DELIBERATE HYPERVENTILATION IN THE TREATMENT OF A CRUSH INJURY OF THE CHEST

A Case Report

BY

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SUMMARY

A case of severe crush injury of the chest associated with a fracture-dislocation of the thoracic spine is reported. The chest was stabilized for fourteen days by intermittent pressure ventilation.

Analgesia and sedation were achieved by constant hyperventilation, maintaining an arterial blood pH in excess of 7.5. No analgesic or sedative drugs were needed and the patient was pain-free, calm and co-operative. His impressions during the period of controlled hyperventilation are recorded. A complete examination of acid-base balance was carried out on alternate days. The treatment of similar severe chest injuries by deliberate hyperventilation is suggested.

In 1956, Avery, Mörch and Benson first described the use of intermittent pressure ventilation in severe crush injuries of the chest to stabilize the chest wall and avoid severe physiological imbalance. Their aim was to achieve apnoea by the production of a mild respiratory alkalosis, adjusting the minute volume of ventilation so as to avoid marked hyperventilation, and to attempt to retain the activity of the patient's own respiratory centre as a sensitive monitor for increasing minute volume. Serial checking of pH and Pco2 levels was undertaken once or twice daily so as to avoid serious deviations in hydrogen ion concentration. Observations made during passive hyperventilation of conscious volunteers (Robinson and Gray, 1961) suggested, however, that deleterious effects are unlikely to arise from more energetic hyperventilation. Indeed, the raised pain threshold, and the changes in mental attitude noted in their investigations would appear to constitute an indication for its routine use in crush injuries of the chest. They noted a maximal rise in the pain threshold at an arterial blood pH of 7.55 and they also observed that the subjects showed a lack of apprehension, extreme cooperativeness and some loss of visceral sensation. These findings would suggest that if a respiratory alkalosis with a blood pH value of at least 7.55 could be constantly maintained by passive hyperventilation during the stabilization of a crushed chest, there would be no necessity to use any sedative or analgesic drugs. Restlessness and disorientation would therefore be avoided and the patient would be comfortable, calm and co-operative.

The following case report may serve to confirm these possibilities.

The patient, a previously healthy male adult, aged 36 years, was admitted to Whiston Hospital on November 27, 1961, having been thrown from his motor-cycle under the rear wheels of a lorry. He was conscious, but shocked and restless with a B.P. of 70/55 mm Hg and pulse rate of 120 beats/min. Both sides of the chest showed paradoxical movement and there was a marked lateral flail segment on the left side anteriorly. No pneumothorax or haemothorax was detected on clinical examination, but there was abdominal tenderness in the left hypochondrium and a paraplegia was present. Portable radiography revealed posterior fractures of the 4th, 5th, 6th, 7th and 8th ribs on the right side, and of the 2nd, 3rd, 4th and 5th ribs on the left side. Both scapulae were fractured, and there was a fracture-dislocation of the 7th on the 8th thoracic vertebra.

The patient was transfused with 3 pints (1.7 L) of blood and 4 pints (2.3 L) of plasma and taken to theatre when his B.P. was 110/70 mm Hg and his pulse rate 106 beats/min. He was still pale, sweating and cyanosed.

Anaesthesia was induced with nitrous oxide and oxygen and controlled ventilation was established.
after curarisation and endotracheal intubation. Laparotomy was carried out and a little blood was found in the mesentery of the ileum. The fracture dislocation of the spine was reduced by manipulation.

Towards the end of this procedure the patient's condition deteriorated with persistent central cyanosis when ventilated with 100 per cent oxygen. Bronchoscopy was carried out and blood clot and mucus were aspirated from the basal bronchi on both sides. Radiography showed partial collapse of both lungs and bilateral haemorrhage. Considerable amounts of blood were aspirated from both right and left pleural spaces; intercostal drains were inserted and connected to water seal drainage. A further pint of blood had been transfused. A tracheostomy was performed and the patient returned to the ward while intermittent pressure ventilation was continued.

Full curarisation was maintained for 6 days and the patient was hyperventilated with humidified air using an East Radcliffe ventilator. d-Tubocurarine chloride 15 mg was given intravenously via a drip tube every 90 minutes. Tracheobronchial toilet was performed every 15 minutes initially, using Pinkerton endobronchial catheters and strict aseptic precautions. Later in the course of treatment only hourly tracheobronchial toilet was necessary. The cuff of the Radcliffe tracheostomy tube was deflated every 4 hours, and the tube changed every 48 hours. Following each manipulation at the tracheostomy site an antibiotic powder spray (Polybactrin) was introduced into the pressure cycle of the respirator, d-tubocurarine was stopped. The patient was soon alert and moving, and it was found that he could flex his hips and knees voluntarily, and that he had full sensation below the segmental level of his fracture-dislocation. There was no difficulty in maintaining the respiratory minute volume previously attained with curare and the respiratory alkalosis was also maintained at a pH of 7.55 and a Pco₂ of 20 mm Hg. At this juncture it was decided to attempt the use of patient-triggered ventilation with a Bird respirator.

On the 7th postoperative day there was diminished movement and absence of air entry on the left side of the chest. Radiography showed collapse of the left lung and the tracheostomy tube in the right main bronchus. Changing the tube did not result in re-expansion of the lung for which bronchoscopy and vigorous hand inflation was required. By the following morning collapse had again occurred, although no fault could be found with the position of the tracheostomy tube. Re-expansion was achieved by vigorous tracheobronchial suction and manual inflation. There was no doubt that the patient-triggered respirator had increased the paradoxicity of the flail segment and the patient was therefore re-established on the East Radcliffe respirator. The patient was quite comfortable when being ventilated with minute volumes up to 18 l./min, and arterial blood samples on alternate days showed that a respiratory alkalosis in excess of pH 7.5 and Pco₂ of 21 mm Hg was being readily achieved.

On the 14th postoperative day the patient was allowed to breathe for short periods without the respirator and had no difficulty in maintaining very adequate ventilation. The following day intermittent pressure ventilation was stopped and the tracheostomy tube removed. The tracheostome closed quickly and and the urinary output was 1½ litres over the preceding 24 hours. Serum electrolytes were within normal clinical limits and were as follows: Sodium 138 m.equiv/l, potassium 5.5 m.equiv/l, chloride 101 m.equiv/l, bicarbonate 25 m.equiv/l, and a base deficit of —8 m.equiv/l. Fluid balance appeared satisfactory.

The results indicated a non-respiratory or metabolic acidosis with a persistently rising base deficit. Using the formula suggested by Astrup (1959), 168 m.equiv of sodium bicarbonate were given by intravenous drip to correct this deficit.

By the following day the patient's condition had improved. He no longer had peripheral cyanosis nor was he sweating. The arterial acid-base state was found to be pH 7.54, Pco₂ 20.5 mm Hg, and the base deficit had been mildly over-corrected to a base excess of 1 m.equiv/l.

Owing to the very great difficulty in maintaining a normal fluid, electrolyte and acid-base balance in patients who are being given intravenous fluids and maintained on intermittent pressure ventilation, it was decided, in spite of the continued signs of ileus, to give the patient a comprehensive liquid diet (Complan) via his Ryle's tube.

As the patient was suffering from increasing oedema of the face, a subatmospheric phase of 4 cm H₂O was introduced into the pressure cycle of the respirator, although the cause may well have been postural, due to the suspension from an orthopaedic frame. This subatmospheric phase did not increase the paradoxical movement of the flail segment. The Complan was well tolerated and bowel sounds were present on the 6th postoperative day. So that the patient could dispense with the Ryles tube and intravenous therapy, d-tubocurarine was stopped. The patient was well tolerated and bowel sounds were present on the 6th postoperative day. So that the patient could dispense with the Ryles tube and intravenous therapy, d-tubocurarine was stopped. The patient was able to breathe for short periods without the respirator and had no difficulty in maintaining very adequate ventilation. The following day intermittent pressure ventilation was stopped and the tracheostomy tube removed. The tracheostome closed quickly and

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The respirator was set to deliver a minute volume of 15 l. with a respiratory rate of 20–25/min, maximum inflation pressure required being between 20–25 cm H₂O.

On the 1st postoperative day the following acid-base data were obtained from a sample of arterial blood using the method of Robinson and Utting (1961): pH 7.55, Pco₂ 18.7 mm Hg, buffer base 37.5 m.equiv/l, standard bicarbonate 20 m.equiv/l, and base deficit —5 m.equiv/l.

During the first 4 days the patient was maintained with intravenous infusions of saline and dextrose. Oxytetracycline and a vitamin B and C complex were added to each bottle. Hydrocortisone 100 mg had been given intravenously during the operation and this drug was continued in decreasing doses for the next 10 days.

On the 2nd postoperative day the lungs were shown to be re-expanded and the intercostal drains were removed. In view of the paraplegia, pelvic hooks and Steinmann's pins were inserted to enable the patient's legs and trunk to be supported from an orthopaedic frame. For this procedure the patient was ventilated with 1–2 per cent halothane in oxygen. No bowel sounds were heard this day and the patient appeared to have a paralytic ileus.

On the 3rd postoperative day, the patient's general condition showed deterioration. He had become pale and was sweating. Peripheral cyanosis was present and he had a raised pulse rate of 120 beats/min. No other abnormal clinical signs were present except the continued absence of bowel sounds. Arterial acid-base estimations gave the following results: pH 7.38, Pco₂ 23.5 mm Hg, buffer base 36 m.equiv/l, standard bicarbonate 16.5 m.equiv/l, and a base deficit of —8 m.equiv/l. Fluid balance appeared satisfactory.

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The Complan was well tolerated and bowel sounds were present on the 6th postoperative day. So that the patient could dispense with the Ryles tube and intravenous therapy, d-tubocurarine was stopped. The patient was soon alert and moving, and it was found that he could flex his hips and knees voluntarily, and that he had full sensation below the segmental level of his fracture-dislocation. There was no difficulty in maintaining the respiratory minute volume previously attained with curare and the respiratory alkalosis was also maintained at a pH of 7.55 and a Pco₂ of 20 mm Hg. At this juncture it was decided to attempt the use of patient-triggered ventilation with a Bird respirator.

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cleanly and no further complications were encountered. The pelvic hooks and Steinmann's pins were removed after the cessation of intermittent pressure ventilation. An operation for spinal fusion was performed uneventfully 52 days after the accident.

On the 22nd day after his accident the patient, an intelligent but rather nervous man, was asked to give his impressions which were recorded on sound tape.

The patient remembers the accident and being brought to hospital. He remembers having his clothes cut off and being shaved prior to laparotomy. He has no memory of the events that took place in the operating theatre, but recalls remarks probably made as he was taken to the ward. He remembers awakening in the ward and finding that he could neither move nor speak, a situation which, as he explains later, occasioned him little or no anxiety.

His memory for events between laparotomy and the end of the period of curarization is partly fact and partly fantasy. For a long time he imagined himself to be lying in a dockside office, the tiled walls of which were glaringly white and several feet thick. He imagined that one of the people attending him was an old sailor, possibly because one of the doctors answering urgent calls to his bedside did so dressed in a rough roller-neck sweater. He had, however, sufficient insight to know that he was deluded and hallucinated, and he could, by an effort of will, enforce his return to the world of reality. He recalls from this period, accurately and in detail, the description given by a doctor of the mechanism of the Radcliffe ventilator.

Despite the fact that analgesics were withheld, he "never had any pain" during the period of controlled respiration. But between the time of his accident and the laparotomy his "chest really hurt" and the pain was bad enough to bring tears to his eyes.

Aspiration of the trachea was not a painful business, but made his throat feel as if it was on fire. Changing the tracheostomy tube also produced a burning sensation in his throat, and the feeling of heat might not subside for what appeared to him to be about 1 hour.

Whilst curarized the patient was not aware of any proprioceptive sensation. He felt no urge to change the position of a limb, or to scratch. At all times he felt comfortable but "didn’t seem to be in bed". He felt "as if he were safely curled up in a sack".

He did not feel hungry or thirsty, and remembers no intestinal or bladder sensations.

Whilst curarized he could "hear and recognize all the voices of the staff". He was "surprised that they thought I was paralyzed. Quite early on I could feel them probing the soles of my feet but I couldn’t move them. I thought it was the end of a pair of scissors that the doctor was scraping my feet with. . . . I could feel it quite plain. I tried to tell them I could feel the scraping but couldn’t speak". His inability to communicate did not unduly worry him; he knew that "they must find out sooner or later".

A source of discomfort was the electric light. "When I first arrived in here I thought that that bright spot up there (the lamp filament) was John Bull, and that he wanted to fight me. He was grinning and leering at me all night long. . . . In the first few days I was here I seemed to be in a big warehouse or toilet with glaringly white tiles. I climbed up the walls several times because that fellow John Bull was laughing at me and wanting to take a cork at me; and I wanted to take a cork at him. . . . I knew at the time it wasn’t real, but part of a dream. . . . I wasn’t frightened by it."

During the first two weeks he had a bad taste in his mouth, and his tongue felt bruised. He resentfully recalls a Ryles tube being passed through his nose and throat. The bad taste in his mouth persisted as long as he remained on a ventilator.

The fact that he could neither move nor speak while he lay curarized did not frighten him. "I’d heard from the nurses that I was supposed to be like that. I’d heard the doctors and nurses talking and heard them say I was under this ‘curi-something’ from South America—so that was it. I gathered I was meant to be paralyzed. . . . No, there was no fear in my mind; none whatever. I had complete confidence." He was always quite sure he was going to live, although at first he "didn’t realize how badly damaged" he was supposed to be.

A cause of unpleasantness was the periodic deflation of the cuff of the tracheostomy tube, because this meant “the snakes and coughing and
spitting and all the rest”. He always thought of the suction catheters as snakes and thinks that the idea may have sprung from his meditation thoughts on the “South American poison”. “When I first arrived in here those things were definitely snakes. They went down my throat and were not manipulated by any human being.”

Whilst curarized he suffered the not unpleasant hallucinations and delusions already referred to, but suffered no frightening nightmares, nor has he been troubled by nightmares since. If he had to be curarized and artificially ventilated again, the prospect would not fill him with apprehension.

Whilst he was curarized the patient was unaware that he was being artificially ventilated, and he therefore had no fear the ventilator might stop. Later he realized that the ventilator was helping him to breathe and he then occasionally became fearful of a possible breakdown. The patient’s most unpleasant experience arose from this: “There was a night when the [cuff of the] tube went on me and the clickety-click [the pressure cycling mechanism of the Bird respirator] went on me . . . then I really panicked . . . . I felt the doctor didn’t know what to do, and I heard that the doctor who did know wasn’t around . . . . I felt I was suffocating.” Despite this frightening experience the patient said he had little fear of a second failure. He had been told not to worry and he knew that a spare machine was available.

COMMENT

This patient was admitted as an emergency to a typical general hospital with only the beginnings of a specialized respiratory unit. He was too ill for transfer to a thoracic unit and was nursed in the side room of a busy surgical ward by devoted but inexperienced staff. Nevertheless, our aims on management were well defined and to a satisfying extent attained. Large respiratory minute volumes were well tolerated both with a curarized patient and without the use of this drug. An acceptable degree of analgesia was achieved and the patient appears to have been calm and comfortable. No supplementary sedatives or analgesics were required. The patient was able to maintain contact with his environment at all times and was never restless or unco-operative. This, together with the initial prolonged period of curarization, was of considerable help in maintaining the unstable reduction of the fracture-dislocation of the spine. The discomfort caused to the patient by a bright overhead light when he was curarized and could not look elsewhere has caused us some concern. The new Respiratory Department of the hospital is fitted with a form of diffused lighting.

The estimation of arterial blood pH and Pco₂, with the assessment of the non-respiratory acid-base state was necessary to diagnose and correct the metabolic acidosis occurring in this case. This probably resulted from the large transfusions and the inadequate calorific intake. Estimation of arterial Pco₂ alone would appear to be an insufficient guide to the hydrogen ion regulation of a patient on prolonged intermittent pressure ventilation. The use of an interpolation technique for the estimation of Pco₂ makes the production of such acid-base data a simple and rapid procedure.

The patient preferred the East Radcliffe to the patient-triggered machine, but was biased by the fact that the patient-triggered machine ceased to cycle one night. This respirator also increased the paradoxicity of the flail segment. Other authors have experienced difficulty with patient-triggered respirators in this type of case (Windsor and Dwyer, 1961; Sillar, 1961).

Asked what he thought himself was the most important factor contributing to his sense of security, he was emphatic that this lay in the manner of the doctors and nurses attending him. “When I knew that they knew what they were doing, I was quite happy and content . . . . It was only when they seemed to hesitate in handling me that I felt scared.”

ACKNOWLEDGMENTS

Our thanks are due to Dr. J. R. Esplen for his assistance in the management of this case and for making the tape-recording; also to Mr. H. O. Williams, the orthopaedic surgeon in charge of the case, and Mr. J. A. Martinez who performed the laparotomy.

REFERENCES


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SOMMAIRE

Compte-rendu d'un cas d'écrasement grave du thorax s'accompagnant de fracture et dislocation de l'épine thoracique.

La cage thoracique fut stabilisée pendant 15 jours par ventilation intermittente de la pression. Une hyper-ventilation constante permit d'obtenir analgésie et sédation, le pH artériel étant maintenu à plus de 7,5.

Ni analgésie ni sédatifs ne furent nécessaires et le patient reposa sans douleur, calme et donnant son assistance au traitement.

Le compte-rendu reproduit les impressions notées par le patient pendant la période d'hyperventilation contrôlée.

Tous les deux jours l'équilibre acido-basique subit un examen complet.

Les auteurs recommandent le traitement de lésions graves analogues de la cage thoracique par hyper-ventilation délibérée.

ZUSAMMENFASSUNG

Ein Fall einer schweren Brustkorbquetschung mit Fraktur-Dislokation der Brustwirbelsäule wird berichtet. Der Brustkorb wurde 15 Tage lang durch intermittierende Druckatmung stabilisiert.


An jedem zweiten Tag wurde eine vollständige Untersuchung des Säure-Basen-Gleichgewichts ausgeführt.

Die Behandlung ähnlich schwerer Brustkorbverletzungen mit absichtlicher Hyperventilation wird empfohlen.

BOOK REVIEW


This well-produced volume, written mainly for German part-time anaesthetists, aims at deepening their knowledge and understanding of general anaesthesia. It is not meant to serve as a textbook or synopsis but deals in six chapters with selected pharmacological, physiological and technical problems which may be met with in day-to-day-work.

The book incorporates much modern literature as well as original work by the authors: for example on the efficiency of various brands of soda-lime, or (very interesting) on the site of pressure lesions caused by Magill endotracheal tubes. The teaching is sound and follows mainly the British pattern, with a few exceptions like the continental habit of reducing pre-operative fever by antipyretics, or the routine use of the quick-injection technique for thiopentone for which a 5 per cent solution is regrettably not condemned. One may disagree with the views that ether odour is not unpleasant, that intravenous barbiturates increase tolerance for ether vapour, or that for induction ether in concentrations up to 20 volumes per cent is needed for about 15 minutes. But these minor points do not detract from the value of the clear and sensible presentation of the various subjects.

Apart from an unusual number of good illustrations, photographs and diagrams, the authors use three different means of stressing their points, framing of a sentence in black lines, bold face type and italics. This may tempt the busy part-time anaesthetist to look only at illustrations and special types of print, thinking that thereby he has grasped the essentials, while in fact these cannot be mastered without the solid foundation of the whole text.

The book will make a valuable contribution to the promotion of good anaesthesia in a country where the specialty is now progressing at a quick pace.

Luise Wislicki