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Review

Intra-abdominal injury from extra-peritoneal ballistic trauma

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ABSTRACT

Over the last century sporadic reports have described intra-abdominal injury without penetration of the abdominal cavity but the underlying mechanism of energy transfer appears variable. This article reviews the 19 documented cases of this phenomenon and discusses the mechanism of energy transfer in both primary blast injury and ballistic injury that may be responsible.

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Introduction

The risks of visceral injury from abdominal ballistic trauma have been well known for centuries[1] and are estimated to occur in up to 90% of cases,[2] although some can be managed non-operatively without significant missed injuries,[3] but the risk of internal injury when there has been no breach of the peritoneal cavity is much less well recognised and limited to a 19 published cases (Table 1). Within this limited number of cases there is no clear delineation of a mechanism of causation as the injuries have been caused by both low and high energy transfer mechanisms. None of the published reports to date has reviewed the entire series of cases.

World Wars 1 and 2

There are only three cases described from the World Wars. Fraser and Bates[4] described a wound track that was clearly extraperitoneal on exploration but had ruptured the urinary bladder in both its intra- and extraperitoneal portions. Two years later Richards[5] discussed four cases where minimal cutaneous wounds concealed intraperitoneal injury. In three of those cases the breach of peritoneum is clearly described, but in the fourth no such description is made and it can be presumed that the caecal and terminal ileal perforations were caused by an extraperitoneal passage of a missile. Contained within the hundreds of cases described by Gordon-Taylor in his description of the abdominal surgery of 'Total War' is a single case of a bomb fragment penetrating injury to the right groin in whom laparotomy revealed an intact peritoneum and three perforations of the terminal ileum.[6] In all three of these cases it is impossible to identify whether these were low or high energy transfer wounds and these cases are not

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Table 1
Reports of intra-abdominal visceral injury from penetrating missiles without peritoneal or diaphragmatic penetration. LET (low energy transfer); HET (high energy transfer); ICS (intercostal space); AL (axillary line).

Authors (year)[Ref.]	Mechanism of Injury	Energy transfer	Intra-abdominal Injuries
Fraser and Bates (1916)[4]	Not specified	Unknown	Intra-and extra-peritoneal bladder rupture
[a]Richards (1918)[5]	Not specified	Unknown	1 caecal and 3 terminal ileal perforations
Gordon-Taylor (1942)[6]	Bomb fragment	Unknown	3 perforations of terminal ileum
Edwards and Gaspard (1974)[7]	.32 hand gun	LET	Mid-jejunal perforation
Ben-Menachem (1979)[8]	.22 handgun	LET	Perforation of terminal ileum
	.22 handgun	LET	Terminal ileal mesenteric haemorrhage
Kennedy et al. (1991)[9]	.38 handgun	LET	Splenic capsular tear – left undisturbed
	Unknown GSW	Unknown	Splenic capsular tear – left undisturbed
	9 mm handgun	LET	Splenic parenchymal laceration. Suture splenorraphy
Maron and Baker (1994)[10]	AK 47 GSW	HET	Splenic parenchymal laceration → splenectomy.
Sasaki and Mittal (1995)[11]	Unknown GSW	Presumed HET	Mid-jejunal perforation
Velitchkov et al. (2000)[12]	AK-47 GSW	HET	5 perforations of mid-ileum perforation
Sharma et al. (2004)[13]	Shotgun Wound – SI	HET	Caecal contusion with perforation
	7.62 rifle GSW	HET	Perforation of the splenic flexure of colon
Edwards and Heath (2004)[14]	.22 rifle	LET	Perforation of the splenic flexure of colon
Bounovas et al. (2005)[15]	Shotgun Wound – SI	HET	Perforation of the splenic flexure of colon
Klein et al. (2007)[16]	.223 Rifle GSW	HET	Perforation of splenic flexure of colon
Nessen et al. (2008)[17]	M-16 Assault Rifle	HET	Perforation of transverse colon
Webster et al. (2011)[18]	Assault rifle GSW	HET	Perforation of hepatic flexure of colon

[a] From the author's description this case is presumed to represent intraperitoneal injury from extraperitoneal wounding although is not entirely certain.

discussed further as their reporting is brief and additional information not available.

Low energy transfer wounds

Following World War 2, no further cases of this phenomenon were reported until 1974 when Edwards and Gaspard described a patient who sustained a low energy transfer wound crossing tangentially across the abdominal wall resulting in a mid-jejunal perforation.[7] Four further low energy transfer gunshot wounds yielded injuries to the terminal ileum, the ileal mesentery and two of the spleen.[8,9] The third case reported by Kennedy et al. does not describe the bullet involved but examination of the case would suggest that a low energy transfer mechanism is most likely. In the six probable low energy transfer cases, four were taken to theatre directly on the basis of likely trajectory despite benign abdominal examinations and no evidence of free intra-abdominal air on plain radiographs.[8,9] In two other low energy transfer cases,[7,8] normal initial investigations prompted observational management, although one case had wound debridement that confirmed an extraperitoneal track.[7] Ben-Menachem's case progressed to peritonitis 'several hours' after initial review[8] and Edwards' case four days after wound debridement[7] – laparotomies revealed terminal ileal mesenteric haemorrhage and mid-jejunal perforation respectively. The most recent low energy transfer case was operated on due to worrisome trajectory in the face of a normal CT scan and identified a splenic flexure colonic perforation.[14]

High energy transfer wounds

The remaining cases are likely to be high energy transfer wounds; six from assault rifles[10,12,13,16–18] and two self inflicted shotgun wounds[13,15] and one of unknown source.[11] The energy transfer of shotgun injuries is variable but when shot at close range act as high energy transfer weapons. There were six colonic perforations,[13,15–18] two of the small bowel[11,12] and a single splenic laceration.[10] In these eight patients, six proceeded to immediate laparotomy: two had significant peritoneal irritation on initial examination[11,13] and one had a grossly positive diagnostic peritoneal lavage.[10] One patient had unexpected free intra-abdominal air on a CT chest performed for a trajectory that included the lower chest[15]; the two remaining cases were local nationals injured by high energy transfer gunshot wounds in Afghanistan – one had a negative CT scan but progressive abdominal signs[18] whilst the other underwent laparotomy for a worrying trajectory where it was not clear whether CT scanning was available.[17] In the three other cases, one patient had sudden onset abdominal pain with progressive signs on examination 25 min after initial assessment with normal radiographs and laboratory investigations[13]; CT confirmed intra-abdominal air. The second case had a small bleb of air evident on initial CT but a benign examination; repeat CT two days later revealed extensive intra-abdominal air which prompted laparotomy.[16] The final case had normal plain radiographs, abdominal ultrasound and intravenous urogram initially and underwent wound debridement only. Abdominal pain and peritonitis supervened four days after wound exploration and laparotomy revealed five perforations of the mid ileum.[12]

Other cases

Aside from the 19 cases discussed here the literature alludes to others. Gordon-Taylor wrote "Hollow viscera have been ruptured by fragments which have not penetrated the coelomic cavity, as was pointed out by Owen Richards, Sir John Fraser, and others in the last war"[12] whilst Nessen et al. suggest that the Wound Data and Munitions Effectiveness Team (WDMET) database of injuries sustained by American servicemen in the Vietnam War records five further cases of intraperitoneal injury without breach of the peritoneum although further details are not available.[17] Edwards discussed their unit's recent experience with 200 abdominal gunshot wounds; 185 underwent laparotomy and 15 did not.[7] In those undergoing laparotomy, 39/185 had no visceral injury and five had minor injuries that required no treatment (four liver and one small bowel contusion); in four of these five cases there was no peritoneal breach. The reported case of jejunal perforation was the only one out of the 15 conservatively managed cases that required delayed laparotomy.

Blast injury or cavitation?

The pathophysiology of both blast and ballistic trauma is now well understood. Primary blast injury are those injuries caused by the passage of the high pressure shock wave; when this wave hits the body two types of energy waves are generated: a compressive stress wave of low amplitude and high velocity and transverse