 disagreements in total: 33 in which the reading was positive for radiologist 1 but negative for radiologist 2, and 1 in which the reading was negative for radiologist 1 and positive for radiologist 2 (Table 4).

Table 4. Number of inter-observer agreements between radiologist 1 and radiologist 2 for all findings.

Variables/Rad 1-Rad 2	Yes-Yes	No-No	Yes-No	No-Yes
Diaphragmatic injury	41	38	33	1
Pleural effusion	84	25	8	2
Lung contusion	69	30	7	13
Pneumothorax	67	42	4	6
Hemoperitoneum	59	38	19	3
Liver injury	30	81	5	3
Splenic injury	13	99	6	1
Kidney injury	25	86	7	1
Hollow viscus injury	13	87	7	12
Fracture	72	34	7	6
Pneumoperitoneum	20	79	9	11

Source: Own elaboration.

Reading performance

The contiguous injury sign (on both sides of the diaphragm) was the one that contributed most to the classification of patients as positive for diaphragmatic injury, as it was found in 73 of them based on the interpretation of radiologist 1. This showed that the diagnostic performance of this specific sign was very similar to that of MSCT as a whole, with sensitivity of 86.8%, specificity of 50.6%, PPV of 45%, NPV of 89%, LR+ of 1.759 and LR- of 0.2599 (Table 5).

For radiologist 2, the most common sign in the patients studied was also contiguous injury, but the discontinuous diaphragm sign was also highly frequent (Table 6).

Table 5. Sensitivity analysis according to radiological signs as interpreted by radiologist 1.

Signs	Surgery	Rad 1	TP	TN	FP	FN	PPV	NPV	Sensitivity	Specificity	AUC	LR+	LR-
Herniation of abdominal viscera	38	4	3	80	1	35	0.7500	0.6957	7.89%	98.77%	0.5333	6.395	0.9326
Collar sign	38	4	4	81	0	34	1.0000	0.7043	10.53%	100%	0.5526	-	0.8947
Dependent viscera sign	38	3	1	79	2	37	0.3333	0.6810	2.63%	97.53%	0.5008	1.066	0.9983
Contiguous injury sign	38	73	33	41	40	5	0.4521	0.8913	86.84%	50.62%	0.6873	1.759	0.2599
Discontinuous diaphragm sign	38	16	12	77	4	26	0.7500	0.7476	31.58%	95.06%	0.6332	6.395	0.7198
Diaphragmatic thickening sign	38	18	13	76	5	25	0.7222	0.7525	34.21%	93.83%	0.6402	5.542	0.7012

Rad 1: radiologist 1; TP: true positives; TN: true negatives; FP: false positives; FN: false negatives; PPV: positive predictive value; NPV: negative predictive value; AUC: area under the curve; LR+: positive likelihood ratio; LR-: negative likelihood ratio.
Source: Own elaboration.

Table 6. Sensitivity analysis according to radiological signs as interpreted by radiologist 2.

Signs	Surgery	Rad 2	TP	TN	FP	FN	PPV	NPV	Sensitivity	Specificity	AUC	LR+	LR-
Herniation of abdominal viscera	38	1	1	81	0	37	1.0000	0.6864	2.63%	100%	0.5132	-	0.9737
Collar sign	38	3	3	81	0	35	1.0000	0.6983	7.89%	100%	0.5395	-	0.9211
Dependent viscera sign	38	2	0	79	2	38	0.0000	0.6752	0.00%	97.53%	0.4877	0	1.0253
Contiguous injury sign	38	35	23	69	12	15	0.6571	0.8214	60.53%	85.19%	0.7286	4.086	0.4634
Discontinuous diaphragm sign	38	22	21	80	1	17	0.9545	0.8247	55.26%	98.77%	0.7701	44.76	0.453
Diaphragmatic thickening sign	38	4	0	77	4	38	0.0000	0.6696	0.00%	95.06%	0.4753	0	1.0519

Rad 2: radiologist 2; TP: true positives; TN: true negatives; FP: false positives; FN: false negatives; PPV: positive predictive value; NPV: negative predictive value; AUC: area under the curve; LR+: positive likelihood ratio; LR-: negative likelihood ratio.
Source: Own elaboration.

Discussion

Considering the available literature on the diagnostic performance of MSCT to identify diaphragmatic injuries, it was expected that such a study could somehow replace the different modalities of surgery for screening these injuries in patients with thoracoabdominal trauma. However, although the present study determined that this test is sensitive (94%), which is consistent with what has been reported in the literature,[15,16,21-23] it is not specific (46%). However, thanks to its high negative predictive value (94%), MSCT could safely report that a patient is negative for diaphragmatic injury.

The present study also had a distinctive characteristic found in similar studies, which is its prospective and double-blind nature, making this scenario comparable to the reality of medical practice but without interfering in decision-making regarding surgical confirmation of tomographic findings.

The contiguous injury sign proved to be the most consistent for both radiologists when validating whether there was a diaphragmatic injury or not; these results are similar to those described in previous studies.[15,16,21] It is worth noting that this sign is one of the least complex at the time of interpreting the CT scan since it only requires observation of a lung injury and a lesion of the upper abdomen to determine its positivity. Furthermore, it does not require a thorough evaluation of the diaphragm and had a sensitivity of 86% for radiologist 1, a specificity of 85% for radiologist 2 and, most importantly, LR+ of 1.75 and 4, respectively. This indicated that in patients with probability of diaphragmatic injury before undergoing the test due to risk factors, the presence of this sign increases the likelihood of presenting this type of injury and surgical or laparoscopic therapeutic procedures should be prioritized in this type of patient.

From an investigative point of view, the results, databases, and imaging bank obtained for the present study will allow moving forward in the search for heterogeneity factors that may affect the interpretation of MSCT and establish strategies or propose a methodology for radiologists to interpret diaphragm MSCTs in a sequential manner, using a checklist, to improve interobserver agreement.

Similarly, it is possible to perform a second analysis in which a third reader resolves disagreements between radiologist 1 and radiologist 2, thereby obtaining diagnostic performance of the method rather than of the individual reading the studies.

Conclusions

Sensitivity of MSCT for the diagnosis of diaphragmatic injuries found in the present study is similar to that reported in the literature, but its specificity differs significantly from that stated in previous investigations. However, the good intra- and interobserver agreement values obtained allowed demonstrating the consistency of this imaging examination.

In this regard, taking into account the sensitivity, NPV and LR- values obtained in the present study, it is concluded that MSCT may be a useful tool to treat hemodynamically stable patients with penetrating thoracoabdominal trauma since conservative management could be considered in patients in whom diaphragmatic injury is not detected by this type of CT scan.

Conflicts of interest

None stated by the authors.

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