

Mild Left Diaphragmatic Injuries in the Thoracoabdominal Penetrating Traumas: Diagnostic Efficacy of Computed Tomography vs. Laparoscopy

Mohammad Hadi Niakan¹, Farzad Dalfardi², Ali Tajaddini³, Elham Mohajeri⁴, Saeid Esmailian^{4*}

¹Trauma Research Center, Shahid Rajaee (Emtiaz) Trauma Hospital, Shiraz University of Medical Sciences, Shiraz, Iran

²Fellowship Resident of Vascular Surgery, Department of General Surgery, School of Medicine, Shiraz University of Medical Sciences, Shiraz, Iran

³Department of General Surgery, School of Medicine, Shiraz University of Medical Sciences, Shiraz, Iran

⁴Health Policy Research Center, Institute of Health, Shiraz University of Medical Sciences, Shiraz, Iran

*Corresponding author:

Esmailian Saeid

Department of Radiology, Health Policy Research Center, Institute of Health, Shiraz University of Medical Sciences, Shiraz, Iran. Tel: +989120463698
E-mail: esmailian@sums.ac.ir

Received : January 07, 2022

Published : January 17, 2023

ABSTRACT

Background: Penetrating Diaphragmatic trauma injuries were low frequent and important thoracoabdominal injuries. Among stable mild injuries, there was controversy in their management. This study was designed to investigate the diagnostic efficacy of computed tomography (CT) for the detection of diaphragmatic injury in cases undergoing diagnostic and therapeutic laparoscopic surgery in the left thoracoabdominal penetrating injuries. **Methods:** The study was a retrospective cross-sectional study. Thirty-one stable normal imaging patients with penetrating thoracoabdominal injury between January 2021 to January 2022 referred to Shiraz Trauma center were included. CT scan images and laparoscopic surgery results were reviewed. Two trained, blinded Radiologists reviewed the Patient's images separately. All findings were entered into a pre-designed checklist. **Results:** 31 male patients with a mean age of 30.58 ± 14.43 years were admitted to the ICU. The mean ISS was 10.71 ± 4.32 . The chest tube was inserted for 23 (74.1%), and the mortality rate was zero. Only 6(19.4%) patients had positive laparoscopic 17 patients had positive CT scans. curled sign was the most finding 16(51.61%), Band sign 3(10%), collar signs 1(3.2%) and dangling sign 1(3.2%) only one %patient showed a positive collar sign. And only one dangling sign; in addition, the band sign 3 (10%) of the patients. All of them were associated with the curled sign. **Conclusions:** CT scans among Mild left penetrating Diaphragm Injuries patients had Sensitivity of 85.7% and specificity of 56.00%. Moreover, Curled diaphragm sign was the most frequent Indirect Finding.

Keywords: Diaphragmatic injury, thoracoabdominal penetrating traumas, computed tomography, Laparoscopy

BACKGROUND

Traumatic diaphragmatic injuries are defined as damage to the muscle sheet between the thoracic and abdominal space due to penetrating or blunt or iatrogenic injuries [1]. Post-penetrating trauma Diaphragmatic injuries prevalence was reported between 0.8% to 15% or more in young male patients [2]. Missed diaphragmatic injuries may gradually enlarge over time and later appear with a chronic diaphragmatic hernia [3]. These hernias have a high tendency to become complicated due to intestinal potential morbidity rate of 30% and mortality rate as high as 10% obstruction or strangulation of visceral organs that led to a potential morbidity rate of 30% and mortality rate as high as 10% [4] Managing an asymptomatic patient with a penetrating injury to the thoracoabdominal region should prevent these consequences [5].

These injuries can be diagnosed early but, in many cases, are ignored despite medical imaging tools [3]. Diagnostic procedures include plain chest radiography, upper gastrointestinal contrast examination, fluoroscopic evaluation of diaphragmatic movement, ultrasound, CT scan, Laparoscopy, and video-assisted thoracic surgery (VATS). The most common methods are chest radiography and CT scan [6].

The CT scan with intravenous (IV) contrast evaluates traumatic injuries to the thoracoabdominal region. CT scan findings in traumatic diaphragmatic rupture include diaphragmatic discontinuity (the most common sign), thickening of the diaphragm muscle tissue, organ herniation, dependent viscera sign, dangling diaphragm sign, contiguous injury at either side of the diaphragm, as well as the Collar sign, which is the focal contraction of the abdominal organs (mainly the intestine or stomach) at the site of the hernia [7]. CT scans have been reported to have a sensitivity of 87-61% and a specificity of 72-100% [6].

This study was the most extensive sample size among stable Mild penetrating diaphragmatic Injuries cases. The main goal of this study was to compare the efficiency of CT scan imaging with laparoscopic surgery in diagnosing Mild diaphragmatic injuries in patients with penetrating trauma to the thoracoabdominal region. This study would show if the surgeons could trust and rely on the findings of

a normal CT scan in patients with penetrating trauma to the thoracoabdominal region so that the surgical guidelines will show the appropriate treatment for this type of patient and will save the surgeon time and reduce the complications and the costs imposed on the health and insurance system, in addition, the Sensitivity and specificity of the CT scan for Mild diaphragmatic injuries were estimated.

MATERIALS AND METHODS

The present study is a retrospectively cross-sectional study. Among those who were referred to the Shahid Rajaei (Emtiaz) Hospital, Shiraz, Iran (level 1 trauma center and tertiary referral center for the Fars province hospital affiliated with Shiraz University of Medical Sciences) between January 2021 to January 2022.

All patients referred to Shahid Rajaei Hospital with penetrating thoracoabdominal trauma were included in this study by census Sampling.

Patients who needed emergency surgery (patients with peritonitis, abdominal distention, free gas in the peritoneum, etc.), patients with Right side injuries, Patients with any direct or indirect sign of Diaphragmatic Injuries in First CT scan, patients who were not initially symptomatic but became symptomatic within 24 hours, and the Patient who needed laparotomy and thoracotomy for the other reasons were excluded from the study.

Demographic data, including age, gender, Injury Severity Score (ISS), chest tube insertion, chest radiography findings, the conversion rate of the Laparoscopy to laparotomy, underlying diseases, and the reason for diagnostic-therapeutic interventions was collected by the data collection.

A physician first evaluates patients to assess their hemodynamic status and the presence of symptoms. All the patients with penetrating thoracoabdominal trauma with stable vital signs entered the study and all the patients with severe accompanying injuries in other areas or had unstable vital signs were excluded from the study. Asymptomatic patients who did not require emergency surgery were admitted to the emergency department and underwent a thoracoabdominal CT scan and serial abdominal examination during the first 6 hours.

Imaging of all the patients was performed in a single imaging center by a 16-slice CT scan machine and contrast

injection protocol (Lightspeed GE Medical Systems).

The attending general surgeon or the senior surgical assistant evaluated the CT scans of patients. Patients without any direct imaging findings for diaphragmatic damage (Diaphragmatic outline continuity defect, dangling diaphragm sign, Complete lack of diaphragmatic visualization) or completely normal Imaging, though clinical findings indicated suspected diaphragmatic damage were transferred to the operating room for explorative laparoscopic surgery and possible repair of the diaphragmatic damage.

If diaphragmatic damage was observed in the Patient's Laparoscopy, the type of operation was changed to laparotomy at the same time, and the Patient's diaphragm damage was repaired.

After collecting the laparoscopic information of the patients, all the CT scan imaging of the patients, which were stored in the PACS (Picture Archiving and Communication System), were interpreted and reviewed by Two Radiologist

with experience in trauma by the Use of their national code and blinding the results of laparoscopic surgery. Both radiologists were blinded to each other's assessment results and independently using a pre-designed checklist. The CT scan images were reviewed at one time based on a pre-designed checklist using medical monitors. All the patient imaging findings and their clinical findings were rechecked at last. The radiologic checklist included three categories: indirect findings (Collar sign, Hump sign, Band sign, Dependent viscera sign, Sinus cut-off sign, Abdominal organ disorganization or location), Indirect additional findings (Peritoneal fluid surrounding thoracic organs, Abdominal organs surrounding the fluid or thoracic organs, Pneumothorax or pneumoperitoneum, Hemothorax or hemoperitoneum), and Uncertain findings (Diaphragmatic thickening, Peri-diaphragmatic extravasation of contrasted blood, Reduced diaphragmatic support and Fractured rib). All results retrieved by research conseil. For inter-observer reliability test (Cohen's kappa calculation) was used. Then, the final CT results were determined by their consensus discussion for diagnostic performance analysis.

Table 1: The CT scan data collection checklist according to the diaphragmatic damage [8]

Indirect findings	Definition
Collar sign	Constriction of the viscera within the diaphragmatic defect (i.e., Collar too tight)
Hump sign	The hump shape of the liver herniated through right-sided injury (similar to the collar sign on the left).
Band sign	Linear area of hypoattenuation through the herniated liver
Curled Diaphragm Sign	Irregular diaphragm thickening.
Dangling sign	The free edge of the diaphragm curls inward toward the center of the body.

During this research, the principles of medical ethics and research ethics have been thoroughly observed, and efforts have been made to avoid conflict of interest. No diagnostic or interventional modality was performed outside the standard protocols available in the trauma center for the Patient. All radiographic examinations are routine hospital procedures, and this study only examined their effectiveness and did not incur additional costs for the patients. (Ethics Code: IR.SUMS.MED.REC.1400.012)

Data were analyzed using statistical package for social sciences (SPSS) software (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp). Continuous variables were presented as Mean and standard deviation; categorical variables were presented as counts and percentages. The diagnostic efficacy of the CT scan was evaluated by two statistical criteria of Sensitivity and specificity. Interobserver reliability on CT diagnosis of COVID-19 was evaluated using Cohen's kappa calculation ($\kappa < 0.40$, poor agreement; $0.40 < \kappa < 0.60$, moderate

agreement; $0.60 < \kappa < 0.80$, good agreement; and $\kappa > 0.80$, excellent agreement). Mean \pm standard deviation (SD) and categorical variables are expressed as frequency and percent.

RESULTS

Out of 2418 patients with penetrated trauma, 43 patients with penetrating trauma to the thoracoabdominal area were recorded. At last, 31 patients were finally included in the study according to the inclusion and exclusion criteria.

All patients were male and had a mean age of 30.58 ± 14.43 (mean \pm SD) years, with a maximum of 65 years and a minimum of 15 years. Four patients were admitted to the intensive care unit (ICU) before the operation, and the mortality rate was zero. The mean Injury Severity Score (ISS) was 10.71 ± 4.32 . The minimum number for ISS was four, and the maximum number was 24.

The chest tube was inserted for 23 (74.1%) patients during the treatment process, and 8 (25.8%) patients did not need the chest tube insertion. Finally, only 6 (19.4%) patients

had laparoscopic findings for rupture diaphragm, and Laparoscopy was converted to laparotomy to repair the diaphragm.

Cohen's Kapa value was 0.86. According to the radiological studies, plain graphic images did not have a finding in favor of diaphragm damage. CT scan imaging findings showed no signs of direct findings of diaphragmatic injury. Based on these findings, out of 31 patients, 17 had positive findings. The curled sign was the most radiological finding; only one Patient showed a positive collar sign. Furthermore, only one dangling sign; in addition, the band sign in laparoscopic findings was positive in about 3 (10%) of the patients. All patients with positive collar signs, dangling signs, and also 2 cases of band Signs were associated with the curled sign. It should be mentioned that other radiological findings in the data collection checklist (Table 2) were not detected.

In this study, the Sensitivity of the CT scan based on indirect findings was 85.7% and the specificity was 56.00%. Also, the Sensitivity and specificity of radiological signs were compared in table 2.

Table 2: CT scan findings in the penetrating diaphragmatic injuries

	Frequency	TP*	FP**	sensitivity	specificity	PLR***	NLR****
CT scan	17	6	0	85.7%	56.00%	1.95	0.26
Curled diaphragm sign	16(51.61%)	5	11	83.3%	56.0%	1.89	0.30
Band sign	3(9.6%)	3	0	100%	100%	---	---
Collar sign	1(3.2%)	1	0	100%	100%	---	---
Dangling sign	1(3.2%)	1	0	100%	100%	---	---

*. True Positive **.. False Positive ***. Positive likelihood ratio ****. Negative likelihood ratio

DISCUSSION

Diaphragmatic injuries in asymptomatic patients with Mild left injuries with no direct signs remain one of the most challenging and complex diagnoses without Laparoscopy. These types of patients needed to be better studied, and there were many controversies about them. In addition, in traumatic centers, even at the first level or other levels, there were always some limitations regarding equipment,

OP personnel, trained surgeons, or even time and place. The surgeons and bed managers should decide on their available beds in the EM ward and surgical wards, so Imaging could play a valuable role in deciding the best approach for patients. In most surgical approaches usually, the first imaging modality is a plain X-ray through our experience, and in this study and the result of other similar studies about preoperative X-ray, roll showed undiagnostic results [9] except for finding bowel loops in the Chest cavity, most

of the X-rays were not diagnostic for Diaphragmatic hernia also in our study we could not find any helpful findings for this Mild penetrating cases[10], While, the Sensitivity of the CT scan based on indirect findings in our penetrating cases was 85.7% with the specificity 56.00%. Similar previous studies were reported. CT scan diagnostic sensitivity ranges from 17% to 67%, and the specificity ranges from 42 to 82% for injury detection [8, 11-15]; these high range differences between studies referee to different case selections, different conditions, and different CT scan multidetector. And most of the studies recommended operative intervention could be more helpful for diaphragmatic injuries detection, although, as mentioned before, there were always surgery intervention limitations for evaluation of every individual. since the Positive likelihood ratio and Negative likelihood ratio determined in our study 1.95 and 0.26, Based our findings we suggested in case of absence of any direct findings in CT scan among stable patients and also in the absence of other indirect signs in the CT scan we can trust on CT scan findings and follow patients with Imaging and serial Examination.

The Curled diaphragm sign was the most frequent Indirect Finding 16(51.61%) among our Patient CT scans, So the Curled diaphragm sign has the Sensitivity and specificity as same as Overall CT scan findings in the diagnosis of mild penetrating Diaphragm Injuries. Although we reported 11 cases of False Positive in Curled diaphragm signs, it still was significant findings in these patients. After that, the Band sign, Collar sign, and Dangling sign were observed in three (10%), 1(3.2%), and 1(3.2%) of the cases with no False positive, which made them rare but trustful findings in the Mild penetrating Diaphragm Injuries. These findings were similar to other previous studies [8,15].

The average age of the participants in this project was 30 years, which is consistent with most studies in this area. All participants in the project were male, and this was compatible with the other studies in which the majority of patients were men [16-18].

Using Imaging modalities such as CT scans could lead to avoiding surgical intervention, and only patients with equivocal or positive Imaging findings would proceed to the operation room. Then, the frequency of non-therapeutic and non-necessary laparoscopies and related Complications would be reduced.

Despite reviewing 31 confirmed patient cases, more conclusions, such as multicenter and cumulative studies with long duration, are required to design better conclusions about this condition.

CONCLUSIONS

CT scans among Mild left penetrating Diaphragm Injuries patients had Sensitivity of 85.7% and specificity of 56.00%. Furthermore, Curled diaphragm sign was the most frequent Indirect Finding. In stable patients and completely normal CT scans, non-necessary laparoscopies could be avoided.

ACKNOWLEDGMENTS

We express gratitude to the patients who kindly consented to participate in this thesis work and the publication of this manuscript. This paper is the result of Dalfardi's residency dissertation to obtain the specialty in general surgery, which has been registered with the research project number 21451 in the Vice-Chancellor for Research and Technology Development of Shiraz University of Medical Sciences, School of Medicine, Shiraz Iran.

REFERENCES

1. Eren S, Çiriş F. (2005). Diaphragmatic hernia: diagnostic approaches with review of the literature. *Eur J Radiol.* 54(3):448-59.
2. Neal M. (2013). Abdominal trauma. *The Trauma Manual: Trauma and Acute Care Surgery 4th ed LWW.* 365-367.
3. Reber P, Schmied B, Seiler C, Baer H, Patel A, Buchler M. (1998). Missed diaphragmatic injuries and their long-term sequelae. *J Trauma.* 44(1):183-188.
4. Shaban Y, Elkbuli A, McKenney M, Boneva D. (2020). Traumatic diaphragmatic rupture with transthoracic organ herniation: a case report and review of literature. *Am J Case Rep.* 21:e919442-1.
5. Rambau M, Bhuiyan M. (2021). Missed traumatic diaphragmatic hernia and literature review. *South African Medical Journal.* 111(11b):1152-1154.
6. Panda A, Kumar A, Gamanagatti S, Patil A, Kumar S, Gupta A. (2014). Traumatic diaphragmatic injury: a review of CT signs and the difference between blunt and penetrating injury. *Diagn Interv Radiol.* 20(2):121-128.

7. Mancini A, Duramé A, Barbois S, Abba J, Ageron F-X, Arvieux C. (2019). Relevance of early CT scan diagnosis of blunt diaphragmatic injury: a retrospective analysis from the Northern French Alps Emergency Network. *J Visc Surg.*156(1):3-9.
8. Uhlich R, Kerby JD, Bosarge P, Hu P. (2018). Diagnosis of diaphragm injuries using modern 256-slice CT scanners: too early to abandon operative exploration. *Trauma Surg Acute Care Open.* 3(1):e000251.
9. Mjoli M, Oosthuizen G, Clarke D, Madiba T. (2015). Laparoscopy in the diagnosis and repair of diaphragmatic injuries in left-sided penetrating thoracoabdominal trauma: laparoscopy in trauma. *Surg Endosc.* 29(3):747-752.
10. Stein DM, York GB, Boswell S, Shanmuganathan K, Haan JM, Scalea TM. (2007). Accuracy of computed tomography (CT) scan in the detection of penetrating diaphragm injury. *J Trauma.* 63(3):538-543.
11. Mahajna A, Mitkal S, Bahuth H, Krausz M. (2004). Diagnostic laparoscopy for penetrating injuries in the thoracoabdominal region. *Surg Endosc.* 18(10):1485-1487.
12. Berardoni NE, Kopelman TR, O'Neill PJ, August DL, Vail SJ, Pieri PG, et al. (2011). Use of computed tomography in the initial evaluation of anterior abdominal stab wounds. *Am J Surg.* 202(6):690-696.
13. Kones O, Akarsu C, Dogan H, Okuturlar Y, Dural AC, Karabulut M, et al. (2016). Is non-operative approach applicable for penetrating injuries of the left thoraco-abdominal region? *Turk J Emerg Med.* 16(1):22-25.
14. Leung VA, Patlas MN, Reid S, Coates A, Nicolaou S. (2015). Imaging of traumatic diaphragmatic rupture: evaluation of diagnostic accuracy at a level 1 trauma centre. *Can Assoc Radiol J.* 66(4):310-317.
15. Hammer MM, Flagg E, Mellnick VM, Cummings KW, Bhalla S, Raptis CA. (2014). Computed tomography of blunt and penetrating diaphragmatic injury: Sensitivity and inter-observer agreement of CT Signs. *Emerg Radiol.* 21(2):143-149.
16. Ilhan M, Gök AFK, Bademler S, Cüçük ÖC, Soytaş Y, Yanar HT. (2017). Comparison of single incision and multi incision diagnostic laparoscopy on evaluation of diaphragmatic status after left thoracoabdominal penetrating stab wounds. *J Minim Access Surg.* 13(1):13-17.
17. Ochsner MG, Rozycki GS, Lucente F, Wherry DC, Champion HR. (1993). Prospective evaluation of thoracoscopy for diagnosing diaphragmatic injury in thoracoabdominal trauma: a preliminary report. *J Trauma.* 34(5):704-710.
18. Yucel M, Bas G, Kulalı F, Unal E, Ozpek A, Basak F, et al. (2015). Evaluation of diaphragm in penetrating left thoracoabdominal stab injuries: The role of multislice computed tomography. *Injury.* 46(9):1734-1737.