that the post-operative ventricular tachycardia did not produce hypotension or pulmonary oedema.

The operation of aorto-coronary by-pass has been very successful in the treatment of intractable angina, but objective evaluations of its effect on left ventricular function are few. Chatterjee *et al.* (1972), Gareth Rees *et al.* (1971), have shown that this operation does produce symptomatic and measurable improvement in the indices of left ventricular contractility in patients with ischaemic heart disease. The cure of refractory ventricular tachycardia in this case provides further evidence for the beneficial action of aorto-coronary bypass grafting on left ventricular function.

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Retroperitoneal rupture of the duodenum due to blunt trauma

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Summary

The subject is reviewed and a further case of retroperitoneal rupture of the second part of the duodenum due to blunt abdominal trauma in a child is reported. The equivocal initial clinical signs and characteristic X-rays are described.

Incidence

In a review of the literature from 1902 to 1942 Harrold (1951) found that rupture of the duodenum occurred in 9% of 717 cases of intestinal rupture due to non-penetrating trauma. Hanley in 1958 quoted the incidence until that time as having been estimated as follows: 10% of all gastrointestinal ruptures were duodenal, a quarter of those were retroperitoneal, and 90% of the latter involved the second or third part. In an analysis of eighty-six traumatic duodenal injuries Burrus, Howell and Jordan (1961) found that only 10% of these injuries were due to blunt trauma, and Webb *et al.* (1958) found similarly that in their series of fifty duodenal injuries 10% followed blunt trauma. Under these conditions the duodenal

lesion tended, in a higher percentage of cases, to be much more severe than that due to a penetrating wound. It would also appear reasonable to expect the incidence of retroperitoneal perforation to be higher after blunt trauma and that of intra-peritoneal perforation to be higher after penetrating wounds. This is partly confirmed by the findings of McCort (1966) who gives the order of frequency of duodenal injuries following blunt abdominal trauma as:

- (1) intramural haematoma;
- (2) retroperitoneal perforation;
- (3) intraperitoneal perforation.

This has, therefore, been a relatively rare lesion but has probably started to increase in frequency over the past two decades with the increasing numbers of motor vehicle crashes. Roman, Silva, and Lucas (1971) reported that at fifty laparotomies performed for blunt abdominal trauma each year over a 10 year period, approximately 5% of the patients had a duodenal injury. Eighteen of the twenty-three patients with duodenal injuries in their series (from Detroit) had been involved in automobile accidents.

with thirteen specifically stating that they had hit the steering-wheel. Resnicoff, Morton and Bloch (1967) noted that of nine patients with this lesion eight had been involved in automobile accidents and all were young adults. That the injury is said to be ten times more common in men than in women (Kelly and Todd, 1956) probably reflects this association with automobile crashes. Associated intra-abdominal injuries and multiple extra-abdominal injuries are both common, the most frequent concomitant intra-abdominal injuries being lacerations of the liver and damage to the pancreas, great vessels, biliary system, stomach, spleen or right kidney. Roman *et al.* (1971) proposed a useful classification of the injuries as:

Type 1: serosal tear or intramural haematoma without complete perforation or associated pancreatic injury,

Type 2: complete perforation or transection of the duodenum with no pancreatic injury,

Type 3: any duodenal injury in combination with injury to the head of the pancreas;
and found the incidence in their twenty-three patients to be: Type 1, three cases; Type 2, seven cases, and Type 3, thirteen cases.

Mechanism of injury

There is usually a history of a severe blow to the abdomen but the injury may sometimes appear minimal to the patient and produce few symptoms for several hours. At the present time the commonest cause is a steering-wheel injury and this can largely be prevented by the use of a properly worn seat-belt and shoulder harness in conjunction with a collapsible steering column (Roman *et al.*, 1971). In this context it is interesting to note that in the papers on retroperitoneal rupture of the duodenum the steering-wheel is often quoted as a cause but I have not found an instance in which the seat-belt was incriminated. However, in papers on seat-belt injury it is now well documented (Garrett and Braunstein, 1962; Witte, 1968; MacLeod and Nicholson, 1969) that seat-belts of the lap type, especially if worn loosely, can cause severe retroperitoneal duodenal damage in motor vehicle occupants who, admittedly, without the seat-belts would have been killed instantly or suffered severe head, chest or skeletal injuries. Since 90% of retroperitoneal ruptures occur in the second and third parts it has been suggested that a bursting, or blow-out, lesion, caused by rapid increase in pressure in the duodenal loop due to compression whilst it is functionally closed proximally by the pylorus and distally by acute angulation formed by the ligament of Treitz, may be the commonest mechanism (Rothchild and Hinshaw, 1956; Webb *et al.*, 1958). The tears often occur in the outer convex border of the loop and may be quite long with edges showing only oedema rather than contusion of all layers which

would be expected with crushing trauma. However, Roman *et al.* (1971) suggest that this explanation may be rather unlikely. Their experimental findings in dogs showed that sudden rise in intra-luminal pressure with saline or air caused a pinpoint perforation near either end of the occluded loop whereas in practice the clinical injuries are often transverse lacerations near the middle of the loop. On the other hand it is interesting to note that Geoghegan and Brush (1956) found that relatively small forces applied to canine small bowel segments protected by abdominal wall preparations caused hydraulic blow-out ruptures of fluid-filled closed-loop segments whereas the same forces applied to similar but empty and open-ended segments produced no ruptures. In the duodenal loops included in their series the fluid-filled closed-loop specimen sustained a blow-out perforation whilst the empty open-ended specimen had only a sero-muscular injury. These closed-loop blow-out lesions are commoner in the proximal jejunum or distal ileum (Evans, 1973) but it would seem possible that this mechanism of injury could produce a duodenal perforation when the fluid-filled closed-loop situation was present. It has also been postulated that a hydraulic blow-out may occur when gastric contents are propelled under pressure through the open pylorus and strike the duodenal wall with enough force to rupture it. Salisbury (1945) described a case in which a gunner sustained a recoil blow in the left upper quadrant of the abdomen from a 25 pounder field gun and attributed the rupture of the second part of the duodenum to the rise in pressure when the gaseous contents of the stomach were forced into it.

A tangential force applied to the junction between a fixed retroperitoneal part and a mobile part may cause tearing near either or both ends of the duodenum or rarely even complete avulsion of the whole loop. A shearing force applied to a fixed part may result in a transverse tear such as is often seen clinically in the second part. It has also been suggested (Fish and Johnson, 1965) that compression of the costal arches and upper portion of the abdomen may drive the liver and diaphragm upwards thus causing the common bile duct and hepatoduodenal ligament to pull on the pancreaticoduodenal region resulting in a duodenal injury distal to the ampulla of Vater. Finally the first and fourth parts of the duodenum may be ruptured by direct compression between the external object and the vertebral column. Simpson (1950) described a case in which this was the probable mechanism of a rupture of the posterior wall of the first part of the duodenum. Resnicoff *et al.* (1967) postulate an oblique force from a left anterior direction as a cause of compression and rupture of the fourth part. In considering these mechanisms it must be remem-

bered that, on compression from in front, the head of the pancreas will tend to move to the right with the second and third parts of the duodenum and the body and tail will probably move to the left with the first and fourth parts of the duodenum, the stomach and proximal jejunum (Roman *et al.*, 1971). The frequency of combined pancreatoduodenal injuries suggests that direct compression of this anatomical unit may well be the commonest mechanism of injury. However, it is probable that shearing forces, direct compression and increased intra-luminal pressure all act to some extent in each case on a viscus which, as Kelly and Todd (1956) point out, is often distended by fluids from the stomach, bile duct, pancreatic duct, and its own mucosal surface.

Diagnosis

The difficulty in diagnosis is emphasized by Resnicoff *et al.* (1967) who found that on average 6 hr passed between the time of injury and surgical intervention and that the diagnosis could be established pre-operatively in only one-third of the cases. Several authors stress that the clinical signs may be minimal initially and may be modified by many factors including the size of the tear and the nature of any associated injury. Intra-mural haematoma often presents insidiously as duodenal obstruction and sometimes with no definite history of trauma (Caird and Ellis, 1958). In retroperitoneal rupture the history of trauma is nearly always present and usually considerable force is described though occasionally it may have appeared minimal. Right upper quadrant or epigastric pain and tenderness are the most constant symptoms and sign. Guarding or rigidity may be absent for several hours. Nausea and vomiting may occur. Surgical emphysema may occasionally be felt in the abdominal or thoracic wall or in the posterior pelvic wall on rectal examination (Harkins and Nyhus, 1969). The temperature and pulse rate may or may not be raised. In other words the clinical picture is very variable and a high index of suspicion is required to make the diagnosis early (Hanley, 1958). Cope (1968) points out that even in intra-peritoneal lacerations of the gut the symptoms and signs are often equivocal for some hours due to paresis of the bowel wall, and pouting of mucous membrane to plug a small hole in addition to the sealing action of fibrinous exudate. The differential diagnosis often includes ruptured liver, pancreas, spleen or kidney. Stripping of the parietal peritoneum lining the right paracolic gutter by duodenal contents and blood can produce an appendicitis-like picture.

Radiological examination

Firstly the chest should be examined by an upright postero-anterior film to exclude pulmonary, pleural

or diaphragmatic damage. An antero-posterior supine abdominal film and a left lateral decubitus film (patient lying on left side with right side up) form the basic radiographic examination. Gould and Thorwarth (1963) recommend that a right lateral decubitus and supine cross-table lateral may also be of value. To these, should they prove inconclusive, may be added contrast films using a sterile water-soluble medium (Kemp Harper, 1967; Meyers, 1968). Special views for the ribs, spine and pelvis are often also indicated. In the case of intramural haematoma of the duodenum the plain abdominal film may show a large amount of gas in the stomach and possibly tapering or cut-off of the gas shadow at the haematoma site. Contrast studies may reveal the mass and show a coil-spring appearance due to crowding together of the thickened, oedematous valvulae conniventes (Felson and Levin, 1954). This may be useful in the patient who develops duodenal obstruction after observation for some time. Retroperitoneal perforation of the duodenum results in escape of gas and gastroduodenal contents plus blood into the right retroperitoneal 'space'. On X-ray there may be

- (1) A bubbly, mottled configuration in the general location of duodenum. This is probably the commonest sign and the most difficult to interpret.
 - (2) Bubbles or pockets of gas outlining the right kidney.
 - (3) Gas outlining the lateral border of the right and possibly also the left, psoas muscle.
 - (4) On the other hand the lateral border of the right psoas may be obscured by haematoma and duodenal contents.
 - (5) Retroperitoneal air in the infra-diaphragmatic or pelvic regions.
 - (6) Mediastinal or even cervical emphysema.
 - (7) Subcutaneous emphysema in the right flank.
 - (8) Intraperitoneal air, free or encapsulated.
 - (9) Displacement of the hepatic flexure antero-medially by haematoma.
 - (10) Local abscess, with fluid level in the region of the duodenum.
- (Kemp Harper, 1967; Meyers, 1968.)

If plain films are negative and clinical signs remain equivocal an upper gastro-intestinal examination with a sterile water-soluble contrast medium should be performed. It should be noted that in the presence of obvious pneumoperitoneum the presence of gas in the retroperitoneal tissues may easily escape detection (Meyers, 1968). Should there be unexpected deterioration after apparently adequate surgery prompt re-examination with a sterile water-soluble contrast medium may reveal leakage at the repair site or further undetected duodenal perforations. In this way a leak may be detected before frank fistula develops.

Management

This is fully covered in the article of Roman *et al.* (1971) and is now only outlined. Firstly, observation in hospital is essential if there is any possibility of damaged viscus after blunt abdominal trauma. Secondly, routine resuscitative measures, observations and investigations are set in motion, the value of radiology having been emphasized. Thirdly, thorough exploration at early laparotomy should be undertaken if clinical or radiological signs point to retroperitoneal rupture. The mortality when repair is delayed more than 24 hr is 65% whereas it is only 5% when repair is performed early (Roman *et al.*, 1971). A crepitant, bubbly, black-green haematoma may be found in the transverse mesocolon, small bowel mesentery and retroperitoneal areolar tissue in the right upper quadrant and around the right kidney. Wide mobilization of the duodenum by a Kocher manoeuvre is then required. This is most important since it has been estimated that over 30% of retroperitoneal ruptures are missed at the time of initial exploration (Rothchild and Hinshaw, 1956; Kelly and Todd, 1956; Harkins and Nyhus, 1969). Intramural haematoma can be carefully evacuated through a transverse serosal incision at the junction of the distal end of the haematoma and normal bowel wall. Gastro-jejunostomy might also be added if necessary. When the diagnosis of intramural haematoma has been made accurately by radiology conservative management has been adopted with success (Felson and Levin, 1954). Complete perforations are best closed transversely in two layers. If the rupture is longitudinal transverse closure should be performed if possible but if the tear is too long or the damage too extensive for this, then resection and end to end anastomosis may be required in order to avoid the strictured segment which would be liable to follow longitudinal repair. Gastro-jejunostomy may be necessary if the duodenal wall is very oedematous and contused. Complete transection is best treated by direct end to end anastomosis if this is possible. Alternatively closure of the distal duodenal stump and duodeno-jejunostomy may be performed. The jejunal serosal 'patch' technique may be used to close a defect in which there has been actual loss of bowel wall tissue due to necrosis following severe contusion. In this technique a loop of intact jejunum is fixed over the defect in the duodenal wall (Kobold and Thal, 1963; Roman *et al.*, 1971). Associated injury of the head of the pancreas may pose a difficulty in management. A simple contusion usually only requires drainage of the area by a soft rubber tube. Subcapsular haematoma requires drainage. Rupture of the pancreas is best treated by pancreaticoduodenectomy. Damage of the ampulla may require re-implantation of the common bile duct and pancreatic duct (Welch, 1966). Drainage of the retro-

peritoneal space is advisable after all these procedures, the drain being kept away from the duodenal repair line (Resnicoff *et al.*, 1967).

Complications

These are well documented and include retroperitoneal cellulitis, peritonitis, paralytic ileus, duodenal obstruction, duodenal fistula, duodenal stenosis, local abscess, subphrenic abscess, bile or pancreatic duct stenosis, pancreatitis, pseudocyst of the pancreas, stress gastro-intestinal haemorrhage, wound infections and dehiscence, pulmonary infections, and renal failure.

Results

The mortality of this lesion remains considerable at about 25% overall. Roman *et al.* (1971) found in a retrospective analysis of the literature on duodenal injury published since 1950 that the mortality for their Type 2 injury was 13% of fifty-five patients, and for their Type 3 injury, 68% of twenty-two patients.

Case report

A 9-year-old boy was admitted to Lincoln County Hospital in April 1972 approximately 1 hr after falling from a stone wall. During the fall he had dislodged a stone slab from the top of the wall and this slab had then toppled off the wall and fallen about 7 ft, striking him in the right side of the abdomen. He complained of right upper abdominal pain and right flank pain but no shoulder-tip pain. On examination the pulse rate was 88/min, B.P. 100/70, temperature 36.4°C, and there was diffuse tenderness in the right upper quadrant, right flank and right iliac fossa, but no guarding. There was a faint bruise in the right hypochondrium and bowel sounds were present. Rectal examination was negative. He vomited twice within the first hour of admission and this appeared to relieve the pain to a considerable extent. An hour and a half after admission the symptoms and signs were less marked than on admission and the pulse rate had settled to 70/min. Routine urinalysis was negative. Abdominal X-rays showed a considerable quantity of gas in the stomach and gas pockets in the region of the hepatic flexure and ascending colon, although at this time these areas of gas were thought to lie within the colon (Figs. 1 and 2). Over the next 3 hr the pulse rate gradually rose to 96/min, the B.P. to 120/85 and the bowel sounds became diminished. The patient became more restless and the bruising in the right hypochondrium was more obvious. Guarding developed over the right side of the abdomen and the bowel sounds disappeared. The X-rays were re-appraised and the possibility of retro-peritoneal gas bubbles from rupture of the duodenum was considered. Laparo-

FIG. 1. Supine antero-posterior view of the abdomen showing large quantity of gas in stomach and mottled appearance in region of hepatic flexure.

FIG. 2. Supine cross-table lateral view of abdomen showing characteristic mottled appearance of gas bubbles. These lie in a sponge-like mass of haematoma + extravasated duodenal contents spreading in retroperitoneal areolar tissues + between layers of roots of mesenteries.

tomy was performed approximately 5½ hr after injury through an upper right paramedian incision. There was no intra-peritoneal blood but a large retroperitoneal haematoma was present, originating in the right upper quadrant and tracking down around the right kidney, hepatic flexure and ascending colon. The layers of the transverse mesocolon and small bowel mesentery were being dissected up by haematoma which was darker in colour than would have been anticipated had it been composed only of blood. The ascending colon and hepatic flexure were mobilized. Reflexion of the right posterior parietal peritoneum exposed the haematoma which was found to crepitate, being honeycombed with numerous small air bubbles and to consist of blood mixed with bile, in

an oedematous stroma. The exploration was continued to expose the lower pole of the right kidney which was found to be intact, and the second and third parts of the duodenum. The duodenum was now mobilized by Kocher's manoeuvre and there was found to be a transverse laceration of virtually the whole posterior wall of the distal part of the second part. The laceration was repaired transversely in two layers and the haematoma evacuated as far as possible. The right retroperitoneal space was drained via a separate stab incision. The post-operative course was uneventful apart from an early pyrexia of 38°C which responded to a 7 day course of i.m. ampicillin. The patient was discharged on the seventeenth post-operative day and has continued to remain well.

Discussion

Retroperitoneal rupture of the duodenum is now most often the result of a motor vehicle collision and is therefore increasing in frequency (Roman *et al.* 1971). The difficulty in making the diagnosis early is described by many authors and several describe the latent period during which symptoms and signs are minimal. Repeated careful abdominal examination (British Medical Journal, 1971), and X-ray examination (Meyers, 1968) by plain abdominal films of sterile water-soluble contrast medium are the most useful means of making the diagnosis pre-operatively. When an upper right quadrant retroperitoneal haematoma is found at laparotomy for blunt abdominal trauma thorough exploration of the haematoma and wide mobilization of the duodenum are essential if the lesion is to be recognized and dealt with adequately (Johnson, 1957). Finally it is to be hoped that the increase in frequency of this injury can be reversed by the introduction of increasingly effective means of protection for motor vehicle occupants.

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