World Journal of Pediatric Surgery

Cases of pediatric intra-abdominal solid organ injury induced by blunt trauma experienced over a 15-year period at two centers in Japan

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To cite: Matsui M, Sugita K, Kawano T, *et al*. Cases of pediatric intra-abdominal solid organ injury induced by blunt trauma experienced over a 15-year period at two centers in Japan. *World Jnl Ped Surgery* 2023;**6**:e000560. doi:10.1136/wjps-2023-000560

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Received 10 January 2023
Accepted 19 May 2023

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ABSTRACT

Objective The present study attempts to clarify the clinical features of pediatric intra-abdominal solid organ injury at two institutions.

Methods The injured organ, patient age, sex, injury grade, imaging findings, intervention, length of hospital stay, and complications were retrospectively reviewed using medical records at two centers from 2007 to 2021.

Results There were 25 cases of liver injury, 9 of splenic injury, 8 of pancreatic injury, and 5 of renal injury. The mean age of all patients was 8.6±3.8 years old, with no difference between organ injury types. Radiological intervention was performed in four cases of liver injury (16.0%) and one case of splenic injury (11.1%), and surgery was performed in two cases of liver injury (8.0%) and three cases of pancreatic injury (37.5%). All other cases were treated conservatively. Complications included adhesive ileus in one case of liver injury (4.0%), splenic atrophy in one case of splenic injury (11.1%), pseudocysts in three cases of pancreatic injury (37.5%), atrophy of the pancreatic parenchyma in one case of pancreatic injury (12.5%), and urinoma in one case of renal injury (20.0%). No mortalities were observed.

Conclusion Pediatric patients with blunt trauma had favorable outcomes at two pediatric trauma centers covering a broad medical area, including remote islands.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ In the treatment of blunt abdominal trauma in children, it is necessary to accurately diagnose the injured organ and the severity of the injury, and quickly make a decision on whether to choose conservative treatment, laparotomy, or non-laparotomy treatment, including interventional radiology.

WHAT THIS STUDY ADDS

⇒ Regarding the clinical outcomes of blunt abdominal trauma in children, conservative treatment was chosen in most cases and surgery was performed in only 12.8% of cases.
⇒ Pediatric patients with blunt trauma had favorable outcomes at two pediatric trauma centers covering a large medical area, including remote islands.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ To consolidate care for pediatric abdominal trauma patients, development of regional guidelines and trauma registry is imperative.

INTRODUCTION

Trauma is one of the leading causes of death and disability in children globally.[1] Abdominal trauma occurs in approximately 25% of children with major trauma, and it is caused by blunt forces in most cases. Blunt abdominal trauma often leads to solid organ injury. The spleen is the most commonly injured organ, followed by the liver. Pancreatic injury is less common, but must not be overlooked due to its relatively high morbidity and mortality.[2] Enhanced CT is the gold standard for identifying abdominal injuries. The sensitivity of ultrasonography (US) varies between 56% and 97% in detecting hemoperitoneum in cases with abdominal organ injury, and the utility of performing a routine focused assessment with sonography for trauma examination is limited in children.[3] When pancreatic duct injury is suspected, endoscopic retrograde cholangiopancreatography can play an important role in obtaining an accurate diagnosis while also providing important information which can help in selecting optimal therapeutic options.[4] Magnetic resonance cholangiopancreatography is also a non-invasive and useful modality to work up pancreatic injury if patients are stable.[5] While it is widely accepted that most hepatic or splenic injuries can be managed non-operatively regardless of grade, management of pediatric pancreatic injury remains controversial. In any case, treatment at a specialized facility is almost always considered to be highly desirable.

Our prefecture (Kagoshima) has 605 islands and a very broad medical area extending 600 km from north to south and is characterized by a large number of inhabited islands. In our region, there are only two facilities capable of providing advanced treatment for pediatric trauma, such as treatment by pediatric surgeons, radiological intervention, and pediatric intensive care, and when specialized care is needed such patients must be transported by either airplane or helicopter.

In this study, we attempt to clarify the current status of care for severe pediatric trauma patients at two regional pediatric trauma center hospitals while also identifying the issues that need to be addressed in order to consolidate the care for these patients. The purpose of this study is to provide a reference material for improving the system of pediatric trauma care and to also consider some of the common problems when compared with other regions.

Table 1 Patients' background characteristics and causes of injury

Variables	Values (n=39)
Age (years)*	8.6±3.8
Sex, n (%)	
Male	22 (56.4)
Female	17 (43.5)
Pediatric Trauma Score*	10.5±1.9
Glasgow Coma Scale score*	14.8±0.8
Systolic blood pressure (mm Hg)*	112.7±16.7
Respiratory rate (beats per minute)*	23.2±4.9
Revised Trauma Score*	7.8±0.3
Injury Severity Score*	10.7±6.7
Mechanism, n (%)	
Traffic accident	11 (28.2)
Bicycle accident	6 (15.4)
Blow	13 (33.3)
Fall	9 (23.1)
Injured solid organ, n (%)	
Liver	25 (64.1)
Spleen	9 (23.1)
Pancreas	8 (20.5)
Kidney	5 (12.8)
Other injured organs, n (%)	
Thorax	7 (17.9)
Extremity	7 (17.9)
Face	5 (12.8)
Head and neck	4 (10.3)
Adrenal gland	2 (5.1)

*Data are presented with mean±SD.
SD, standard deviation.

METHODS

This is a retrospective study at two pediatric trauma centers in the southern Kyushu area of Japan. Blunt intra-abdominal solid organ injuries (liver, spleen, pancreas, or kidney) from 2007 to 2021 were included in this study. We excluded any patients who had a traumatic brain injury, or who were brought in while undergoing cardiopulmonary resuscitation and expired within 24 hours. The diagnosis was confirmed by imaging studies including enhanced CT and/or US in all patients. The medical charts were reviewed to collect data on age at diagnosis, sex, type of blunt trauma, injured organ, American Association for the Surgery of Trauma injury score,[6] imaging findings, type of intervention, length of hospital stay, and late complications.

Statistical analyses

Fisher's exact test was used for comparisons of nominal variables, and the results are shown as number and percentage. The Mann-Whitney U test or Welch test was used for comparisons of continuous variables, and the results are shown as mean±standard deviation (SD), or median (interquartile range) .

RESULTS

Patients' background characteristics and cause of injury

A total of 39 patients were enrolled in this study (table 1), of whom 56.4% were male (n=22) and 43.5% were female (n=17). The mean age of the patients was 8.6±3.8 years . The Pediatric Trauma Score (PTS)[7] of all cases was 10.5±1.9 scores, and the Revised Trauma Score (RTS) of all cases was 7.8±0.3 scores . The Injury Severity Score (ISS) according to the Abbreviated Injury Scale of all cases was determined as 10.7±6.7 scores.[8] The most common causes of injury in all cases were traffic accidents (28.2%), followed by blows (33.3%), bicycle accidents (15.4%), and falls (23.1%). The liver was the most commonly damaged organ in 25 cases (64.1%), followed by the spleen in 9 cases (23.1%), the pancreas in 8 cases (20.5%), and the kidney in 5 cases (12.8%). Other injuries were observed in the chest or thorax in seven cases (17.9%), in the extremities in seven cases (17.9%), in the face in five cases (12.8%), and in the head and neck in four cases (10.3%). Adrenal injuries were also observed in two cases (5.1%).

Treatment and clinical outcome of cases according to the injured solid organ

The treatment and outcomes of the cases according to the injured solid organ are shown in table 2. There were no significant differences by age or gender with regard to the type of injured organ. The most common causes of liver (60.0%) and pancreatic (62.5%) injuries were traffic accidents, including bicycle accidents, while the cause of splenic and renal injuries tended to be a blow.

Table 2 Treatment and clinical outcome of cases according to injured solid organ

Variables	Injured Organ Liver (n=25)	Spleen (n=9)	Pancreas (n=8)	Kidney (n=5)	P value
Age (years)*	7.0 (3–10)	9.5 (10–12)	11 (9.8–12.3)	12.0 (12–15)	<0.01
Sex, n (%)					0.97
Male	12 (48.0)	6 (66.7)	5 (62.5)	3 (60.0)	
Female	13 (52.0)	3 (33.3)	3 (37.5)	2 (40.0)	
Cause of injury, n (%)					0.10
Traffic accident	15 (60.0)	1 (11.1)	5 (62.5)	1 (20.0)	
Blow	5 (20.0)	5 (55.6)	3 (37.5)	3 (60.0)	
Fall	5 (20.0)	3 (33.3)	0 (0.0)	1 (20.0)	
AAST grade, n (%)					0.11
I	4 (16.0)	2 (22.2)	2 (25.0)	3 (60.0)	
II	12 (48.0)	2 (22.2)	1 (12.5)	0 (0.0)	
III	3 (12.0)	4 (44.5)	5 (62.5)	1 (20.0)	
Operative			3/5 (60.0)		
IV	4 (16.0)	1 (11.1)	0 (0.0)	1 (20.0)	
Operative	1/4 (25.0)				
V	2 (8.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Operative	1/2 (50.0)				
Time until consultation (hours)*	4 (2–6)	10(5–24)	5.5 (4–63)	7 (6–8)	0.09
Radiological intervention, n (%)	4 (16.0)	1 (11.1)	0 (0.0)	0 (0.0)	
Surgical intervention, n (%)	2 (8.0)	0 (0.0)	3 (37.5)	0 (0.0)	
Intensive care, n (%)	6 (24.0)	1 (11.1)	1 (12.5)	0 (0.0)	
Bed rest (days)*	9 (7–14)	7 (7–14)	14 (10–16)	14 (7–14)	0.80
Hospitalization (days)*	15 (9.5–20.5)	12 (10–24)	28.5 (19.3–48.5)	18 (7–20)	0.08
Imaging for follow-up, n (%)					0.01
Ultrasound	10 (40.0)	2 (22.2)	0 (0.0)	4 (80.0)	
CT	16 (64.0)	8 (88.9)	6 (75.0)	4 (80.0)	
MRI	0 (0.0)	0 (0.0)	3 (37.5)	0 (0.0)	

*Data are presented with median (IQR).
AAST, American Association for the Surgery of Trauma; IQR, interquartile range; MRI, magnetic resonance imaging.

Radiological intervention was performed in four cases of liver injury (16.0%) and one case of splenic injury (11.1%), and surgical intervention was performed in two cases of liver injury (8.0%) and three cases of pancreatic injury (37.5%). All cases excluding one patient who underwent surgical intervention were treated conservatively. In the image grade classification by the American Association for the Surgery of Trauma, the liver, spleen, and pancreas were most commonly grade III. Grade V was also seen in the liver in two cases. The average time from injury to transfer to either of the two centers was 25±69 hours. There were 12 patients who took more than 10 hours to arrive at our centers. All of them were transferred to a nearby hospital and some received inpatient care. Thereafter, they were referred to our two centers for more advanced medical care. Arterial embolization as radiological intervention was performed in four cases of liver injury (16.0%) and one case of splenic injury (11.1%). Surgery was performed in two cases of liver injury (8.0%) and three cases of pancreatic injury (37.5%). Six cases of liver injury (24.0%) and one case of pancreatic injury (12.5%) and one case of splenic injury (11.1%) were initially treated in the intensive care unit. Pancreatic injuries had the longest hospital stay (median 28.5 (19.3–48.5) days), followed by hepatic, splenic, and renal injuries.

Comparison of patients with single solid organ injury and those with multiple solid organ injury

Single solid organ injuries were seen in 31 patients and multiple solid organ injuries in 8 patients (table 3). The mean ages were 10 (7–12) and 8.5 (6.5–10) years old, respectively. Regarding the cause of trauma, blows were the most common cause of single solid organ injury,

Table 3 Single solid organ injury versus multiple solid organ injury

Variables	Single solid organ injury (n=31)	Multiple solid organ injury (n=8)	P value
Age (years), median (IQR)	10 (7–12)	8.5 (6.5–10)	0.43
Sex, n (%)			1.00
Male	17 (54.8)	5 (62.5)	
Female	14 (45.2)	3 (37.5)	
Mechanism, n (%)			0.02
Traffic accident	5 (16.1)	6 (75.0)	
Bicycle accident	6 (19.3)	0 (0.0)	
Blow	13 (41.9)	0 (0.0)	
Fall	7 (22.6)	2 (25.0)	
Injured organ, n (%)			0.03
Kidney	2 (9.7)	4 (50.0)	
Liver	20 (64.5)	6 (75.0)	
Spleen	6 (19.4)	4 (50.0)	
Pancreas	8 (25.8)	1 (12.5)	
Injury Severity Score, mean±SD	8.5±6.0	15.5±7.5	0.01
Pediatric Trauma Score, mean±SD	11.4±1.4	7.9±2.6	<0.01
ICU hospitalization, n (%)	2 (6.4)	7 (87.5)	<0.01
Bed rest (days), mean±SD	10.2±5.8	21.2±6.8	0.01
Mortality, n (%)	0 (0.0)	0 (0.0)	n.s.

ICU, intensive care unit; IQR, interquartile range; SD, standard deviation.

while traffic accidents were the most common cause of multiple solid organ injuries, and the difference was significant. The trauma scores, ISS and PTS, were significantly different between the two groups. All but one case with multiple solid organ injuries were treated in the intensive care unit. Bed rest also significantly differed between the two groups (10.2±5.8 days and 21.2±6.8 days, respectively).

Comparison of conservative management with operative management

Surgery was performed on five patients, while conservative treatment was chosen for all others (table 4). Arterial embolization was performed in five patients; however, one of them later underwent laparotomy due to inadequate hemostasis. Regarding the cause of surgery, three patients with liver injury, including one who underwent arterial embolization, needed to have their bleeding controlled, and two patients with pancreatic injury underwent drainage surgery. The RTS and PTS did not differ significantly between the two groups. The mean ISS was 9.3±6.2 scores in the conservative management group and 19.0±6.5 scores in the operative management group with a significant difference between the two groups (p<0.01). There were significant differences between the two groups. Blood transfusions were performed in all patients in the surgical group, and in only two patients (6.0%) in the conservative management group. In the conservative management group, one patient had pancreatic pseudocyst, one had pancreatic atrophy, one had splenic atrophy, and one had a urinary mass; in the operative management group, two patients had a pancreatic pseudocyst and one had a small bowel obstruction as complications. However, there was no significant difference between the two groups.

Patient presentation on operative management

Patient presentation on operative management is shown in table 5. Two patients with liver injury underwent surgery. Both patients were transported to our hospital within 2 hours. One with grade IV liver injury underwent left lateral segmentectomy for rebleeding after embolization. Another patient with grade V underwent hemostatic suture and hepatorrhaphy for bleeding control. Three patients with pancreatic injury underwent surgery. All had grade III injury. One underwent open gastrocystostomy for a symptomatic, 80 mm pancreatic pseudocyst on day 16 after admission. The remaining two patients with pancreatic injury underwent drainage surgery.

DISCUSSION

This study focused on pediatric trauma outcomes and retrospectively reviewed the treatment of these patients at two institutions. The major findings of this study are as follows: (1) regarding the clinical outcomes, conservative treatment was chosen in most cases and surgery was performed in only 12.8% of the cases; (2) pediatric

Table 4 Non-operative management versus operative management

Variables	Non-operative management (n=34)	Operative management (n=5)	P value
Sex, n (%)			1.00
Male	18 (52.9)	3 (60.0)	
Female	16 (47.1)	2 (40.0)	
Revised Trauma Score*	7.8±0.2	7.5±0.6	0.16
Injury Severity Score*	9.3±6.2	19.0±6.5	<0.01
Pediatric Trauma Score*	10.8±1.7	9.2±2.6	0.13
Transfer time, median (IQR)	†5 (2.5-10)	3 (2-5)	0.38
Blood transfusion, n (%)	2 (6.0)	5 (100)	<0.01
ICU hospitalization, n (%)	4 (11.8)	4 (80.0)	<0.01
Radiological intervention, n (%)	4 (11.8)	1 (20.0)	0.52
Complications, n (%)	Pseudocyst: 2 (5.8) Pancreatic atrophy: 1 (2.9) Splenic atrophy: 1 (2.9) Urinoma: 1 (2.9)	Pseudocyst: 1 (20.0) Adhesive intestinal obstruction: 1 (20.0)	n.s.

*Data are presented with mean±SD.
†Time to radiological intervention after injury: 3.3±4.5 hours.
ICU, intensive care unit; IQR, interquartile range; SD, standard deviation.

patients with blunt trauma had favorable outcomes at two pediatric trauma centers covering a large medical area, including remote islands; and (3) increased ISS might be a significant factor associated with the perceived need for operative treatment.

The operative rate was 12.8% (8.0% of patients with liver injury and 37.5% of patients with pancreatic injury) in our study. Ozturk *et al*[9] reported 205 pediatric blunt abdominal solid organ injury cases, of whom 35 (17%) patients were treated operatively. Spijkerman *et al*[10] also reported 121 pediatric blunt abdominal injury cases, of whom 18 (14.9%) were treated operatively. In this report, 5 out of 43 (11.6%) patients with liver injury and 3 out of 7 (42.6%) patients with pancreatic injury underwent surgery. Our result does not seem to be so different from these results. Non-operative management (NOM) is considered the standard for blunt liver and splenic injury according to a retrospective study. Holmes *et al* showed an NOM failure rate of 3% for isolated liver injuries and 4% for isolated spleen injuries.[11] None of our cases required surgery on the spleen, and conservative treatment, including embolization, is considered very effective. Despite a significant number of publications on this topic, the management of pancreatic injury remains controversial. Most patients with grade I and II pancreatic injuries can be managed non-operatively. However, as for grade III, laparoscopic resection has been reported to be effective in some studies.[2] Additionally, the NOM failure rate is as high as 26% for pancreatic injuries, and especially high in patients with ductal injury.[12] In this study, all grade I and II pancreatic injuries were treated non-operatively, while all grade III pancreatic injurieswere initially treated non-operatively, three of which eventually required surgery. These results might support the idea that conservative treatment is the mainstay of treatment for pediatric abdominal blunt trauma, but the requirement for surgery should be determined carefully.

Table 5 Patient presentation on operative management

Patient	Target organ	AAST grade	Indication	Surgical procedure	Time to intervention
1	Liver	IV	Bleeding after radiological intervention	Left lateral segmentectomy	8 hours
2	Liver	V	Bleeding	Hemostatic suture, hepatorrhaphy	4 hours
3	Pancreas	III	Pseudocyst	Gastrocystostomy	Day 16
4	Pancreas	III	Pancreatic duct injury	Drainage	Day 2, day 11
5*	Pancreas	III	Pancreatic duct injury	Drainage	Day 44

*Patient 5 underwent endoscopic retrograde pancreatography for pancreatic stent on day 10 after admission.
AAST, American Association for the Surgery of Trauma.

There are several scoring systems for trauma severity classification even in children, but the ISS is often used since it is known to correlate well with the mortality of patients.[8] The PTS is a scoring system that has been developed to classify the severity of pediatric trauma at the initial stage of treatment and is based on six factors: weight, respiratory status, contraction, blood pressure, consciousness, open wound, and fracture.[7] Tepas *et al*[13] found that the PTS value at admission was significantly related to the ISS value at discharge or death. Because it is pointed out that when PTS is used for triage, severe cases with a low PTS can be preferentially transferred to a higher trauma center, and medical facilities and other medical resources can be used more efficiently. While ISS is calculated based on anatomical severity, RTS and PTS concentrate more on physiological severity. In our study, RTS and PTS were not correlated with surgery, and only ISS was well correlated. This can be explained by the fact that three out of five surgical cases were patients with pancreatic injury whose vital signs were relatively stable at admission. On the other hand, PTS was correlated well with the length of intensive care unit stay in multiple trauma cases. These results may suggest that early transfer to a pediatric trauma center should be considered if pediatric abdominal trauma patients show either high ISS or low PTS at local hospitals.

Another problem is that of transfers. Our region has many remote islands, and direct transfer to two facilities is sometimes very difficult; we had 12 patients who were seen for more than 10 hours at a local clinic, all of whom were then transferred to a nearby hospital, in some cases for inpatient care, and only thereafter were they referred to our center. Available evidence shows no difference in mortality between transferred patients and those who received direct hospitalization. However, most studies exclude patients who died in outlying island hospitals, and therefore the association between transfer and mortality rates may remain unclear.[14] Prospective studies, such as the use of population-based trauma registries, are needed to determine whether the process of interhospital transfer to higher tertiary care compared with direct admission to a trauma center adversely affects the clinical outcomes of trauma patients. For this purpose, it is necessary to develop population-based trauma registries in our region. Also, this study revealed that both trauma centers in our region have neither institutional nor shared guidelines for pediatric abdominal trauma. It is imperative to create our regional pediatric abdominal trauma guidelines considering geographical features. Such new guidelines will facilitate transfers from remote islands and lead to better clinical outcomes of pediatric trauma patients in our region.

Limitations

The present study was associated with some limitations, including the fact that it was conducted retrospectively over a 15-year period and not so many cases were examined. There were also multiple problems, such as the fact that we had to consider emergency surgery for liver and pancreatic injuries together.

Conclusions

In conclusions, pediatric patients with blunt abdominal trauma had favorable outcomes at two pediatric trauma centers covering a large medical area, including remote islands. To consolidate care for pediatric abdominal trauma patients, development of regional guidelines and trauma registries is imperative.

Acknowledgements We thank Brian Quinn for his comments and help with the article.

Contributors MMa wrote the main manuscript text. KS and TKaw analyzed the data, made the tables, and wrote the main manuscript text. NN, AN, MMur, KYan, SO, TH, KYam, WY, and MMut collected the data based on medical records. All authors were in charge of patients' management. TKaj and SI gave conceptual advice. All authors reviewed the manuscript. SI accepts full responsibility for the work.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient consent for publication Consent obtained directly from patient(s).

Ethics approval This study involves human participants and was performed in accordance with the Ethical Guidelines for Medical and Health Research Involving Human Subjects by the Ministry of Health, Labour and Welfare of Japan in 2014 and complies with the Helsinki Declaration of 1964 (revised in 2013). The study was approved by the local ethics committee of our institution (27-119). Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request.

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