Surgical Management of Traumatic Diaphragmatic Hernia: a Single Institutional Experience of More Than Two Decades.

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Abstract

Background: We present here our experience with surgical management of traumatic diaphragmatic hernia, trying to find out the era impact of different periods on the outcome and risk factors of mortality.

Methods: A series of 63 patients with traumatic diaphragmatic hernia were referred to us and operated on during March, 1990-August, 2017. The patient records were reviewed and statistically analyzed to demonstrate injury characteristics and to find out optimal treatment strategy, risk factors of death as well as the difference between two periods (1990-2005, 2005-2017) divided by introduction of computed tomography at our institution.

Results: The overall mean age was 31.2±16.3 years old with a female to male ratio of 11/52. The mechanism was penetrating trauma in 19 cases (30.2%), and blunt trauma in 44 cases (69.9%). Two thirds of the patients in the latter period yet none in the former period underwent computed tomography. Ten patients (15.9%), of which 8 in the former and the other 2 in the latter period (p=.042), had late diagnoses. The most commonly used incision was a thoracotomy (n=43, 89.6%). There was no statistical difference in etiology or mortality between the two periods. Univariate analysis showed survivors were younger, and had lesser injury severity scores (ISS) and lower American Association for the Surgery of Trauma (AAST) grade than nonsurvivors. By multiple logistic regression analysis, increased age (odds ratio, 1.275; p=.013) and greater ISS (OR, 1.174; p=.028) were risk factors of death in all patients.

Conclusions: High definition computed tomography has significantly improved the preoperative diagnosis rate. The transthoracic approach could be used in selected cases with traumatic diaphragmatic hernia with good outcomes. Patients with greater ISS and advanced age are at higher risk of death.

Background

Diaphragmatic injuries are not uncommon with rates as high as 5% for patients hospitalized after motor vehicle accidents, and 15% for patients after penetrating injuries to the lower chest and upper abdomen. Almost half of these patients are presenting with traumatic diaphragmatic hernia\(^1\). By virtue of its location between the abdomen and chest, an injured diaphragm is almost always associated with other thoracic or abdominal injuries \(^1\) and potentially life threatening with a high mortality rate.

The advances in trauma diagnosis, critical care and surgery have greatly changed the management of diaphragmatic injuries over the last two decades. Diagnostic modalities included from traditional plain radiographs \(^2\), ultrasonography \(^3\), to computed tomography and diagnostic laparoscopy \(^4\)–\(^6\) and thoracoscopy\(^7\). And surgery has evolved from open thoracotomy and laparotomy to minimally invasive endoscopy procedures. We made this study to summarize the characteristics of traumatic diaphragmatic hernia (TDH) and associated injuries. And to examine the shift in patterns of diagnosis. And we also tried to identify predictors of death in this series of patients with TDH.
Materials And Methods

Data collection

The study was approved by Institutional Review Board of our institution (HCHLL-2018-2) and all methods were performed in accordance with the relevant guidelines and regulations. Informed consent was waived for retrospective nature of the study. The inclusion criteria were patients with TDH who underwent surgical treatment from March 1990 to August 2017 at our institution, a tertiary referral center. Patients who had been surgically treated would be excluded from this study. Specifically, the time span was divided by year 2005, when the CT was introduced at our institution and has changed the diagnostic mode significantly. Patient records, operative reports, and discharge summaries were collected retrospectively to obtain data of patient demographics, type of injury sustained and mechanisms, operative procedures, and survival. We categorized mechanisms of injury as blunt trauma for motor vehicle collision (MVC), crush injuries from fallen walls/buildings, and penetrating traumas for gunshot wound (GSW) and stab wound (SW). Injury Severity Scores (ISS) for each patient were calculated by the same person throughout (one of the author: X.D.). All patients were analyzed according to the mechanism of injury, ISS, time point of diagnosis, associated injuries, surgical routes, including thoracotomy, laparotomy or thoracoabdominal incisions and outcomes. For the classification of diaphragmatic injury, the American Association for the Surgery of Trauma (AAST) diaphragmatic injury score was used.

Statistical analysis

Data analysis was performed using SPSS version 17.0 for Windows (IBM, Armonk, NY, USA). All quantitative data were presented as mean values ± standard error of the mean. All patients were analyzed according to the mechanism of injury, Injury Severity Scores (ISS), time of diagnosis, associated injuries, surgical routes and mortality using the Student t test or the Chi-square test. Multiple logistic regression was used to determine significant risk factors of the probability of nonsurvival. P ≤ 0.05 was considered significant.

Results

A total of 63 patients (52 males, 82.5%) with traumatic diaphragmatic hernia were identified from the patient record documents from 1990 to 2017 (36 cases in 1990–2005, 27 cases in 2005–2017). No patient was excluded. The mean age for all was 31.2 ± 16.3 years old (range, 0.5–69). Penetrating TDH occurred in 19 of 63 (30.2%) compared with 44 from blunt injuries (69.8%). Stab wounds caused 14 (73.7%) of the 19 penetrating injuries, and gunshot wounds resulted in the rest. Motor vehicle crashes resulted in 27 of 44 blunt injuries (61.4%), and crush injuries for the rest. The mean age (23.6 ± 9.5 years old) in the penetrating group was significantly younger (p = 0.042) than in the blunt group (33.5 ± 19.7 years old), while the mean ISS (p = 0.029) and AAST grade (p = 0.014) were significantly lower in the penetrating group than in the blunt group. Out of the 63 cases, 45 were injured in the left, 16 in the right and the rest 2 in both sides (p = .002). (Table I)
There were 33 associated injuries including 3 in the head, 8 in the thorax, 11 of abdominal solid organs, 5 of abdominal hollow viscera, 3 of the pelvis and the spine. The stomach was the organ most frequently found herniating into the chest (32 of 63, 50.8%), followed by the spleen (17 of 63, 3.0%), and small bowel (9 of 63, 14.3%). The TDH was diagnosed preoperatively in 53 of 63 patients (84.1%), diagnosed and repaired later within the same hospital stay in 6 (9.5%), and was missed and treated 4 months to 12 years later in 4 (6.3%). Two thirds of the patients (19/27) in the latter period compared with none in the former period underwent CT scan. Ten patients (15.9%), of which 8 in the former and the other 2 in the latter period (p = .042), had late diagnoses. (Table II)

The most common operative approach is thoracotomy, in 45 cases. The rest included 2 bilateral thoracotomies, 11 laparotomies, 9 thoracoabdominal incisions. Of the 63 cases, 7 died. Four died of severe multi-organ failure and 3 of underresourced primary treating hospital and delayed referral. The rest were discharged uneventfully. No significant difference of mortality between two periods was found.

Univariate analysis showed older age (p = .017), higher ISS (p = .026) and AAST grade (p = .014) were associated with nonsurvival(Table IV). Multiple logistic regression analysis suggested that advanced age (p = .013) and higher ISS (p = .028) were predictors of death. (Table V)

Discussion

Diaphragmatic injuries were first described in 1541 by Sennertus. This condition is not uncommon with rates as high as 5% for patients hospitalized after motor vehicle accidents, and 15% for patients after penetrating injuries to the lower chest and upper abdomen. Almost half of these injuries develop into hernias. A number of series showed more patients with traumatic diaphragmatic injury(TDI) suffered from penetrating trauma as compared with blunt trauma while other series have suggested that the majority of TDI, up to 80%, resulted from blunt trauma. Lewis thought that these discrepancies in frequency are likely the result of variations in geographic and socioeconomic factors of the study populations. In our TDH cohort, blunt trauma was predominantly higher for we had selectively excluded the cases of TDI without herniation. So we speculate that since a lot of TDI were not able to be recognized promptly, especially for the penetrating injuries which may not present with herniation, these cases might have been missed in some previous studies. And it may also have added to the discrepancies in frequency of the mechanisms. The most common causes of TDH in our series (MVC, GSW, and SW) are consistent with previously reported data. MVC comprised 61.4% of all cases, which was by far the most common cause. All or at least a large proportion, of penetrating injuries were due to stab and GSWs, which was consistent with our estudy. It is desirable that diaphragmatic injuries be diagnosed before the complications like diaphragmatic hernia and strangulation occur since mortality and morbidity increase after the herniation and strangulation of the abdominal viscera in the thoracic cavity. However, according to our experience, in a significant proportion of the cases diaphragmatic injuries were insidious with no visible signs on Chest X-ray, which was reported to be very
useful and with sensitivities up to 94% in the presence of a hernia. In the early period, we utilized conventional chest X-ray, combined with abdominal ultrasound and barium meal trying to achieve early diagnoses. Though all cases enrolled in the study presented with herniation, as reported previously, some of them were not diagnosed in a timely fashion. The most common cause of delayed diagnosis was the right sided diaphragmatic rupture. According to reports, only 17% of the cases of right sided rupture are diagnosed with chest X-ray. In our study, 6 (60%) cases of delayed diagnosis were of the right sided hernia. Another important reason probably is the films were interpreted by surgeons. Although they were able to identify all cases of diaphragmatic hernia, many cases of injury without an obvious hernia were missed. Furthermore, sometimes, the hernia might have mimicked an elevation of diaphragm especially in the right hemithorax with the liver herniating into the chest or it might have been misdiagnosed with hemothorax or encapsulated effusion. As mentioned above, there were 4 delayed diagnoses which were confirmed 4 months to 12 years later after discharge from hospital. Delayed or missed diagnoses may place patients at risk for morbidity and mortality. In some cases, it could be insidious for delayed hernia formation or small openings. In the recent period, we have been using CT scan (initially, 16 multi-slice, then 64 multi-slice) characterized by high space definition and multi-planer reconstruction ability to help diagnose and have achieved a minimal number of missed diaphragmatic injuries. CT has greatly enhanced the ability of early diagnosis and is reported to have a sensitivity of 71% (78% for the left and 50% for the right) and a specificity of 100% and an accuracy of 88% for the left and 70% for the right sided injuries. With CT scan, the early diagnosis rates were significantly higher than it had been before (p = .042) (Table II).

The incidence of associated injuries was 52.4%, and the most common associated injury was rib fracture followed by intra-abdominal injuries, which are similar to previous series. Some studies have suggested nearly 100% incidence of associated injuries, implicating a discrepancy from ours. This may be explained by the different enrollment criteria. In our study, we excluded all patient died before admission while some previous studies included such patients. Since associated injuries add to ISS scores leading to higher mortality, those who died before hospitalization probably had higher ratio of associated injuries.

The operative approach of choice is affected by whether there are associated injuries. Though it was reported that the incidence of associated additional intra-abdominal injuries was up to 100% of patients, we chose a thoracotomy as our main approach (71.4%) (Table III) for an incidence of associated abdominal injuries of 25.4% (16/63) in our series. A posterolateral thoracotomy warrants a good exposure of diaphragm as well as part of the abdominal organs. We have found it easier to reduce the herniated contents and to repair the diaphragm through a thoracotomy when there are no intra-abdominal injuries. Importantly, in cases of delayed presentation, thoracotomy is an accepted approach as it is difficult to release the intra thoracic adhesions through a laparotomy. Many authors choose laparotomy or laparoscopy as the route of choice. A Laparotomy may be used in patients presenting with abdominal symptom or physical signs and will be more frequently used in our future practice as more evidence coming up in favor of a laparotomy. In patients with severe injury of the
junction between thorax and abdomen, a thoracoabdominal incision may be the approach of choice. Another important factor impacting surgeon’s choice of approach is the familiarity and comfort level for a surgeon\textsuperscript{32}, which is also the case in this study. Physicians should keep in mind that injuries might happen in both sides. A case in our cohort presented with shortness of breath and low saturation of blood oxygen after surgical repair of left diaphragm injury. Further investigations suggested right diaphragmatic rupture and hepatic herniation into the chest. The patient had to undergo another right thoracotomy and recovered without major morbidity.

The mortality in our study (11.1\%) is much lower than other published series\textsuperscript{11,17,33}. Several reasons may have contributed to it. First, our study only enrolled the patients who had survived to hospital admission, yet many had died before admission. Second, the referrals from other hospitals were sometimes limited to relatively less severely injured patients, so a lot of severely or critically injured patient were not included. Third, our study focused specifically on TDH, which is only a subset of TDI. However, we found risk factors for death similar to published studies\textsuperscript{11,28,34}. Older age (p = .017), higher ISS (p = .026) and AAST grade (p = .014) by univariate analysis were associated with nonsurvival. Multiple logistic regression analysis suggested that advanced age (p = .013) and higher ISS (p = .028) were predictors of death.

Table I shows older mean age, higher ISS score and AAST grade in blunt group than in penetrating group. The age difference implicates a socioeconomic impact on the mechanisms of injury. According to the mechanisms, more associated injuries, which apparently add to ISS score, might be found in blunt injuries. But same as previous report\textsuperscript{1}, no difference in mortality was found between the two mechanisms. Since the volume of cohort is small, large-scale study is warranted.

**Conclusion**

Our study found that the demographics and constituent ratio of the mechanism varied between TDH and TDI. Diaphragmatic hernias were more common after blunt injury chest. Right sided rupture was a common cause of delayed diagnosis. The application of multi-slice CT scan has significantly increased early diagnosis rate of TDH. But at present, we have not found significant difference in mortality between two periods though significant advances in trauma management, critical care, and interventional radiology might have improved survival in this population in the latter era. Diaphragmatic hernia repair could be done through a thoracotomy with acceptable results provided there are no intra-abdominal injuries or diaphragmatic injuries presenting late. Older age, higher ISS and AAST grade were predictors of death.

**List Of Abbreviations**

ISS = injury severity scores, AAST = American Association for the Surgery of Trauma, TDH = traumatic diaphragmatic hernia, GSW = Gunshot wound, MVC = motor vehicle collision, TDI = traumatic diaphragmatic injury, CT = computed tomography
Declarations

Acknowledgements

Not applicable.

Author Contribution

All authors made substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data; XD, EH were involved in drafting the manuscript and revising it critically for important intellectual content; XD, DZ performed the surgical procedures and collected the data. All authors read and approved the final manuscript.

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Availability of data and materials

All data generated or analyzed during this study are included in this published article.

Ethics approval and consent to participate

All procedures performed in this study involving human participants conformed to 1964 Helsinki declaration and its later amendments or comparable ethical standards and the ethical standards of the institutional and/or national research committee. Consent to participate was waived by IRB since this was a retrospective study.

Consent for publication

Informed consent for publication was waived by IRB since this was a retrospective study.

Competing interests

The authors declare that they have no competing interests.

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**Tables**
### Table I.  
Demographics of the population

|                  | Total, n (%) | Blunt, n (%) | Penetrating, n (%) | P value |
|------------------|--------------|--------------|--------------------|---------|
| Patients No.     | 63           | 44 (69.8%)   | 19 (30.2%)         | N/A     |
| Mean age, years ± SD | 31.2 ± 16.3  | 33.5 ± 19.7 | 23.6 ± 9.5         | .042    |
| Male             | 52 (82.5)    | 36           | 16                 | N/A     |
| Mean ISS ± SD    | 26.6 ± 20.7  | 36.3 ± 23.2  | 20.8 ± 17.4        | .029    |
| AAST grade       | 2.1 ± 0.7    | 2.8 ± 0.9    | 1.5 ± 0.3          | .014    |
| Survival to discharge | 56 (88.9)   | 40 (63.5)   | 16 (25.4)          | .734    |
| Mortality        | 7 (11.1)     | 4 (9.1)      | 3 (15.8)           | .670    |

N/A: not available; AAST, American Association for the Surgery of Trauma.

### Table II.  
Imaging modality in different periods

|                  | 1990–2005 | 2005–2017 | P   |
|------------------|-----------|-----------|-----|
| Mechanisms       | Penetrating(19)/ Blunt(44) | 8/28      | 11/16 | .113 |
| Chest X-ray(63)  | 36        | 27        | 1.000|
| Ultrasound(44)   | 23        | 21        | .235 |
| Barium meal(7)   | 4         | 3         | 1.000|
| CT scan(19)      | 0         | 19        | .000 |
| Preoperative diagnosis | 28/36(77.8%) | 25/27(92.6%) | .002 |
| Mortality        | 5/36      | 2/27      | .685 |
Table III.

Incisions with etiology of blunt and penetrating diaphragmatic injuries

| Causes       | Thoracotomy* | Laparotomy | Thoracoabdominal incision |
|--------------|--------------|------------|---------------------------|
| MVC 27(42.9) | 23           | 3          | 1                         |
| Crush 17(27.0)| 14           | 2          | 1                         |
| SW 14 (22.2) | 5            | 4          | 5                         |
| GSW 5(7.9)   | 3            | 1          | 1                         |
| Total 63(100)| 45(71.4)     | 10(15.9)   | 8(12.7)                   |

*: including 2 bilateral thoracotomies

GSW, Gunshot wound; MVC, motor vehicle collision; SW, stab wound; TDH, traumatic diaphragmatic hernia.

Table IV.

Univariate analysis for the prediction of nonsurvival

|                     | Survivors (n = 56) | Nonsurvivors (n = 7) | P value |
|---------------------|--------------------|----------------------|---------|
| Mean age, years ± SD| 30.2 ± 16.7        | 41 ± 18.8            | .017    |
| ISS ± SD            | 25 (11.7)          | 47 (17.9)            | .026    |
| Gender              | 1.000              |                      |         |
| Male                | 46                 | 6                    |         |
| Female              | 10                 | 1                    |         |
| AAST grade ± SD     | 1.4 ± 0.3          | 2.9 ± 0.7            | .014    |

ISS, Injury severity score; SD, standard deviation; AAST, American Association for the Surgery of Trauma.
Table V.

Multiple logistic regression analysis for the prediction of nonsurvival

|              | OR   | 95% CI         | P value |
|--------------|------|----------------|---------|
| Gender       | 0.983| 0.264–2.541    | 0.891   |
| Mechanism    | 0.639| 0.131–1.567    | 0.233   |
| Age          | 1.275| 1.023–1.196    | .013    |
| ISS          | 1.174| 0.968–1.105    | .028    |

ISS, Injury severity score