INTRODUCTION

Traumatic diaphragmatic rupture (TDR) is not a very uncommon injury, mostly caused in pedestrians by sudden impact with speeding motor vehicles. Injuries in vehicle occupants like seat belt or steering wheel compression on frontal collision is also not uncommon. Sudden compression by fallen walls, trees, poles etc during natural disasters, or stampede, fall from a height during normal walks of life are some other mechanisms of TDR. Large TDRs can result into traumatic diaphragmatic hernia (TDH). Sharp penetrating injuries in abdomen or chest such as bullets or knife or sharp objects like metal rods, glass fragments, can also cause TDR. Incidence of TDRs ranges between 0.8 and 15% according to level of urbanization in the geographic location of primary trauma. Radiological imaging are often not diagnostic of small TDRs if they do not cause TDH. TDRs are sometimes diagnosed during emergency laparotomy or thoracotomy by examination of diaphragm whereas TDH need imaging studies. The surgical management is the only treatment for TDRs and TDH. The risk factors for mortality and morbidity depends on associated collateral injuries sustained during trauma. The aim of this retrospective study was to evaluate manifestations of effects of diaphragmatic rupture after thoraco-abdominal trauma, and to discuss their epidemiology, diagnosis, nature and treatment with an aim to impart comprehensive timely management to reduce morbidity and mortality.

MATERIAL AND METHODS

This was a retrospective review of 18 patients documented and treated by us over two decades for TDR, with or without TDH, who were treated by us in Medical College Hospital, Kolkata, and Calcutta National Medical College, Kolkata, from April 1998 to November, 2019. A retrospective analysis was performed in relation to the outcome of these patients. The demographic profile of the patients, side of TDR, history of mechanism of injury, imaging studies performed, type of operation, emergency or non emergency, mortality and survivability were noted with detailed inputs against the patients assigned with serial numbers (Table-1).

There were 15 males and 3 females and age ranged from 18 to 62 years, with a median age of 34.5 years. The patients were categorized as severe when there was evidence of penetrating trauma. The aim of this retrospective study was to present our experience with its different mechanisms of rupture after thoraco-abdominal trauma, and to discuss their epidemiology, diagnosis, nature and treatment with an aim to impart comprehensive timely management to reduce morbidity and mortality.

Keywords: Traumatic Diaphragmatic Rupture, Traumatic Diaphragmatic Hernia, Thoracotomy, Laparotomy,
which included 4 with penetrating and 5 with blunt trauma injuries between 4 to 10 hours which also depended on the time of arrival after the trauma. The other 9, in the non severe group, who were resuscitated and stabilized, were operated mostly after 24 hours. In 1 old case of TDH, it was 2 years after blunt trauma, when TDH was symptomatic (Sl No. 18).

Investigations included X-ray of chest in all patients. CT scan of chest and abdomen was done in 10 patients and MRI was done only in a single case (SL No 3).

Operation
In severe group, laparotomy was done in 5 patients of blunt trauma while in 4 patients of penetrating trauma in the severe group, thoracotomy or thoracoabdominal exploration was done. In the 9 patients in the non severe group, the approach for repair of TDH was thoracotomy or thoraco abdominal exploration.

TDH was repaired in two layers with # 1-0 polypropylene sutures. Such tears 2 to 5 cm in length, were noted in the left side in 5 patients and right in 2 with acute penetrating trauma. TDH was present in TDRs larger than 9 cm in 9 patients non severe group and 1 in severe group. TDH was diagnosed through a 3 cm TDR in only 1 in non severe group with a history of old trauma (Sl No.18). Herniated viscera included stomach and adjacent small and large gut through TDH in both sides while in 1 case it was additionally liver on the right side.

Some relevant case histories
In a patient of chest injury in a young man (Sl No.2), TDH was diagnosed after resuscitation and performing a CT scan in an outside hospital after trauma before referral. He was hit from front on his left side of the chest by a moving vehicle from behind. But no evidence of intra-abdominal grievous injury was present. After exploration through left anterolateral thoracotomy, TDH was repaired with polypropylene mesh (Figure-1).

In one patient of blunt trauma due to hit and run by a speeding vehicle (Sl No.5), Laparotomy was done for uncontrollable intra abdominal bleeding. Pelvic fracture was the source of hemorrhage and an incidental 4 cm TDR was found in left cupola of diaphragm without TDH. It was closed but the patient expired later due to hemorrhage.

In one case of TDH, a patient was admitted with features of shock and a history of partial run over injury (Sl No.3) by a driver reversing back a light empty truck. After it’s wheels ran over half of the right side of abdomen of the person knocked down, it instantly moved away forward on being alerted. X ray of chest showed lower 6th and 7th rib fractures with X ray suggestive of pneumothorax. Chest drain showed blood mixed bilious discharge. MRI after 48 hours showed right sided TDH (Figure-2) It was explored almost 72 hours after the trauma. Exploration revealed a single loop of jejunum herniated with right lobe of liver into right hemithorax. There was a perforation in the junal loop without contamination of the abdominal cavity. The rupture in jejunum was repaired with resection and anastomosis and TDH was closed with polypropylene mesh.

In one case, a young girl (Sl No. 17), developed TDH due to run over by an empty bullock drawn cart. It’s wheels had car tyres (which are being used more instead of the traditional wooden and iron wheels) which ran from right to left. After resuscitation, an X ray chest showed fracture of lower ribs with evidence of right sided opacity with hemothorax (7th, 8th and 9th). Chest drain was put and hemothorax was drained. There was no other intra abdominal injury. A CT performed later showed evidence of right TDH (Figure No.3) which was repaired with mesh.

In one patient (Sl No.18) who had a history of a thoraco abdominal trauma by fall from a height 2 years back, and treated conservatively, presented recently with an obstructed TDH with omentum without any sac. There was a 3 cm antero medial tear located near the sternum coastal attachment of right half of diaphragm. Repair was also done with mesh. In a unique case of penetrating injury, a flying piece of glass missile, broken off from a window show case (Sl No.11), during depression created within a shop during a cyclonic storm, pierced through the right chest of a young man causing hemothorax. Persistent bleeding needed urgent thoracotomy through right 7th space (wound of entry) which showed a bleeding intercostal artery injury which was controlled. The diaphragm over the bare area of liver was found to have developed 2 cm TDR and liver was injured. It was sutured through the diaphragmatic tear with # 1-0 polyglactin suture and TDR wound was closed with # 1-0 polypropylene suture.

In the case of a stab injury by knife (Sl No.4), from the back of left chest, a rent was found to be present in the left dome of diaphragm (7 cm). The herniating fundus of the stomach after examination was reduced into the abdomen and the left TDH wound was repaired in two layers. But later within a few hours, evidence of peritonitis was noted. Rexploration through laparotomy revealed an injury to the back of the stomach lower down the body, which was missed during an earlier examination. It was repaired and the patient made uneventful recovery.

In a case of bullet injury sustained from a pipe gun (a type of improvised country made short range hand gun in India), (Sl No 7) which traversed through the right side of chest, and diaphragm was lodged in the right lobe of liver. Exploration through a right thoraco abdominal approach revealed minimal lung injury. The bullet was extracted and the small 2cm TDR was closed. But the patient suffered from a long continued biliary discharge and wound infection which healed after a month.

In another case of bullet injury by a revolver (Sl No. 1), there were colonic perforations and pancreatic injury. Distal pancreatectomy, colon repair and colostomy were done along with repair of left sided 2 cm TDH. This patient expired after 7 days due to sepsis.

Diaphragm was repaired with # 1 polypropylene mattress sutures in two layers in all cases and mesh enforcement was utilized in 3 patients (Figure No. 2). Analysis was performed in Table Nos. 2 and 3.
| Sl No | Age | Sex | Location and mechanism of injury | Nature Of trauma Blunt Or Penetrating | TDR or TDH with and associated injuries | Investigations | Approach | Operation Severe (S)/ Non severe (N) | Size of TDR (approx) | Cause of death | Died/Sur |
|-------|-----|-----|---------------------------------|--------------------------------------|----------------------------------------|---------------|----------|-----------------------------------|-------------------|---------------|---------|
| 1     | 38  | M   | Left, (Revolver bullet)         | Penetrating (left chest and abdomen) | TDR, Liver pancreas and colon injury   | CXR           | Th Abd   | 6 Hrs, S                          | 2 cm, Sepsis      | Died          |
| 2     | 32  | M   | Left, (MV hit)                  | Blunt, (chest, medium impact)        | TDH with stomach,Rib#                 | CXR, CT      | Th       | 1 Day, N                          | 12 cm             | Sur           |
| 3     | 25  | M   | Right, (MV partial run over)    | Blunt, (partial run over by truck over abdomen)medium impact | TDH with Rt Liver, jejunal rupture, Rib # | CXR, MRI    | Th Abd   | 3 Days, N                         | 20 cm             | Sur           |
| 4     | 34  | M   | Left, (Snub injury by knife)    | Penetrating (left lower chest)       | TDH, Stomach injury                   | CXR,         | Th and late Lap | 7 hours, S                       | 7 cm               | Sur           |
| 5     | 56  | M   | Left, (MV hit)                  | Blunt, (abdomen and Pelvis,)         | TDR, Pelvic #,                        | CXR           | Lap      | 3 Hours, S                        | 4 cm pel hge       | Died          |
| 6     | 44  | M   | Left, (MV hit)                  | Blunt, (chest, medium impact)        | TDH, Limb #, Spine #                  | CXR, CT      | Th       | 1 Day, L                          | 12 cm             | Sur           |
| 7     | 37  | M   | Right, pistol bullet            | Penetrating (from lower chest to right lobe of liver) | TDR, Liver injury,                    | CXR           | Th Abd   | 7 hours,S                         | 2 cm               | Sur           |
| 8     | 28  | M   | Left MV, (steering wheel)       | Blunt, abdomen, steering wheel compression | TDH with stomach, Rib #              | CXR, CT      | Th       | 1 Day, N                          | 11 cm             | Sur           |
| 9     | 29  | M   | Left, (wall collapse)           | Blunt, (fall of mud wall over chest and abdomen) | TDH,Rib# and intestinal perforation | CXR, CT      | Lap      | 8 Hours,S                         | 5 cm Sepsis        | Died          |
| 10    | 54  | F   | Left, (MV hit)                  | Blunt, (chest, high impact)          | TDR, Rib #, multiple bowel perforations | CXR          | Lap      | 4 Hours, S                        | 5 cm Sepsis        | Died          |
| 11    | 21  | M   | Right, (missile injury)         | Penetrating sharp injury by Glass fragments | TDR, Liver penetrating inj          | CXR           | Th       | 7 Hours, S                        | 2 cm               | Sur           |
| 12    | 37  | M   | Left, (MV hit)                  | Blunt, chest medium impact           | TDR, Rib #                            | CXR, CT      | Th       | 1 Day, N                          | 10 cm              | Sur           |
| 13    | 23  | M   | Left, (MV hit)                  | Blunt, chest, high impact            | TDH, Liver, kidney, intestinal inj,   | CXR, CT      | Lap      | 8 hours,S                         | 9 cm Sepsis        | Died          |
| 14    | 47  | M   | Left, (MV)                      | Blunt, chest high impact             | TDH,Rib#, stomach Int inj           | CXR, CT      | Lap      | 8 Hours, S                        | 12 cm Sepsis       | Died          |
| 15    | 32  | M   | Left, (MV)                      | Blunt, (chest, medium impact)        | TDH, stomach herniation,            | CXR, CT      | Th       | 1 Day, N                          | 12 cm              | Sur           |
| 16    | 53  | M   | Left, (MV hit)                  | Blunt, (chest, medium impact)        | TDH, stomach herniation,            | CXR, CT      | Th       | 1 Day, N                          | 12 cm              | Sur           |
| 17    | 18  | F   | Right, (Ballock cart run over)  | Blunt, compression injury to abdomen | ®TDH, with stomach herniation, Ri    | CXR, CT      | Th Abd   | 2 Days, N                        | 12 cm              | Sur           |
| 18    | 54  | F   | Right, (fall from a ht)         | Blunt, (chest, medium intensity localized trauma) | ®TDH,with herniation of omentum    | CXR, CT      | Th and Lap | 2 years, L                        | 2 cm               | Sur           |

SI No= Serial number, Sex= M (male) or F (Female), S (sharp) may be due to knife, missiles like glass fragments, or bullets, TDR= traumatic diaphragmatic rupture, TDH= Traumatic diaphragmatic hernia, CXR= chest X ray, SPINE #= vertebral spine fracture. MV hit = Injury to pedestrian by impact of a speeding motor vehicle, MV Steering wheel = Compression of driver against the steering wheel of MV on frontal collision, inj= injury, Ballock cart run over = run over by a bullock cart with rubber tyre, Wall collapse = fall of mud wall on house collapse, ®= right side, glass missiles =broken pieces of glass flying after break during storms. MRI = Magnetic resonance imaging, E= Early operation within 8 hours of injury, L=Late operation after 24 hours of injury, ®= right side, Int inj= intestinal injury.

Table-1: Summary of demographic characteristics of the study population
RESULTS

There were 3 females and 15 males. The average age was 37.28 ± 12.75 years with a median age of 34.5 years. TDH was more common in the left side. Most affected age group with diaphragmatic ruptures was found in 12-56 years. The mean sizes of the defects with TDH in 11 patients varied from 2 to 20 cm with mean 11.81 cm. Mortality was 33.33% (6 out of 18). It was 1 out of 4 (25.0%) among the TDR by penetrating injuries while it was 5 out of 14 (35.71%) cases of TDR by blunt injuries. The present collective review suggests 14 (77.78%) of the injuries were due to blunt trauma and 4 (22.22%) were due to penetrating trauma (Table 1 and 2).

In the severe group, out of the 4 patients with penetrating injury, there were 3 survivors and a single mortality while all the 5 patients with early laparotomy did not survive. In the non severe group all the patients survived operation. Most of the survivors were followed up for 1st 1 to 2 years and did not have recurrence within that period. The follow up of the last patient (Sl. No.18) is only 2 weeks. Causes of death among both the sharp and blunt trauma cases varied among bleeding, shock, intestinal injury and sepsis.

Mean hospital stay

The mean hospital stay was 14 days with extreme of 50 days in cases of survivors. All the datas were processed in Microsoft XL, tabulation done, and statistical averages, standard deviations and relevant proportion were calculated. No further statistical tests could be done due to small numbers of these cases.

| Variables | Total | Survived(S) | Died(D) |
|-----------|-------|-------------|---------|
|           | (n=18) | (n=12)      | (n=6)   |
| Age, years | 38± 11.01 | 34.66±11.34 | 44.66±10.11 |
| Male gender | 15/18 (83.33%) | 10/16(62.50%) | 6/16(37.50%) |
| Female    | 3/18(16.67%) | 2/2(66.67%) | 1/3 (33.33%) |
| Blunt trauma | 14(77.78%) | 9/18(50.00%) | 5/18(27.78%) |
| MV impact | 9/18 (50.00%) | 5/9(55.56%) | 3/9(33.33%) |

Table-2: Analysis of baseline characteristics of blunt or penetrating trauma in 18 patients and the outcome after operation.
There may be a few reported cases involving the right diaphragmatic dome. The right dome tear is often fatal because the force required to rupture the right dome is massive and cause extensive collateral damage to other intra abdominal organs, spine, pelvis and great vessels with high pre hospital mortality. In the past, incidence of TDR was reported as rare or infrequent. Extensive use of CT scan increased the pre operative diagnosis of TDR to 6%. But such increased diagnosis of TDR is due to inclusion of the more severely injured patients into emergency surgery, as a result of better resuscitation and improved advanced trauma life support services. Majority of the TDRs were caused by motor vehicles injuries in pedestrians. Recent report from Canada on the contrary cited a higher proportions of MV occupants to have suffered TDR due to vehicular collisions. This may be due scanty pedestrians encountered in Canadian roads unlike the Indian subcontinent. Run over by animal drawn carts are not uncommon in the rural Indian subcontinent but unlike the Western world too and we also had one such case (Sl. No.3).

**DISCUSSION**

**History**

Diaphragmatic hernia was first described in 1541 by Sennertus in an autopsy finding. Ambroise Pare in 1579 described TDH again as an autopsy finding after a gunshot wound sustained 8 months back in a French artillery captain who died due to strangulation in a portion of herniated intra thoracic colon. In 1853 the first antemortem diagnosis of traumatic rupture of diaphragm was made by Bowditch and the first successful diaphragmatic repair was reported by Riolfi in 1886 in a patient with omental herniation. The blunt injury causes increased intra abdominal pressure applied to the abdomen or flanks and according to Pascal’s law, is distributed equally in all directions through the fluid abdominal contents. The left dome of the diaphragm is not buffered by solid viscera as on right and ruptures due to transmitted pressure.

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Probably, high intra abdominal pressure (IAP) generated caused equal pressure on both sides, and the left dome being relatively unprotected, resulted in left dome rupture. Another mechanism for development of TDR in this case could be fractured lower 7,8,9 rib fragments causing tear at the lateral costal attachment of the right side of diaphragm as described by other authors.17 Mechanisms of TDR has also been explained by the fact that the contracted diaphragm during fall and direct impact, is distorted by opposing forces leading to a tear in the membrane.13 Such trauma could also explain the 2 cm antero medial tear located near the sterno costal attachment of right half of diaphragm in our last case (Sl. No. 18) who sustained thoraco abdominal trauma 2 years back by fall from a height and presented with an obstructed hernia without any sac containing omentum only 2 weeks back. However, it was difficult to decide whether it was a Morgagni’s hernia being symptomatic at a later stage of life or a truly traumatic origin as because no X ray of chest, before or soon after trauma was ever done, as she never had any symptoms for last 2 years. Incidents of relatively less severe trauma raising instantaneous raised IAP due to frontal collisions18 were also present in other cases of TDR too (Sl No. 2,6,8,12,15,16) and all survived operation. Severity and nature of compressive forces determine collateral damage and survival. Thus, severe blunt trauma like falling of walls or frontal collisions by vehicles in high speed, in certain cases resulted in TDR (Sl. Nos.5, 9,10,13,14) and resulted in severe collateral damage due to pelvic or solid organs or small and large gut injuries and death.

It is also intriguing to find most cases of severe blunt abdominal trauma in our series required laparotomy for intra abdominal injuries with the findings of smaller TDR (2 to 4 cm). In a recent Korean study17 it was found that the diameter of TDR was larger in the non-severe group (9.70 ± 4.10 cm) than the severe group (4.80 ± 3.60 cm) and this finding is agreeable to ours.

Alertness at the time of contact injury: Sudden thrust from the front on the torso of an alert subject, coordinated reflex contraction of the thoracic, abdominal and pelvic muscles, generates increased intra-abdominal pressure (IAP), displaces the diaphragm upwards. This muscular defense serves as protection due to reflex contraction of the muscular abdominal and thoracic wall and acts as deterrent to intra abdominal organ injuries [18 Stokes IA]. The same injury on an unaware and sleeping subject may cause intra abdominal hollow or solid viscus injury along with TDR which is exemplified in the patient in Sl No 9.18 Diagnosis of TDH is frequently not obvious and is missed in 7% to 66% of such patients with blunt injury while the actual incidence may be higher.19 Thus, for a delayed diaphragmatic rupture, it was also hypothesized that most patients with delayed diaphragmatic ruptures had no acute TDR. The diaphragmatic muscle became devitalized several days or months after the initial injury20 resulting in its later lysis.21 Therefore, X ray of chest is often not diagnostic initially due to slow herniation of abdominal contents through the diaphragm and requires follow up with serial X Rays22 or CTs if they are available.

Patients of TDR with penetrating injuries like bullet or knife or sharp fragments as observed in our patients were the ones who had naturally been selected by nature to reach hospital alive. Injury to pancreas, small gut and colon produced much complicated local wound, sepsis with dehiscence and added to later mortality (Sl. No.1). In the patient with stab injury (Sl. No.4) stomach injury was initially missed which was only confirmed by a 2nd look laparotomy. So, watchful monitoring is needed in post operative period. In case of the low velocity bullet injury to the liver after causing TDR (Sl. No. 7), biliary drainage continued for over a month. Watchful expectancy resulted in effective healing of the biliary fistulas and our method of management was in agreement with those of others.23 Out of the patients who were admitted with blunt trauma in our series, 6 did not require urgent surgery other than intercostal chest drain for chest injuries due to hemothorax and/or pneumothorax and had surgery on an average 24 hours or longer for TDR or TDH. The prognosis depended on the extent of injury and duration of contamination before surgical intervention as in any other cases of trauma.

The generally accepted protocol in our series in the acute trauma setting tear was laparotomy with management of concomitant intra abdominal injuries, and TDR was a concomitant finding and our protocol is in agreement with others.4,13,14 Because of inclusion of patients with grievous wounds and attempt to salvage such high risk patients like pelvis and intra abdominal injuries, the mortality in our series was high (33.33%) and is in agreement with others (10%–35%).14 We found pelvic fracture, gut injuries and sepsis as risk factors and also reported by others.19,22

CONCLUSION

Complications of diaphragmatic ruptures are mainly determined by injuries associated with TDR like gravity of blunt mechanical thrust imparted to internal organs with range of injuries extending from nil to rupture and/or bleeding. Likewise, penetrating injuries by bullet or knife, may also cause internal injuries depending on the organ involved in damage. As in any other cases of trauma, the principles of trauma care applies to both types of these injuries. Prognosis depends on severity of associated injuries in TDR and incarcerations or obstructions of herniated organs in TDH.

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Ethical Approval: This was a retrospective study and being it retrospective in nature, patient consent was wavered off by the ethics committee of Medical College Hospitals, Kolkata700073 and also Calcutta National Medical College, Kolkata 700014
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