Objective: There is an increasing trend of observational, nonsurgical management of abdominal injuries in children. We analyzed the feasibility and outcome of our management protocol in managing cases of the mesenteric injuries in blunt trauma abdomen in pediatric age group.

Methods: Single-center retrospective analysis of pediatric trauma case records from July 2018 to March 2020 was performed.

Results: Thirty-four cases of blunt abdominal trauma of whom 13 had mesenteric injuries were reviewed. The male-to-female ratio was 2.2:1, and the mean age was 9.11 ± 4.90 years. Mesentery of the small bowel was the most commonly injured segment and treatment consisted of repair of mesenteric tear, resection, and anastomosis with or without stoma formation.

Conclusions: Isolated mesenteric injury of all grades should be managed either with diagnostic laparoscopy or laparotomy irrespective of hemodynamic status.

Keywords: Blunt trauma, bowel injury, mesenteric tear, pediatric trauma

INTRODUCTION

Blunt trauma abdomen accounts for 25% of major pediatric trauma in children and is associated with high fatality if unrecognized. Like adults, 70%–80% of blunt trauma in children occurs due to road traffic accidents, while the rest 20%–30% are because of fall from height, injuries due to contact sports, or child abuse.[1-3] Isolated mesenteric injury is uncommon and is seen in only 3%–5% of trauma cases, but it causes significant morbidity and mortality.[4] In the pediatric population, after liver and splenic injury, hollow visceral and mesenteric injuries are most common.[5-8]

Management of pediatric trauma needs not only expertise and skills but also good infrastructure and dedicated supporting staff. Mostly, the clinical examinations are unreliable either because of crying or due to irritability. The lack of verbal skills of the young child adds to the diagnostic dilemma.

Nonoperative management (NOM) of blunt trauma abdomen involving solid organ injuries of all grades is normative, but the data regarding the management protocol in isolated mesenteric injury in children are lacking in the literature. The optimal management strategy for children with isolated mesenteric injury still needs to be determined. Therefore, we retrospectively reviewed the outcome of all cases of isolated mesenteric injury in our level 1 trauma center in the northern part of India, after getting approval from the Institutional Ethics Committee.

METHODS

We retrospectively reviewed the medical records of all cases of pediatric abdominal injury admitted from July 2018 to March 2020. Institutional Ethics Committee approval was obtained vide letter PGI/BE/562/2020, dated July 28, 2020. Inclusion criteria
included cases of abdominal trauma of <18 years of age with the presence of isolated mesenteric injury of all grades. Exclusion criteria included cases with solid organ injuries, penetrating abdominal injuries, the presence of pneumoperitoneum, bowel transection, and hemodynamically unstable cases. All cases were managed by a single trained pediatric trauma surgeon. Complete history regarding the mechanism of injury, injury pattern, and duration of injury was obtained beforehand.

Cases were managed as per the guidelines of advanced trauma life support. Focused Assessment of Ultrasonography in Trauma (FAST) was an integral part of the primary survey and was performed in all cases immediately on arrival. Thorough examination of the abdomen was performed, especially to look for abdominal distension, bruises, signs of peritonitis, etc. For continuous monitoring, all the pediatric cases were shifted to pediatric surgical intensive care units from the emergency receiving area, and vitals were recorded. The repeat radiological investigation was sought if needed. FAST positive and hemodynamically stable cases were subjected to triphasic contrast-enhanced computed tomography (CECT) and observation, NOM was planned. NOM was discontinued if the case presents peritoneal signs, experiences clinical deterioration, or changes in radiological or laboratory findings (leukocytosis and unexplained tachycardia). High index of suspicion along with systematic approach was used to identify the early sign of worsening. To achieve this, regular clinical rounds were taken by the single pediatric trauma surgeon daily.

As per the standard protocol, hemodynamically unstable cases with FAST positive were taken up for emergency surgical intervention without any delay. Surgical intervention in the form of exploratory laparotomy was done by the same trained pediatric surgeon. Intraoperative findings were noted and cross-checked with the preoperative CT findings in the departmental radio conference with the senior radiologist. Postoperatively, all the cases were electively ventilated in pediatric surgical intensive care unit for 24 h. Once the patient was hemodynamically stable and maintaining parameters without mechanical ventilatory support, cases were shifted to ward. Gastrointestinal motility was confirmed before allowing oral feeds, and cases were discharged from the hospital only after establishing full oral feeds. First follow-up was scheduled 1 week after discharge and then regular follow-up after 2 weeks in surgical outpatient department. Mesenteric injuries on CECT were defined by the presence of any of the following signs; fat stranding, mesenteric fat stranding/thickening/hematoma, bowel wall thickening or enhancement, and mesenteric blush. Grading of mesenteric injuries was done as described by Bekker et al.9 Grade I injuries consist of a contained hematoma in the small bowel mesentery. There is intact bowel and mesenteric peritoneum, no exposed mesenteric vessels, and no free intra-abdominal hemorrhage. Grade II injuries consist of a tear into the peritoneum covering the mesentery with exposed vessels and gaping mesenteric fat. Grade III injuries involve a tear in the peritoneum with concomitant gaping mesenteric fat and exposed vessels which are bleeding. Grade IV injuries represent a complete tear through the mesentery, bleeding, or thrombosed vasculature with questionable bowel viability. Grade V injuries were defined as a nonviable injury wherein the mesentery is completely avulsed from its corresponding bowel and active bleeding or clot may be present.

The records were analyzed for demographic profile, mechanism of injury, findings on physical examinations, CECT findings, intraoperative findings, course in hospital, surgical intervention, and outcomes including morbidity and mortality. For statistical analysis, GraphPad Prism 8.4.2 by Dotmatics, San Diego, CA, US was used.

**RESULTS**

Abdominal trauma was present in 179 of 1456 cases (12.29%) presented in the emergency department. Out of these 179 cases, 34 cases (18.9%) were of pediatric age group. Twenty-one of these 34 cases (61.7%) presented with solid organ injury, so they were excluded from the study. Out of these...
21 cases, 5 (19%) died during resuscitation itself. Thirteen cases (38.2%) with isolated mesenteric injury formed the study group. The age of the cases varies from 2 years to 16 years (mean years ± standard deviation 9.11 ± 4.90). There were 9 males and 4 females with a male-to-female ratio of 2.2:1 [Table 1]. The mode of injury was road traffic accidents in 7 (53.8%), fall from height in 3 (23%), sports-related injury in 2 (15.3%), and hit by the sibling 1 (7.6%) [Table 2]. Out of 13 cases, 7 cases (53.8%) developed signs of peritonitis after 48–72 h of observation and underwent exploratory laparotomy along with resection and anastomosis of the injured bowel segment [Table 3 and Figure 1a]. Two cases (15.3%) developed features of peritonitis with sepsis ultimately requiring laparotomy on day 5 of admission. Stoma formation was done in these cases due to unhealthy and edematous bowel tissue, along with features of sepsis [Figure 1b]. Prolonged mechanical ventilation was needed in 3 cases of resection anastomosis and in 2 cases, in which stoma was made. Four cases (30.7%) were subjected to early laparotomy on day 1 of admission based solely upon the findings of mesenteric injury on CECT, and only the mesenteric tear repair was required [Table 4 and Figure 1c]. Elective mechanical ventilation was done for 24 h in all cases as per our department policy. All the 4 cases who underwent early laparotomy were weaned off from ventilator on day 2 of surgery. None of the cases developed surgical complications, and there was no mortality in our study. At present, all cases are in close follow-up and 2 of them are awaiting stoma closure surgery.

**Table 2: Frequency of mode of injuries at time of admission**

| Numbers | Female (n=4), Frequency (n (%) | Male (n=9), Frequency (n (%)) | Total (n=13), Frequency (n (%)) | P       |
|---------|--------------------------------|------------------------------|---------------------------------|---------|
| Road traffic accident | 3 (75) | 4 (44) | 7 (53.84) | 0.3559 |
| Fall from height | 0 | 4 (44) | 4 (30.76) | - |
| Sport injury | 1 (25) | 0 | 1 (7.69) | - |
| Hit by sibling | 0 | 1 (11.11) | 1 (7.69) | - |

**Table 3: Frequency of surgical procedure, ventilation, and observation duration**

| Characteristics | Male (n=9) | Female (n=4) | P       |
|-----------------|------------|--------------|---------|
| Observation duration, mean (h)±SD | 48±39.19 | 42±26.15 | 0.8017 |
| Ventilation duration, mean (h)±SD | 41.33±24.72 | 36±8.48 | 0.7063 |
| Reason for surgical intervention (%) | | | |
| Sign of peritonitis | 4 (55.5) | 3 (75) | 0.1411 |
| Abdominal distension | 1 (11.1) | 0 | - |
| Severe tenderness | 1 (11.1) | 0 | - |
| Radiological evidence of mesenteric injury | 3 (33.3) | 1 (25) | 0.1161 |
| Surgical procedure (%) | | | |
| Resection anastomosis | 4 (55.5) | 3 (25) | 0.1411 |
| Stoma formation | 2 (22.22) | 0 (75) | - |
| Mesenteric repair | 3 (33.33) | 1 (25) | 0.1161 |

SD: Standard deviation

**Figure 1**: (a) Intraoperative pic of mesenteric injury with impending gangrenous bowel. (b) Intraoperative pic of mesenteric injury with bowel perforation. (c) Intraoperative pic of mesenteric tear only

**Discussion**

Much has been published about the blunt abdominal injuries with solid organ involvement but the issues regarding mesenteric injuries in stable cases still haunt the treating surgeon. Despite the recent advances, pediatric intra-abdominal injuries continue to be associated with a high mortality rate simply because of delay in diagnosis by virtue of the nonavailability of proper guidelines. The present consensus regarding the hemodynamic unstable paradigm has shifted toward conservative, observation treatment with advanced imaging, perioperative resuscitations, and aggressive placement of blood products. The issues of isolated mesenteric injuries in pediatric trauma cases who are hemodynamically stable at the time of presentation are still a matter of debate. In a landmark paper in 1972, describing the mechanism of mesenteric injury in blunt trauma abdomen, Orloff and Charters reported a mortality rate of 5%. In 1973, Bolton et al, presented a series of 59 consecutive
cases of blunt trauma abdomen, in which only one case was found to be of isolated mesenteric injury and five cases had small bowel injury.[14] Most of the studies published in the past are retrospective in nature and from the single trauma center only with a smaller number of cases simply because the incidence of mesenteric injury is only 3%–5% of all abdominal trauma cases.

Our study design is also retrospective in nature with a short duration of study interval but with a significant number of cases. In our study, 13 (38.2%) cases had mesenteric injuries which are somewhat higher than that reported in other series.[15-17] The most common cause was a motor vehicle accident seen in 53.8%, followed by a fall from height 23%. Injury to mesentery of small bowel was noted in all 13 cases, documented preoperatively by CECT and confirmed intraoperatively while doing exploratory laparotomy. In a study group of 60 cases, Dauterive et al. reported injuries to the small bowel in less than half of the cases.[18] In our study, 7 cases developed signs of peritoneal irritation after 48–72 h of observational management ultimately requiring laparotomy and resection anastomosis of the injured bowel segment [Table 5]. Initially, in these 7 cases, equivocal clinical examination and lack of highly specific CECT findings such as discontinuity of bowel wall, extraluminal air allowed us to proceed with the NOM protocol. However, gradual clinical deterioration along with the appearance of signs of peritoneal irritation forced us to perform surgical intervention at the later stage. Retrospectively, when CT findings were discussed, we noted that intraoperative grading of mesenteric injuries was found to be worse than those observed in preoperative radiological scans. In due course of time bowel injury led to edema and ischemia which caused

| Table 4: Prevalence of reason for surgical intervention in different ages and gender |
|-----------------------------------------------|-------------|----------------|----------------|----------------|
| Age/gender | Total (n) | Sign of Peritonitis, n (%) | Abdominal distension, n (%) | Severe tenderness, n (%) | Radiological evidence of mesenteric injury, n (%) |
| 0-5 | | | | |
| Female | 1 | 1 (100) | - | - | - |
| Male | 3 | 2 (66) | - | - | 1 (33.3) |
| Total | 4 | 3 (75) | - | - | 1 (25) |
| 6-10 | | | | |
| Female | 3 | 2 (66) | - | - | - |
| Male | 2 | 1 (50) | - | 1 (50) | 51 (0.9) |
| Total | 5 | 3 (60) | - | 1 (20) | 51 (0.5) |
| 11-15 | | | | |
| Female | - | - | - | - | 0 (0.1) |
| Male | 3 | 1 (33.3) | - | - | 2 (33.3) |
| Total | 3 | 1 (33.3) | - | - | 2 (33.3) |
| 16-20 | | | | |
| Female | - | - | - | - | - |
| Male | 1 | - | 1 (100) | - | - |
| Total | 1 | - | 1 (100) | - | - |

| Table 5: Radiological, intraoperative mesenteric injury grading, and surgical procedure performed |
|-----------------------------------------------|-------------|----------------|---------------|----------------|
| Cases | Radiological grading | Intraoperative grading | Surgery (h) | Surgical procedure |
| 1 | Mesenteric hematoma | Grade 3 | 48 | Resection anastomosis |
| 2 | Mesenteric infiltration | Grade 4 | 48 | Resection anastomosis |
| 3 | Mesenteric infiltration | Grade 4 | 72 | Resection anastomosis |
| 4 | Mesenteric thickening | Grade 3 | 72 | Resection anastomosis |
| 5 | Mesenteric infiltration | Grade 4 | 48 | Resection anastomosis |
| 6 | Mesenteric hematoma | Grade 3 | 48 | Resection anastomosis |
| 7 | Mesenteric hematoma | Grade 3 | 48 | Resection anastomosis |
| 8 | Intermesenteric free fluid | Grade 4 | 120 | Stoma formation |
| 9 | Abrupt termination of mesenteric vessel | Grade 5 | 120 | Stoma formation |
| 10 | Mesenteric fat stranding | Grade 2 | 24 | Mesenteric tear repair |
| 11 | Mesenteric infiltration | Grade 3 | 24 | Mesenteric tear repair |
| 12 | Bowel wall thickening | Grade 3 | 24 | Mesenteric tear repair |
| 13 | Mesenteric blush | Grade 2 | 24 | Mesenteric tear repair |
necrosis of bowel and appearance of signs of peritoneal irritation after 48-72 hours of injury. Timely intervention from our side could have stopped this cascade and might have prevented our cases from undergoing resection and anastomosis.

In considering the outcome of our cases, decision was taken for early intervention and the next 4 cases were subjected to laparotomy on day 1 of admission itself based solely on CECT findings of mesenteric injury. Only mesenteric tear repair was required in these cases. Early enteral feeding and early discharge were achieved in these 4 cases, confirming our hypothesis that the early intervention is more beneficial rather than waiting for peritonitis or sepsis.

Analysis of case records of all 13 cases pointed out the fact that preoperative radiological mesenteric injury grades were comparable, while intraoperative findings suggested more severe injury grading in cases which underwent delayed surgical intervention than in those with immediate surgery. It is a matter of debate was the mesenteric injury grade more severe in the patients managed conservatively initially than in those with immediate surgery?

It is well-documented that the sensitivity of radiological scans to detect mesenteric injuries decreases as the time goes on following the injury. This is favored to be because the “more obvious” bowel and mesenteric injuries which require operative management often declare themselves earlier with more overt imaging features.[19] Relying on clinical examination or CT finding alone increases the chances of missing the mesenteric injuries.[10,21] In our study, we supplemented the clinical examination with frequent use of imaging modalities in form of ultrasonography or CECT as per the demand of the situation. Due to our aggressive and early intervention, we succeeded in averting the mortality in our study. Till date, very limited studies are published with small sample sizes and no randomization. For the formulation of protocol, a multicentric prospective study with a large sample size is needed to confirm our observations. This study has its own limitations: retrospective in nature, small sample size, short duration of the interval, and inexperience in the field of pediatric laparoscopy.

CONCLUSIONS

Not only the patients with conclusive findings in CECT such as free intraperitoneal air, solid organ injury with hemodynamically instability but also cases with equivocal, clinical examination and minor mesenteric injuries should be subjected to either laparoscopy or exploratory laparotomy without any unnecessary delay.

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Conflicts of interest
There are no conflicts of interest.

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