UNDER-WATER BLAST INJURY OF THE ABDOMEN.

BY

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During this war there have been a number of reports on the clinical aspects and also on experimental studies of the injuries caused by under-water blast. There are conflicting theories on the mechanism of injury, and there are differences of opinion about treatment. Two personal cases, both operated upon in the earlier days of the war, seem worthy of record as they may provide some evidence in a discussion of opposing views.

Both cases were involved in an incident which occurred during the Dunkirk evacuation. Neither of the men concerned had suffered previous injury nor were they injured when they left the deck of their mined vessel. While swimming some distance away from the sinking ship, both men felt the impact of detonating depth charges which had become submerged with the ship. They were rescued and brought to hospital about twelve hours later.

Case 1.—This patient complained of severe, generalized abdominal pain associated with frequent vomiting. He was extremely anxious and apprehensive, and was afraid to move. He was pale and cyanosed, and respirations were shallow and painful. The pulse was feeble and rapid, the skin dry and inelastic. He had no external injuries, and there was no sign of free fluid in the abdomen. Generalized, board-like rigidity, marked tenderness and silence on auscultation of the abdomen, indicated the necessity for urgent exploration, which was carried out after about two hours of resuscitation.

A right paramedian incision, splitting the rectus muscle, showed neither bruising nor haemorrhage of the abdominal wall. There was no free fluid within the peritoneal cavity and no signs of peritonitis. The bowels were not distended; they were cold, and felt and looked "lifeless." There were numerous and widespread subserous haemorrhages over all the loops of small and large bowel, on the stomach, and over the lower part of the right side of the liver; the haemorrhages varied in size from a pin-head to half an inch in diameter; many were present in the mesenteries and omentum. Segments of jejunum and ileum, two or three inches in length, were discoloured, reddish and darker than neighbouring portions, by clot-like content within the lumen; these clots could easily be milked along the bowel, discolouring a new segment and leaving the previous one light again. There were fecal masses in the left colon. There was neither bowel perforation nor mesenteric tear, and no evidence of vascular thrombosis.

He died in about forty-eight hours.

Case 2.—The complaint was mainly of increasing pain in the right side of the abdomen, where the patient had felt "the violent blow" at the time of the explosion. Vomiting, in which blood was not noted or reported, had begun within eight hours. He had no signs of external injury. The general condition, colour and texture of skin and tissues, and pulse volume, were good; his tongue was coated and rather dry. There was marked
tenderness in the right iliac fossa and rigidity, which was not board-like, over the lower two-thirds of the right half of the abdomen; physical signs, not unlike those found with appendicitis.

At operation, performed within fourteen hours of the injury, there was no sign of contusion or haemorrhage in the abdominal wall. An early peritonitis with congestion of serosal vessels and a small quantity of free turbid fluid was present; there were a number of scattered haemorrhages under visceral peritoneum, but not nearly as marked or as widespread as in Case 1. In the right anti-mesocolic taenia, about three inches above the caput ceii, there was an irregular, half-inch-long tear, through which a small amount of faecal matter was oozing into the paracolic gutter. There was but little bruising of the ascending colon in the immediate vicinity of this rent in its wall, and the appearance was that of a primary laceration and not a perforation through a necrosed or contused portion. The faeces which had already collected in the gutter was cleaned away; the rent was repaired, and the wound was closed about a drainage tube. Intravenous "drip" fluid was continued after the operation.

Post-operatively, in forty-eight hours, he developed pain in the lower part of the chest, cyanosis, dyspnœa and a painful cough, coarse rales, diminished air entry, and impaired resonance over both lower lung zones. The condition was considered to be due to pneumonia, either post-operative or post-immersion, together with, or by itself, congestion from overloading with intravenous therapy. In the light of knowledge acquired later, it seems likely that the chest symptoms and signs were due to blast-lung.

(A military posting then broke my contact with the case; however, his subsequent favourable progress and recovery was very kindly communicated to me by Surgeon Rear-Admiral Gordon-Taylor.)

**DISCUSSION.**

**Mechanism of injury.**—The theory that injury is caused by "compression of the abdominal parietes against resistance from water which has entered the lumen of the bowel through the weak anal sphincter," as advanced by Auster and Willard (1943), does not satisfy all the clinical evidence, and the following features appear to make the hypothesis unacceptable:

(a) Case 2, reported above, had a recent, sudden perforation of the colon; yet there was neither flooding of the peritoneal cavity with feculent material nor sign of sea water in the peritoneum. In no other published case is sea water recorded as having been found in the peritoneal cavity at operation.

(b) Case 1, with paralytic ileus, showed no evidence of sea water in the bowel; there were, in fact, palpable faecal masses in the descending and sigmoid colon at the time of operation.

(c) Damage to fluid-filled cavities, such as the urinary bladder, renal pelvis and gall-bladder, is conspicuously absent in all recorded cases; and, as emphasized by Williams (1942), injuries are usually found in gas-filled cavities.

(d) Under-water blast causes lung damage which is similar to that caused by blast in air; and, moreover, human abdominal injury following exposure to aerial blast, though rare, has been noted (Williams, 1942, and Gordon-Taylor, 1943).

The story of the involuntary passage of frequent liquid stools soon after blast injury is quoted by Auster and Willard in support of their theory. This may, however, have other explanations: the phenomenon is known to occur.
when men are exposed to other varieties of destructive and terrifying war weapons; and, secondly, massive bleeding into the bowel lumen is a common pathological result of blast injury, and this blood may constitute most of the "liquid stools."

Clinical data suggest that injury is due to sudden violent compression acting mainly on air-filled cavities. Williams (1942) reports experimental evidence in support of this theory, and he points out that, as there is no mass movement of water beyond the immediate vicinity of the explosion and no negative suction wave, it is the force of the primary pressure pulse generated by the detonation which, acting upon air-containing cavities, causes injury. The physical aspect of the action of the pressure pulse when it arrives at an air-water boundary has, more recently, been discussed by Wakeley (1945). He shows that it is at such a boundary that massive displacements occur, as evidenced by the "dome" and "plume" of water on the surface above the explosion, but that the motion of a particle of water away from the surface is very small; and this author compares this air-water boundary with that made by air-filled abdominal viscera or the pleural cavity when these are submerged. It is the walls of these organs that are submitted to the stresses of the displacing force and so suffer injury.

**Pathology and Treatment.**—Zuckerman (1940 and 1941) records experiments in which animals were subjected to blast in air; the outstanding result was damage to the lungs. The injuries in man, after exposure to aerial blast, are also largely confined to the chest. However, following under-water blast, the relative degrees of damage to the chest and abdominal organs in animals differ from those found in man. In the experimental work on under-water blast reported by Williams (1942) and Cameron et al. (1942), gross damage was either confined to the chest; or, in the small proportion of animals in which abdominal injuries occurred, it was disproportionately severe and extensive in the chest; whereas the records of human cases show that intra-abdominal trauma is commonly the dominating result of under-water blast. It would appear that the difference between the distribution of injuries sustained by man and animals may be accounted for by the fact that the greater portion of the ventral and lateral surface of the animal was under water during the experiments, but that man is usually partially submerged while swimming about in a life-jacket, and he receives the direct impact of the pressure-wave on that submerged portion facing the oncoming impulse.

The abdominal injuries in man may be of all grades of severity. Gordon-Taylor (1943) gives their range as from a mild temporary ileus to the grave condition of complete rupture. Breden et al. (1942) report on nine men who had been subjected to under-water blast. All suffered from early hæmatemesis, abdominal pain, and diarrhœa with melena: seven, who presented tender abdomens and "slight rigidity" when seen by the authors three days after the event, recovered uneventfully without operative interference; the other two recovered after drainage of peritoneal abscesses which had developed gradually in nine or ten days. Such uniformly happy results do not always occur. Of the cases recorded by Pinnock and Wood (1943), five men had symptoms
suggesting serious trauma to internal organs; one, suffering from blast lung, but without evidence of injury to abdominal organs, recovered; the remaining four, with evidence of abdominal injuries, died. Other case reports, as by O'Reilly (1941) and Auster and Willard (1943), illustrate further that the range of injuries varies from the very slight to the grave and fatal types.

The two cases reported in this paper are both of grave severity. Case 1 demonstrates that intramuscular and mesenteric haemorrhages may be so extensive as to cause a severe complete ileus. Case 2 shows that in addition to the gradual "silent" penetration giving rise to late abscesses and fistulae, and in addition also to delayed perforations through bruised portions of bowel wall giving rise to general peritonitis some days after the injury, there may be a bowel perforation of a more acute and sudden nature arising at the time of the injury and causing an immediate peritonitis. The treatment of these types of cases raises anxious and pressing problems.

There is, broadly speaking, not much difference of opinion on the necessity for preliminary resuscitative measures and the care of any associated extra-abdominal lesions; but on the question of surgical interference and exploration of the abdominal injuries there are notable differences of attitude. Blast injury of the abdomen is so often associated with other gross injuries that it presents a very grave operative risk; the varying degrees of severity and the wide range of injuries caused by under-water blast add further to the problem. Generalization, therefore, about exploratory surgery cannot be absolute or final; individual consideration of each case is perhaps even more emphatically necessary than for any other abdominal condition.

The argument for operating in the presence of recognized manifestations of abdominal catastrophe has strong support. Pinnock and Wood (1943) stress "board-like rigidity," and Ogilvie (1942) emphasizes "a silent abdomen," as indications for laparotomy. The first of the two personal cases recorded in this paper provides apparent contrary evidence, for although both signs were present, damage amenable to surgical treatment was not found at operation. It is likely that this case had suffered such widespread blast injury that, even if the expected perforation or gross laceration had been found, its surgical repair could not have helped recovery; and it is likely that a wider experience and knowledge of blast injuries in general might have led to the selection of the case as one of those "upon which it is better not to operate." Consideration of such selection aside, the presence of either board-like rigidity or a silent abdomen makes it dangerous to delay exploration beyond the period necessary for the treatment of shock.

It is in the group of cases with clinical manifestations of lesser degree that most of the doubt arises. That cases exhibiting hematemesis, melena, abdominal pain, and "slight rigidity," can recover without early operative treatment is evident in the series reported by Breden et al. (1942). But it is equally clear that, not only cases with board-like rigidity, but also those with a lesser degree of rigidity, as presented by the second of the cases reported here, require urgent early operative treatment. The problem is similar to that presented by other abdominal injuries except for the additional hazards of
possible lung damage; and, provision for this being made by choice of anaesthetic, the policy of "look and see" would appear to be safer than an attitude of "wait and see."

SUMMARY.

Two cases of under-water blast injury of the abdomen are recorded. The mechanism of injury and the pathology are discussed; and it is suggested that, as far as treatment is concerned, these types of abdominal injuries fall into line with others—when in doubt, it is safer to explore than to temporize.

REFERENCES.