Post-Traumatic Respiratory Insufficiency: What is 'Shock Lung'?

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Patients who have suffered major trauma may develop a characteristic pattern of respiratory insufficiency (Proctor *et al.*, 1970). The clinical picture has been emphasised by extensive studies in the Vietnam war (Martin *et al.*, 1969; Powers *et al.*, 1972; Simmons *et al.*, 1969), and it has become apparent that in spite of the tremendous advances in medical and surgical care, this pulmonary condition associated with non-thoracic trauma has not changed in 25 years. In the past it has been known as 'congestive atelectasis' (Jenkins *et al.*, 1950), a syndrome of wet lungs that develops without elevation of pulmonary or central venous pressures. The physiological measurements are interesting. Collins *et al.* (1968) in their study of combat casualties found that many had low pO_2 levels, yet normal or low pCO_2 and increased minute ventilation. Similarly, Lowery *et al.* (1969) in the Da Nang area found that although casualties might be admitted with a normal pO_2 maintained for some hours, yet twelve hours later the value was often below 70 mm/Hg. The tidal volume also falls and is compensated for by a rise of respiratory rate, so that the minute volume may be unchanged. Nevertheless, this is a dangerous pattern of breathing, which, being shallow and rapid, will favour alveolar collapse. Pulmonary alveolar/arterial oxygen differences rise from the normal level of less than 5 per cent, to values of as much as 30 to 40 per cent. The amount of dead space (Vd) in relation to tidal volume (Vt) is also increased from a normal of 0·3, to well over 0·4. However, measurements of lung compliance can appear to be normal. Such patients present a picture of laboured rapid breathing with cyanosis, which is often resistant to oxygen therapy, and they are often still hypotensive as a result of shock. The chest X-rays often show surprisingly little but may show a reticular infiltrate, which progresses into a diffuse infiltration or patchy consolidation (Maddison *et al.*, 1968). At the same time clinical examination of the chest typically reveals no evidence of rales, the neck veins are flat, and the central venous pressure is normal or low. The phases of post-traumatic respiratory insufficiency are shown in Table 1.

TABLE 1. The phases of post-traumatic respiratory insufficiency (Moore *et al.*, 1969)

Phase I.	Period of shock Spontaneous hyperventilation and hypocapnia
Phase II.	Early respiratory distress Hypoxia due to shunting of 10–20% cardiac output Hyperventilation and hypocapnia
Phase III.	Gross hypoxia: mechanical ventilation required Chest X-rays show 'shock lung'
Phase IV.	Terminal anoxaemia with final carbon dioxide retention

The autopsy changes that correspond to the post-traumatic state are now well known (Webb, 1969). There is a spectrum of change (Mallory *et al.*, 1950; Martin *et al.*, 1968) described as interstitial and intra-alveolar oedema (85 per cent), with intra-alveolar (55 per cent) and interstitial haemorrhage (25 per cent) and patchy atelectasis (70 per cent), fat embolism (65 per cent), or bronchopneumonia (25 per cent). It is clear that many aetiological factors can be involved. Thus, it could be that alterations in perfusion associated with vasoconstriction or mechanical blockage of capillaries, together with a tendency to alveolar collapse on account of the breathing pattern, in combination with fluid overloading as a result of overtransfusion, has led to this variety of changes. A more specific entity has been described by some authors (Blaisdell and Stallone, 1970; Mittelmeyer and Sandritter, 1972), who noted that early autopsy showed petechial haemorrhages on the lung surface, and focal areas of congestion and atelectasis within the lung substance. Later, large areas of the lung showed haemorrhagic consolidation. What is characteristic of this early stage is the finding of thrombo-emboli in the small pulmonary vessels. There are also the aforementioned areas of alveolar congestion and haemorrhage, focal atelectasis, interstitial and intra-alveolar oedema and often hyaline membrane formation. These authors considered that this state of 'shock lung' could in part be the result of microembolism.

Some of the many aetiological factors responsible for respiratory insufficiency in shocked patients are listed in Table 2.

These states have in common pulmonary oedema due to an increase of capillary permeability, combined with an increase of pulmonary capillary pressure, and associated with a decline of lung surfactant. In true 'shock lung' microembolism appears to be the main feature, but it will be appreciated that this cannot be clinically assessed. Only if there is clinical suspicion will the relevant investigations be instigated and, even then, since such patients are very ill, the final diagnosis may be retrospective.

TABLE 2. Aetiological factors in 'shock lung'

1. Fluid overload and lowered surfactant
2. Physical exhaustion: inactivity: airways obstruction
3. Aspiration pneumonia
4. Fat embolism and fatty acid toxicity
5. Blood transfusion with stored blood
6. Oxygen toxicity
7. Haemorrhagic shock
8. Septic or endotoxin shock
9. Acidosis and hypoxia
10. 'Shock lung' as the result of microembolism by platelet aggregates

A brief discussion of each of these mechanisms of respiratory insufficiency in the shocked patient now follows. Most are familiar, as they contribute to the progressive pulmonary insufficiency seen post-operatively in surgical patients (Collins, 1969; Dowd and Jenkins, 1972).

1. FLUID OVERLOAD AND LOWERED SURFACTANT

Experience has shown that after hypovolaemic shock, crush injuries, and ventilation with pure oxygen, the lungs are easily overloaded with fluid. Non-colloids do, of course, distribute mainly to the extravascular tissues and thus oedema is readily caused, without an elevation of the central venous pressure. However, a reduction of pulmonary surfactant is thought to be the main reason. Surfactant is a lipoprotein complex produced by the alveolar cells, with lecithin as the principal phospholipid. The surface tension within the alveoli is normally increased when the alveoli expand in inspiration and is reduced in deflation. In the absence of surfactant these surface tension forces within the alveoli lead to alveolar collapse, so that there is deterioration of respiratory function. In the experimental traumatic lung syndrome labelling studies show that loss of surfactant is delayed by its half-life of 18 to 24 hours. This loss is due to damage to the Type II alveolar cells that produce surfactant (Henry *et al.*, 1967), rather than by direct alteration or loss of the lipoprotein. Exudation of plasma protein into the alveoli will also neutralise the surface tension reducing effect of existing surfactant (Harlan *et al.*, 1966).

2. PHYSICAL EXHAUSTION: INACTIVITY: AIRWAYS OBSTRUCTION

Alteration in the energy cost of ventilating the lungs can be due to alteration of the pattern or amount of ventilation, or to changes in the elasticity of the lungs known as compliance. Work performed in breathing can be shown as a volume-pressure loop, obtained by plotting expiratory volume on a vertical axis against transpulmonary pressure, as measured by an oesophageal

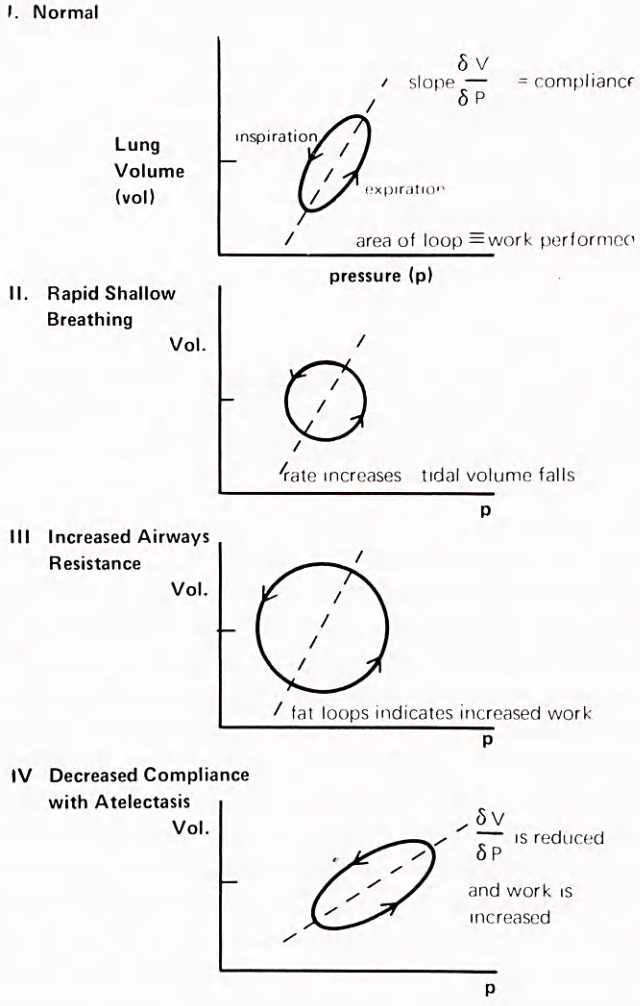

Fig. 1. Pressure : volume loop diagrams relating change of lung volume to transpulmonary pressure (p).

balloon, on the horizontal axis (Comroe *et al.*, 1964; Campbell *et al.*, 1970). Thus, Fig. 1 depicts the increase of work that will result from rapid shallow breathing, an increase of airways resistance, or from a reduction of lung compliance due to atelectasis.

In clinical terms, both rapid shallow breathing and retention of secretion will result from pain and muscle spasm when injuries involve the trunk, or

even with immobilisation or physical exhaustion. Inactivity of the patient permits congestion of the dependent lungs, and a decrease of compliance, together with an increase of airways resistance when there is oedema in small airways. Haemodilution from infusion of crystalloids will aggravate the congestion. Inability to cough up secretions will also cause an increase of airways resistance and this, together with failure to take deep breaths, is a usual cause of atelectasis. The end result will be a decrease of oxygen exchange, decreased compliance, and further increase of the work of breathing.

3. ASPIRATION PNEUMONIA

This may often be an additional feature in exhausted patients, since they are very susceptible to pulmonary infection. Some organisms such as Pseudomonas readily invade the respiratory tract from the gastrointestinal tract and elsewhere.

4. FAT EMBOLISM AND FATTY ACID TOXICITY

These are well-known causes of pulmonary vascular occlusion leading to reduction of alveolar perfusion which, in turn, results in increased dead space to tidal volume ratios, and consequent desaturation of the arterial blood because of the disturbed ventilation/perfusion relationships. Increased numbers of unventilated alveoli lead to a wastage of ventilatory volume, but the minute volume is increased in an attempt to maintain normal carbon dioxide tensions (Prys-Roberts *et al.*, 1970). It has been estimated that the amount of marrow fat from fracture sites, or of adipose tissue from sites of soft tissue trauma, needs to be of the order of 20 to 40 ml in order to obstruct the filtering bed of the lung (Watson, 1970). The diagnosis is established by the finding of dyspnoea with cyanosis, associated with petechial haemorrhages, fat in the urine, an elevated serum lipase, and, in the worst cases, signs of cerebral damage. When there is already haemorrhagic or post-traumatic shock, animal experiments indicate that the lethal dose of fat may be reduced by a third, for then emboli are larger and fewer and found principally in the arterioles (Whitely, 1954). The mechanistic explanation is not enough to explain the arterial hypoxaemia, which is in large part due to the toxic action of liberated fatty acids on lung tissue (Szabo, 1970). These cause severe haemorrhagic inflammation of the surface of the alveoli (Ashbaugh and Petty, 1966).

5. BLOOD TRANSFUSION WITH STORED BLOOD

Rapid infusion of stored blood carries the hazard of microembolism of the pulmonary capillaries, with leucocyte and platelet aggregates, which escape the filtering apparatus. This risk is increased when large transfusions are given

under pressure. The risk is also greater with heparinised blood in which aggregates form readily, whereas in acid-citrate dextrose they only form after storage for three to seven days. A similar type of microembolisation of the lungs is found in patients undergoing open heart surgery with disc and bubble oxygenators but can be prevented by removal of the platelet and leucocyte aggregates by Dacron wool filters.

6. OXYGEN TOXICITY

This is a favourite suspect when patients are on respirators, but may be difficult to prove because the underlying disease may also lead to lung damage. There is little danger of oxygen toxicity when the atmospheric concentration is less than 60 per cent, as is the case when face masks, nasal catheters, or oxygen tents are used. In was in fact 180 years ago that Lavoisier reported damage to animals by oxygenation: the lungs showed haemorrhage, congestion, atelectasis and oedema, the 'Lorraine-Smith effect' (Smith, 1899). Ventilation with 90 per cent oxygen for as long as ten days is well recognised as a cause of pulmonary damage (Nash *et al.*, 1967; Soloway *et al.*, 1968). The alveolar cell lining is the site of damage, and pulmonary congestion follows.

7. HAEMORRHAGIC SHOCK

The effect on the lungs of haemorrhagic shock is difficult to evaluate, not least because of species differences (Moss, 1972). Indeed, Cournand (1943) observed that arterial oxygen saturation in man was unaffected by haemorrhage. However, experiments in dogs have shown that haemorrhage can produce a pattern of breathing that is akin to the shock lung syndrome (Gerst *et al.*, 1959), since the dead space to tidal volume ratio is increased, and areas of atelectasis develop associated with capillary congestion. Other investigators have noted that an early increase in pulmonary vascular resistance is premonitory to these post-shock pulmonary complications (Desai *et al.*, 1969). The response of the primate lung is somewhat different from the dog in that interstitial pulmonary oedema appears without capillary congestion. There is, however, little evidence for primary endothelial cell damage in any species.

Recent studies have utilised the fact that potassium pyroantimonate has a great affinity for sodium and produces electron-opaque particles easily recognised with the electron microscope. When primate lungs are studied after haemorrhage, sodium-rich oedema fluid is found to be localised to the collagen fibres in the central portions of the alveolar septa. This was originally described by Cottrell *et al.* (1967), when they proposed that collagen fibres

might act as sponges to pick up interstitial water. Indeed, Moyer *et al.* (1965) and Fulton (1970) have shown how alterations of the pH of collagen might cause increased binding of sodium and water. The metabolic acidosis of haemorrhagic hypotension might be sufficient for this. Gump *et al.* (1971) showed that a bolus of radioactive sodium is not removed by a single passage through normal lungs, but is, when there is interstitial oedema in shock. This technique has been used to study uraemic lungs (Crosbie *et al.*, 1972).

8. SEPTIC SHOCK

Septic shock frequently causes respiratory insufficiency, which can present as pulmonary oedema with a normal or low central venous pressure (McLean *et al.*, 1968). Initially, there is an inflammatory reaction of the pulmonary capillaries, causing alveolar septal oedema and infiltration of mononuclear cells. Atelectasis due to impaired surfactant production follows (Clowes *et al.*, 1968a). In animal experiments it is usual to find an initial rise of pulmonary vascular resistance, quite profound hypoxaemia and a respiratory alkalosis with low pCO_2 levels. Similar changes have been described in patients with peritonitis who develop respiratory failure (Clowes *et al.*, 1968b; Skillman *et al.*, 1969). The vital capacity and also the compliance fall; there are large alveolar-arterial oxygen differences indicating that as much as 30 per cent of the cardiac output is shunted through unoxygenated lung, and the dead space to tidal volume ratio is of the order of 0·6.

The mechanism of pulmonary damage in septic shock is undoubtedly multifactorial and will involve platelet agglutination and intravascular coagulation, release of vasoconstrictor fibrinopeptides (Bayley *et al.*, 1967), release of bradykinin and other inflammatory peptides, and also numerous noxious actions of endotoxin itself. The latter include an increase of capillary permeability, increased reactivity to catecholamines reducing blood flow, spasm of the muscular venules, and actual rupture of capillaries during periods of ischaemia. There is also a damaging effect of endotoxin on vascular endothelium.

In all types of shock many pharmacological agents are released which lead directly to increased pulmonary vascular resistance and increased capillary permeability. Many of these arise from platelet aggregation. Histamine, kinins and endotoxin are particularly potent in inducing capillary permeability. Table 3 summarises some of these effects.

There are several indications that 'shock lung' may often be the result of endotoxinaemia. Certainly, in animals such as the dog and rabbit, endotoxinaemia causes the appropriate microscopic lesion (Cuevas *et al.*, 1972). The role of endotoxinaemia in man is still under investigation, as an appro-

TABLE 3.

Agent	Platelet aggregation	Pulmonary vasoconstriction	Bronchoconstriction
Histamine	0	++	++
Serotonin	++	++	++
Catecholamines	++	++	0
ADP	++	0	++

priate assay procedure has only recently become available (Reinhold and Fine, 1971). However, there is good circumstantial evidence that sepsis in man is a cause of shock lung (Rigby and Christy, 1968; Clowes *et al.*, 1968b).

9. ACIDOSIS AND HYPOXIA INITIALLY FROM SHOCK AND THEN FROM VENTILATION/PERFUSION IMBALANCE

Acidosis and hypoxia may act as cause and effect in a vicious cycle, starting from the initial episode of shock. Both cause a marked increase of pulmonary vascular resistance due to arterial vasoconstriction and also a rise of pressure in the post-capillary venules. The latter will tend to aggravate pulmonary congestion (Berry *et al.*, 1965; Keller *et al.*, 1967) especially when hypoxia leads to capillary permeability. Hypoxia, in turn, results from a variety of factors including alveolar hypoventilation, ventilation/perfusion imbalance, impaired gaseous diffusion across alveoli, or intrapulmonary anatomical shunting from the right to left side of the circulation.

It is the shunting of blood from the right to the left side of the circulation without adequate oxygenation that leads to final deterioration. Shunting is a pathophysiological result of areas of lung being ventilated but not perfused, while at the same time other alveoli are being perfused but not ventilated. This arises basically from atelectasis but also when there is blockage of pulmonary capillaries or other alveolar septal change leading to impermeability of the blood/gas barrier. Additionally, it is recognised that acidotic blood flowing through the lung at an increased rate because of the high cardiac output produced by hypoxia cannot achieve complete oxygenation in a single passage through the lung.

Studies of animals undergoing pulmonary perfusion have shown that a rise of pulmonary venous pressure usually precedes the rise of arterial resistance (Keller *et al.*, 1967). Many factors are known to influence pulmonary venous tone (Hyman, 1966), but recent work has suggested that after injury it can be increased from hypothalamic centres (Moss *et al.*, 1972). Serotonin released from platelet aggregates will also increase pulmonary venous pressures (Radegran *et al.*, 1972).

10. SHOCK LUNG AS THE RESULT OF MICROEMBOLISM BY PLATELET AGGREGATES

The entity not yet accounted for is the condition designated 'shock lung' by such authors as Blaisdell and Stallone (1970) and Mittelmeyer and Sandritter (1971). This condition is thought to arise from pulmonary microembolism in shock. Indeed, the object of this article is to draw attention to its occurrence and to the fact that the association with intravascular coagulation will be recognised only by appropriate clinical investigation.

Mittelmeyer and Sandritter (1971) recount how in a two-year period in the intensive care unit at Freiburg they collected case histories, studies of coagulation factors and detailed autopsies on 42 patients who, as a result of trauma or postoperative complications, subsequently showed this histology of 'shock lung'. Typically they were shocked patients with hypoxia, who nevertheless maintained a normal or low pCO_2, and a large dead space to tidal volume ratio, and who at the onset of the respiratory insufficiency showed a reduction of platelets and coagulation factors indicative of intravascular coagulation. Many underwent a trial with heparin, since the indications were that pulmonary microembolism could be the cause. The fact that, in the post-traumatic period, there may be quite profound inhibition of fibrinolysis in some patients, who subsequently die and show microembolism of the lungs, can be taken as corroborative evidence for this view (Rammer and Saldeen, 1970; Lindqvist *et al.*, 1972).

This particular theory is clearly amenable to experimental analysis. Microembolisation of the lungs, with resulting pulmonary arteriolar thrombi causing areas of collapse and hyaline membrane formation, has been found to

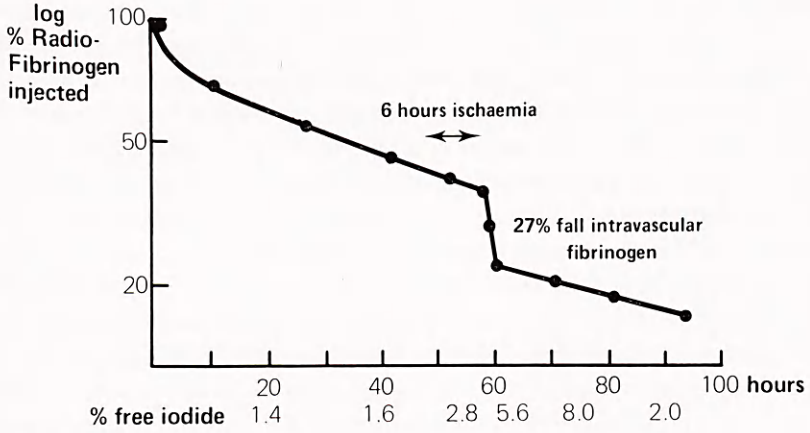

Fig. 2. Tourniquet crush.

occur after crush syndrome injuries. Figure 2 illustrates the effect on radio-fibrinogen catabolism of release of the tourniquet from an ischaemic limb in the rabbit renal failure model (Bywaters and Popjak, 1942). The fall of radio-fibrinogen is in part due to reflow thrombosis of the ischaemic muscle but there is also embolisation from the injured veins to the lungs, as shown by organ counting of radio-fibrinogen. Such animals are seen to have respiratory difficulty, which may well contribute to the renal cortical ischaemia, since, in the rabbit, pulmonary embolisation results in reflex renal cortical ischaemia (Wardle—unpublished).

Allardyce *et al.* (1969) reported studies of microradiography of the lungs in rabbits subjected to haemorrhagic shock. They found that under sub-pleural haemorrhages were areas of diminished perfusion where there was absent capillary and reduced arteriolar filling. Moreover, screen filtration pressures of blood taken from the vena cava, and filtered by Swank's (1961) technique, showed that platelet aggregates appeared in the venous blood as shock developed. They postulated that much of the pulmonary vasoconstriction could be due to serotonin release from damaged platelets. Admittedly, the rabbit has a high serotonin concentration in platelets, but other amines may play a similar role in other species (*see* Table 2). Moreover, Rosoff *et al.* (1971) showed that reduction of platelet serotonin, for example by reserpine treatment, effects a reduction of mortality from thromboembolism. This group advanced the interesting theory that an animal's response to shock may depend on the platelet serotonin content, which, in turn, may bear a relation to its gut microbial flora.

In men with combat injuries intravascular microaggregation has been described by Berman *et al.* (1969), and an increase of screen filtration pressure of venous blood by McNamara *et al.* (1970). For this reason pulmonary microembolisation has been investigated after soft tissue injuries in primates (Berman *et al.*, 1971). Studies, again using screen filtration pressure, showed a rapid generation of intravascular aggregates from injured tissues and at the same time a fall of the platelet count of peripheral venous blood. Using *in vivo* ^{14}C-serotonin labelling of platelets, the authors were able to show that radioactivity accumulated in the lungs of injured animals, indicating that platelets were accumulating in the lung tissue.

Further support for the microembolism theory has been the finding that as small blood clots are infused into the pulmonary arteries of sheep, the amount of arterio-venous shunting increases (Deal *et al.*, 1970). Chavez *et al.* (1970) found that, after embolisation of dogs' lungs with micro-clots, pulmonary venous hypertension developed, accounting for much of the increase of pulmonary vascular resistance, and the associated pulmonary oedema led to

a fall of compliance and reduction of diffusion capacity. The venous hypertension was apparently due to release of serotonin, because it could be prevented by methysergide. However, there is also evidence for arteriolar reflex vasoconstriction which is prevented by denervation of the lungs (Weidner and Light, 1958; Price *et al.*, 1955). Another factor to be considered is that high blood flow through unobstructed segments of the lung may lead to pulmonary oedema in those areas (Hyman, 1970). Redistribution of flow may not only follow mechanical blockage, but also result from the responses of the pulmonary vasculature to hypoxia and acidosis (Randolph and Yuan, 1966). Rather similar congestive changes of the lung may occur due to a rise of pulmonary venous resistance during hypovolaemia (Keller *et al.*, 1967). The role of humoral substances in haemorrhagic shock is also emphasised by the finding that if one lung is excluded from the circulation, that lung is protected from the morphological changes, which are clearly not due to ischaemia alone (Willworth *et al.*, 1967). In fact, ischaemia of the lung for periods of six hours is not associated with any morphological change (Blades *et al.*, 1952).

There is now abundant evidence from histological material to support the view that in injured patients there is microembolism to the lungs, and that this is part of the general process of disseminated intravascular coagulation that occurs in shock (Hardaway, 1970a). Thus, Sevitt (1970) has found that whereas major emboli to the pulmonary arterioles only occur several days after trauma, reflecting the occurrence of leg vein thrombosis, microemboli in the pulmonary capillaries are found within a few hours of injury but disappear by forty-eight hours. Similarly, Remmele and Harms (1968) have described microthrombi in kidneys, liver and lungs in 50 per cent of cases dying within four hours of shock, and yet after forty-eight hours few remaining thrombi were found.

The theory of 'shock lung' is therefore closely linked to opinions on the occurrence of disseminated intravascular coagulation in traumatic, septic, and haemorrhagic shock (McKay, 1969; Hardaway, 1970a; Stalker, 1970). Hardaway has attributed intravascular coagulation to those factors in shock that cause slowing of capillary flow in combination with those that stimulate hypercoagulability of blood, such as acidosis, bacterial toxins and entry of thromboplastin into the circulation. It follows that intravascular coagulation is more likely to occur with septic or traumatic shock than in simple haemorrhage and this prediction has been found to be correct (Hardaway, 1970b). It is not only relevant to 'shock lung', but also to the pathogenesis of acute renal failure.

It must be emphasised that the damage to organs is mainly due to the

vasoconstrictor mechanisms activated by coagulation and not so much to the mechanical blockage of vessels by microemboli. Fig. 3 summarises a variety of factors that can lead to an increased pulmonary vascular resistance. Platelet aggregation can be reversible in the lungs but this is dependent on

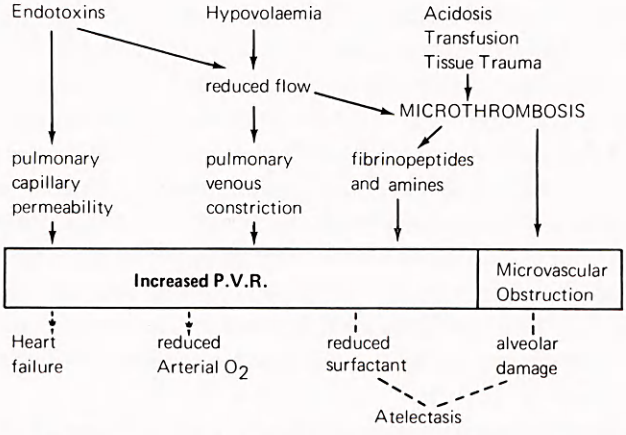

Fig. 3. Causes and effects of increased pulmonary vascular resistance.

activation of fibrinolysis (Van Aken, 1971); fibrinolysis is often inhibited by shock.

INVESTIGATIONS

Except in a few specialised units assessment of 'shock lung' is confined to measurement of the respiratory and cardiovascular pathophysiological effects. Those measurements of respiratory status that must be known include the pCO_2 and pO_2 taken from central venous and arterial catheters, inspired and expired air gases, and basic measurements of air flow, ideally using a pneumotachograph (Peters and Hilberman, 1971). Additionally, transpulmonary pressures measured with an oesophageal balloon give information on compliance. It is evident, however, that for certain diagnosis there must also be facilities for measurement of *in vivo* parameters of the coagulation and fibrinolytic systems and of platelet behaviour. These tests are involving *in vivo* radioactivity measurements to a greater extent than formerly.

Ominous findings after shock are persistent hyperventilation with hypocapnia, and hypoxia refractory to oxygen administration, indicative of a widening alveolar-arterial oxygen difference due to shunting. These are indications for mechanical ventilation, in particular a rise of respiratory rate

to over 35 per minute, a pO_2 of less than 70 mm Hg on mask oxygen, and an alveolar/arterial oxygen difference when breathing 100 per cent oxygen of over 350 mm Hg (the normal difference is 35 mm Hg). A degree of shunting of 40 per cent of the cardiac output presents a critical situation (Wilson *et al.*, 1969, 1970). If ventilation is left too late, a high inspired oxygen concentration, large tidal volumes and high airway pressures are needed to overcome the large shunt, the dead space and the increased stiffness of the lungs (Border *et al.*, 1968). Such serial studies of respiratory insufficiency after trauma have been made by Doty *et al.* (1969) who noted that cure of the hypovolaemia of shock revealed an elevated cardiac rate and output which was consequent on the demand for oxygen. Rather similar studies made on patients with fat embolism have been reported by Prys-Roberts *et al.* (1970) which showed that, early in pulmonary embolic states, there is the same increase of dead space to tidal volume ratio. This measurement has also been advocated by Pontoppidan and associates (1970): a Vd/Vt ratio above 0·6 again indicates the need for ventilation. The minute volume of ventilation necessary to keep the pCO_2 below 40 mm Hg has been found to rise dramatically from 10 litres/minute at the upper acceptable Vd/Vt of 0·4, up to 25 litres/minute at a Vd/Vt of 0·6.

The type of patient to whom these considerations apply can be categorised fairly simply as any patient with hypovolaemic shock due to multiple injuries, sepsis, or liver damage, especially when there is also the risk of acute renal failure.

TREATMENT

Apart from meticulous attention to the details of resuscitation from shock, that is prompt restoration of blood volume and tissue perfusion, it is desirable to institute early mechanical ventilation according to the criteria outlined above. This will also necessitate tracheostomy. The inspired oxygen tension should be kept within physiological limits. One aim should be to correct the functional residual capacity (Comroe *et al.*, 1964), that is the quantity of air remaining in the lungs at the end of a normal expiration, for this value, when compared with the predicted estimate based on age and size, gives an estimate of the amount of lung not being ventilated at the time. Patients with respiratory failure do have low lung volumes and a low functional residual capacity on account of atelectasis, compression of lung tissue, pneumonic consolidation and oedema (Ramachandran and Fairley, 1970). A volume cycled respirator can be used with advantage to increase the FRC and at the same time the amount of pulmonary shunting is reduced (Monaco *et al.*, 1972). Another useful technique is to arrange that expiration occurs against a resistance.

This produces a positive expiration pressure plateau (PEPP) and this manoeuvre leads to improved gas exchange and a better alveolar/arterial oxygen gradient (McIntyre *et al.*, 1969).

Consideration should also be given to the early use of heparin when it would be safe, or otherwise to low molecular weight dextrans that reduce platelet aggregation. Intravenous cyproheptidine can be used to prevent platelet aggregation and for its anti-serotonin effect. Pulmonary oedema should be treated by diuretics, abdominal distension avoided, and measures taken to prevent airways infection or aspiration. It is also necessary to avoid overhydration of shocked patients, to avoid old bank blood, to avoid using high concentrations of inhaled oxygen and to combat infection vigorously. Supportive steroids may be used for short periods as they reduce capillary permeability and maintain the integrity of alveolar epithelium. However, when so used, full consideration should be given to the fact that in large doses they may paralyse the immunological defence mechanisms.

'Shock lung' is not a new syndrome but recognition of the possible microembolic aetiology is new. It is an old entity for which, hitherto, there has been little progress in therapy. Hence, the object of this article has been to highlight recent thoughts on the pathogenesis and to suggest aids to diagnosis in the hope that new means of therapy may be developed.

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Book Review

Hodgkin's Disease. Edited by Sir David Smithers. Churchill Livingstone, 1973, 258 pages. Price £8·50.

This rather beautiful monograph provides a useful review of the rapid advances that have been made in the understanding and treatment of Hodgkin's disease. Nearly all the 20 authors have a close association with the Institute of Cancer Research, the Royal Marsden Hospital, or the Oncology Unit of St Bartholomew's Hospital.

Many of the chapters deal with problems that are not exclusive to Hodgkin's disease and have a much wider relevance. When there is neurological involvement, as in other types of malignant disease, this may be related to a spread of the disease itself, to opportunistic infection, or to an immunological reaction. As in other forms of cancer, the problems of anaemia and bone marrow involvement may be due to haemodilution and haemolysis, or to the secondary effects of treatment. This book helps to put these problems in perspective and also to illustrate the changes in recent emphasis on different forms of chemotherapy and on radiotherapy. A review of the complications of Hodgkin's disease draws attention to the special problems caused by the impairment of immune reactions and a spread of organisms of low virulence. There is also a timely reminder that radiotherapy may be followed by its own endocrine or neurological complications.

The editors have stated that their object is to present aspects of this subject to those who have not been intimately concerned with it or who have been working on isolated parts of the problem. In this they have fully succeeded.

M.H.L.