RESUSCITATION AND SEDATION OF PATIENTS WITH BURNS WHICH INCLUDE THE AIRWAY

SOME PROBLEMS OF IMMEDIATE THERAPY

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CERTAIN ASPECTS of the Cocoanut Grove disaster are characteristic of conditions encountered in most conflagrations of the flash-burn type. In this report attention will be given primarily to the factors of general interest. These matters are particularly appropriate for consideration at this time, for in the present widespread use of mechanized warfare flash-burns are exceedingly common.

As the patients from the scene of the disaster were crowded into the hospital it became apparent early that they were divided sharply into two groups: The living and the dead or near dead. None in the former group died in the first 12 hours; none in the latter group lived more than a few minutes after arrival.

The patients who lay quietly at rest on arrival were in the minority. As soon as it could be established tentatively that these few individuals had not suffered central nervous system injuries or were not stupefied by smoke inhalation and showed no signs of approaching shock, it was clear that the larger, hyperactive group needed the most attention, although, at the same time, the importance of watching these quiet ones was not minimized.

An outstanding characteristic of the living group was hyperactivity, even to the extent of mania in some cases. One's first impulse is to assume that this hyperactivity is due to pain. From the history of other similar tragedies this appears to have been the usual assumption and the patients treated accordingly. A careful appraisal of the causes of this hyperactivity is of real assistance in planning individual therapy. In the Cocoanut Grove disaster we had a unique opportunity for simultaneous observation of a considerable number (39) of victims of the same accident. It was quite apparent that pain was an improbable cause of the observed hyperactivity in many cases. *As time progressed the importance of correctly diagnosing the cause of this hyperactivity in a given case became increasingly clear, for proper therapy depended upon differentiating between three possible major causes:*

COMMON CAUSES OF HYPERACTIVITY

(1) *Pain.*—Unquestionably, pain was present in many patients. This was due to burns, to irritation of mucous membranes, chiefly the eyes and the airway, by irritant gases, and to physical violence as a result of the panic that had occurred.

(2) *Fear and Hysteria*, as a result of the individual's experiences, appeared

to influence the behavior observed of those who had no injuries and doubtless were also a factor in the behavior of many of those with physical injuries as well. It will be recalled that this disaster occurred in a night club at about 10:15 P.M. Alcohol in some cases doubtless contributed to the excitement and the lack of self-control. The panic of the crowd and the physical pain and discomfort shared in producing the hysteria observed.

(3) *Anoxia.*—Cerebral anoxia is well known to give rise to excitement, occasionally to loss of self-control, and at times to manic behavior. This sequence is not infrequently encountered in chronic heart failure. Anoxia was probably a factor in our patients due to two main causes: (1) Interference with oxygen intake from obstruction of the airway was caused by a number of factors, for example, foreign bodies, chiefly vomitus. (This was a common hazard in the comatose but not in the hyperactive group.) Severe bronchial spasm occurred from pulmonary irritation caused by inspiration of the hot and noxious gases and probably interfered with the intake of oxygen. Edema of the airway developed into a problem beginning chiefly about four hours following the burns. How much of a lethal factor edema of the airway was in those who lived only a few minutes, is uncertain. (2) Impairment of oxygen transport by the blood was a factor in the development of anoxia largely as the result of the formation of carbon monoxide hemoglobin. Neither methemoglobin formation nor hemolysis as the result of encounter with noxious gases was a factor in our cases. While acute anemia must always be considered as a cause of cerebral anoxia, neither hemorrhage from associated wounds nor low blood pressure from shock was important here. In about one-third of the patients measurement of the blood pressure was not carried out because of interfering burned areas. Judging from other clinical signs these patients were not in shock. Where it was possible to measure blood pressure, two patients were found to have brief periods of hypotension; but frank surgical shock did not develop in any of the 39 patients.

THERAPY OF THE CAUSES OF HYPERACTIVITY

The importance of properly diagnosing the cause of the hyperactivity emerges from considerations of therapy. Moreover, a clue arises here as to the reasons for the often made recommendation of the use of enormous doses of morphine in burned patients. Occasionally large doses may be necessary; it appears probable in many cases that they are not only unnecessary but are in fact contraindicated. When the hyperactivity of the patients is caused by fear or hysteria or by cerebral anoxia the use of large doses of morphine is obviously unwise. *It seems probable that in burned patients morphine may often have been used in an attempt to treat conditions which will not respond favorably to morphine however large the dose.* An examination of the probable reasons for the use of large doses of morphine may throw some light on what is rational sedation for this group of patients.

PAIN

It has come to be accepted as a fact in medical practice that enormous doses of morphine must be used in the treatment of burned patients, doses that under normal circumstances might of themselves be fatal. Against this is the observation (Hardy, Wolff and Goodell[1]) that the analgetic action of morphine increases rapidly up to 10 mg. (1/6 grain) intramuscularly, but is increased little by doubling or tripling the dose. While little of added benefit is obtained by this doubling or tripling, great increase in the toxic effects, particularly respiratory depression, results therefrom. It seems reasonable to question the advisability of the use of the customary large doses of morphine. Support for this view also emerges, as will be described below, from the realization that other factors besides pain may help to account for the hyperactive, even manic, behavior of individuals who have been subjected to a conflagration.

For pain, morphine administration is the treatment of choice. It must constantly be borne in mind that the common tendency in a disaster of this kind is to overmedicate. Safety depends upon the use of rather small divided doses repeated as necessary. Emphasis on these elementary matters may seem needless; but our experience was otherwise. For intravenous administration somewhat smaller doses are chosen than for subcutaneous or intramuscular use. Intravenous injection of the morphine is best—8 to 10 mg. (1/8 to 1/6 gr.) doses are used. Such doses as these should be injected over 15 to 30 seconds, and may be repeated intravenously in about 15 minutes, until the desired effect is obtained. When many patients need treatment at once there will often not be time to administer the agent intravenously.

Whenever the subcutaneous or intramuscular routes of administration of morphine (or other agents) are considered, it must be borne in mind that under circumstances where the peripheral circulation is slow or inactive, the injected agent may not be absorbed. In patients coming from a fire, several conditions tend to reduce the peripheral circulation and, consequently, the rate of absorption of agents injected into the subcutaneous or intramuscular regions: Chilling from cold water spray and water soaked clothing (our patients had in some cases rectal temperatures as low as 94° F., pain and fear, and low blood pressure from various causes. Under circumstances such as these, agents injected into the subcutaneous or intramuscular regions will be absorbed very slowly if at all. Lack of attention to this possibility may result in repeated injection of the agent into these "refractory" patients. Later, when the peripheral circulation has been reestablished by shock therapy or warmth, the total injected dose may be absorbed at once with disastrous results.

When large numbers are to be cared for as quickly as possible, when the peripheral veins are collapsed, when slow absorption of the agent is desired, and, for various other reasons, subcutaneous or intramuscular use may be employed. Here 15 mg. (1/4 gr.) doses may be administered. In such a case it is advisable to make up the solution (when a considerable number of patients must be treated rapidly) in a 20 cc. syringe with 15 mg. (¼ gr.) per cc. concentration. A second such dose can be repeated in 20 minutes for a robust subject with severe burns. Increase in morphine medication beyond 30 mg. (½ gr.) is made only after one has assured himself that the need is for treatment of pain rather than fear or hysteria or anoxia. Even then, the justification in most cases for such large doses is questionable, as mentioned above.

If there is any possibility that large doses of morphine will be required it is advisable to use an extremity for their injection, and the site should be marked with a dye so that if signs of overmorphinization appear, absorption can be delayed by the use of a tourniquet above the site of injection. An unburned extremity should of course be chosen, for a tourniquet placed about one with peripheral burns would increase the edema formation in the injured area.

FEAR AND HYSTERIA

Fear and hysteria are best treated by repeated intravenous administration of a barbiturate, for example, sodium pentobarbital (nembutal) in 90 mg. (gr. 1.5) doses. In patients with pulmonary damage it is doubtful if more than two such doses should be given initially. While opinions are divided as to the wisdom of using paraldehyde in patients with injury to the lungs, there appears to be no serious objection to the use of small doses intravenously, as follows: Two or three cubic centimeters of paraldehyde may be injected over a half minute. One patient (Case 7) received paraldehyde, 4 cc. intravenously.

ANOXIA FROM AN INADEQUATE AIRWAY

Treatment of an inadequate airway takes precedence over all other forms of therapy. The following factors require consideration in this therapy:

The Removal of Foreign Material.—The Cocoanut Grove victims were either dining or had only recently finished dinner. Probably vomiting was more frequently encountered in this group than is usually the case in burned patients. Vomitus in the airway of the patients who arrived at the hospital either dead or in a moribund condition may have hastened some deaths. It is unlikely that such obstruction was present in the other, the hyperactive, group of patients. Occasionally, aspiration of the mouth and throat of these patients was carried out as a preventive measure.

Intratracheal intubation was carried out in three patients. In one of these cases it was necessary about two hours after admission.

It was considered to be life-saving in this case. Gross overdosage with morphine was present, and the intratracheal tube facilitated artificial respiration which was necessary intermittently over a five-hour period. In another case intratracheal intubation was used to facilitate bronchial aspiration several days after the accident. In the third case the procedure was used terminally to facilitate respiration preceding death. One or two other patients would have received intratracheal intubation had they not been vomiting. It is usually unwise to introduce an intratracheal tube into a vomiting patient, for the necessary local anesthesia may permit the aspiration of vomitus. It is also unwise to insert an intratracheal tube surrounded by an inflatable cuff to prevent aspiration, for such inflatable cuffs have produced damage to normal mucosa of such degree that subsequent to their removal fatal local edema has occurred; therefore, we did not choose to use them in these subjects with already inflamed tissues. The best solution of this problem seems to be careful watching of all patients, with immediate tracheotomy in those that are vomiting when the airway shows signs of inadequacy.

Tracheotomy was required for the first time six and one-half hours following the fire. In all, five tracheotomies were carried out in the 39 patients during the recovery period. Three of the five patients died. The onset of serious *edema* of the airway in our cases, several hours after the burns, is in agreement with the history of other similar disasters, notably that of the Crile Clinic.

Treatment of Bronchospasm.—How great a rôle bronchospasm plays in the inadequate ventilation of the lungs in such patients is difficult to estimate. The bronchospasm was initiated presumably by heat or by the irritant gases breathed. It may have been a factor in precipitating or aggravating pulmonary edema formation. It was the consensus of opinion of those who examined the chests and roentgenograms of the patients that bronchospasm was a factor in producing the well-demonstrated peripheral trapping of air. Local edema, as well as foreign bodies, arising from sloughs in the bronchiolar walls were also doubtless involved in this. Attempts to treat this bronchospasm with epinephrine or ephedrine appeared to be quite unsuccessful. In a few cases the intravenous administration of 0.5 Gm. (7.5 grs.) of aminophylline appeared to be followed immediately by better ventilation and in some cases by cough, with the raising of sputum. This benefit may have lasted for only ten or fifteen minutes; estimation of this was difficult. Whenever injury of the airway has occurred, as in these patients, it is important to humidify the air breathed. All gases administered should be saturated with water vapor.

Oxygen Inspired.—Patients showing any signs of anoxia were immediately given by mask 100 per cent oxygen to breathe. In the first six hours seven of 39 patients required high oxygen concentrations. These were administered in order to get not only as full saturation of hemoglobin as possible through the damaged respiratory epithelium, but also to get the advantage of oxygen dissolved in the blood plasma. Subsequently, a total of 13 patients required oxygen therapy, chiefly by tent.

Increased Pressure in the Airway.—When oxygen is administered in a closed system under positive pressure, a greater diffusing surface is afforded the alveolar gases and the blood, and possibly the smaller airways are increased in diameter by the pressure, with the result that obstructing secretions are less effective in blocking the passages than they were. If this is the situation, drainage might also be promoted by positive pressure. It is said that the use of positive pressure will prevent or curtail the formation of pulmonary edema. This seems to be open to question. Some believe, although incorrectly, that the partial pressure of the alveolar oxygen can be significantly increased by safe positive pressures. While this might be true at very high altitudes it is not true at ordinary atmospheric pressures. Notwithstanding the possible advantages to be gained from positive pressure we decided, rightly or wrongly, not to use it in these cases. In the first place, in a fairly wide experience with positive pressure in patients undergoing thoracic surgery it has been our observation that this procedure often lowers the systemic arterial pressure, probably by interfering with the passage of the blood through stretched out and narrowed alveolar vessels with the result that filling of the left heart is impeded. Positive pressure appears to interfere with carbon dioxide elimination. Finally, several patients exhibited a paradoxical pulse. We construed this to be a further argument against the use of positive pressure.

Helium.—When the tidal volume of air is normal or near normal it is unlikely that helium will be of value as a vehicle for oxygen, although it might be argued that if some bronchospasm is present the use of helium might be desirable. Our experience with helium in these cases was limited to a few trials of an experimental nature in which 75 per cent helium with 25 per cent oxygen was compared with 100 per cent oxygen. It was not possible at this time to make careful blood gas studies. We were not able to detect any improvement in the skin blood color with the helium and oxygen mixture as opposed to the high oxygen atmosphere. On the other hand, the pulse rates under the latter atmosphere were about 20 beats slower than when the helium and oxygen mixture was used (about 140 against 160). The difference in pulse rates suggests that oxygenation was better when 100 per cent oxygen was used than when the helium was employed.

ANOXIA FROM INADEQUATE TRANSPORT OF OXYGEN BY THE BLOOD

Carbon Monoxide Poisoning.—While many of the dead patients showed signs of carbon monoxide poisoning only two, questionably three, of our 39 living patients showed fairly definite signs of it. In these, attempts were made to eliminate the carbon monoxide by the administration of a continuous stream of oxygen containing five to seven per cent carbon dioxide. No rebreathing was permitted here. It is as desirable to give whole blood as soon as possible to these patients as it is to patients who may be anemic following hemorrhage or anemic from encounters with hemolytic gases in the smoke breathed.[2]

Shock.—When the patients arrived we supposed, incorrectly, that many cases of shock would develop. To combat shock, the intravenous injection of fluid was started on each patient within 15 minutes of the time of his arrival, in order to expedite the use of plasma as soon as it could be made ready. Both physiologic saline and five per cent glucose solutions were used. The volume of these fluids administered was sharply restricted. From 200 to 500 cc. were administered before plasma was started or until the decision was made that intravenous fluids were not necessary. Twenty-nine patients received an average of 4.2 units (250 cc. unit) of plasma apiece in the first 24 hours. The variation was from one to nine units per individual in the first 24 hours. In the first seven days 147 units of plasma were administered. Also in the first seven days, 16 whole blood transfusions were administered for patients with reduced oxygen capacity of their blood.

As already pointed out, none of our patients developed frank shock. In the two instances in our cases where the blood pressure was low, even for a brief period, the head-down position was used; but as soon as the systolic arterial pressure had risen to 80 mm. Hg. we began gradually to reverse the position from head-down to head-up. Damage to the lungs must be assumed in patients such as these from the Cocoanut Grove even though it is not apparent. The head-up position reduces the pulmonary venous pressure and minimizes the tendency to edema formation in the lungs.

OBSERVATION OF PATIENTS FOLLOWING IMMEDIATE THERAPY

Factors of importance in the medical administration and organization of the treatment of large numbers of wounded individuals have been dealt with by Dr. Faxon in his accompanying article, and elsewhere by Faxon and Churchill.[3] An indispensable part of the therapy of patients with burns of the airway is continuous and prolonged watchfulness of the respiratory and circulatory systems as well as of the patient's comfort. In the Cocoanut Grove disaster this was handled by the following personnel for dealing with our 39 patients.

Two physicians made rapid and continuous "chest" rounds on all patients following the initial treatment. It was their responsibility to watch the pulmonary ventilation, with particular attention to the development of pulmonary edema and to inadequate oxygenation of the blood from any cause. They called attention to deteriorating cases. They requested any new therapy needed, as intubation, oxygen therapy, etc.

Two men (medical students) made continuous rounds, determined blood pressures, pulse rates and recorded these data.

One physician made "medication rounds," constantly looking for patients who needed further drug therapy, diagnosed the need and administered the appropriate agent. Constant watchfulness for overmedication is essential.

DELAYED REACTIONS

Delayed reactions are to be anticipated. Constant alertness must be maintained for the signs of (a) overmedication, particularly in cases where morphine may have been administered subcutaneously, with delayed absorption as in patients with poor peripheral circulation as a result of chilling or shock; (b) shock, as a result of plasma loss from burned surfaces, or other cause; (c) oropharyngeal, tracheal, or pulmonary edema; and (d) central nervous system damage with delayed onset of cerebral edema with increased intracranial pressure.

Observations of the condition of the blood is of great help in guiding the care of these patients and in providing accurate quantitative data concerning the trend of delayed reactions. For example, the increased time required for a blanched area (made by the light pressure of a finger on the skin of the forehead) to fill in, often provides, in demonstrating the slowing of the peripheral circulation, a sharp warning of decline in the patient's circulatory condition, and of the possible approach of shock. The color of the blood must be maintained as near normal as possible. If assistants and equipment are available, hematocrit readings are obtained, for they are of great value as a guide to the need for whole blood or plasma. These were available by four and one-half hours (3 A.M.) following the accident. The determination of the plasma protein level refractometrically is a brief, simple procedure of value. In the days following the disaster more elaborate studies were possible. Helpful here were determinations (in arterial blood) of oxygen content and capacity. In one or two cases low oxygen values showed an urgent need for red cells. This might have been surmised some hours earlier had adequate attention been given to the low hematocrit values. Carbon dioxide content, plasma p_H, and plasma electrolyte values were helpful although not as important as the previously mentioned determinations.

NEED FOR FUTURE WORK

The Cocoanut Grove disaster called attention to the lack of information concerning the pulmonary lesions produced by fires and at the same time emphasized the need for study of this problem. For many years it has been known that pulmonary burns produced delayed effects in that, initially, victims appear to be in good condition and then rather suddenly develop respiratory impairment, obstruction, possibly bronchospasm and edema, and die. This was strikingly illustrated in the Crile Clinic disaster at Cleveland several years ago, and again recently here. Important gaps in therapeutic knowledge are concerned with (a) how best to overcome deficient gaseous exchange in the lungs arising from bronchospasm or caused by edema and by tissue sloughs; and (b) how to prevent these conditions. With the increase in flashburns as a result of mechanized warfare, or for that matter mechanized civilization, therapy of the pulmonary lesions involved urgently needs study.

SUMMARY AND CONCLUSIONS

The patients who survived the Cocoanut Grove disaster long enough to receive therapy were in many cases hyperactive, even manic. Proper therapy depended upon correctly diagnosing the cause of this hyperactivity in a given case. Three major causes were: Pain; fear and hysteria; and cerebral anoxia.

Morphine is a useful therapeutic agent only for those in the first of these three groups. In the other two groups it is not only ineffective but is contraindicated in large doses. Although large doses of morphine are often employed in treating patients from a conflagration, it seems probable that morphine may often have been used in an attempt to treat conditions which will not respond favorably to morphine irrespective of how large the dose.

In patients who have been water soaked and chilled, who are frightened, or who are approaching shock, or whose peripheral circulation is otherwise greatly reduced, it is unwise to administer morphine (or other agents) subcutaneously or intramuscularly, for absorption will be either absent or greatly retarded. Lack of effect may lead to repeated administration of the agent in an effort to obtain an effect. Later, when the circulation has improved, the total of the subcutaneous injection may enter the circulation at one time with serious, even fatal consequences. Morphine should be administered intravenously to such patients. If, because of the great number of patients to be cared for, one cannot take time for intravenous administration of morphine, the agent should be injected into an unburned extremity and the injection site marked with ink, or a dye, so that if too great absorption of the agent is apparent later on, the inflow can be checked by means of a tourniquet.

For fear and hysteria, intravenously administered barbiturates are useful. For anoxia, arising chiefly from carbon monoxide poisoning, the treatment is seven per cent carbon doxide in 93 per cent oxygen in continuous stream (without rebreathing) and with the administration of whole blood.

Various oxygen therapy technics (intratracheal intubation, tracheotomy, helium, positive pressure) are considered and reasons offered for discarding or employing them in treating the anoxia. The oxygenation problem is greatly complicated by severe bronchospasm and pulmonary edema. Consideration of these factors leads to a discussion of needs for future work.

REFERENCES

[1] Hardy, J. D., Wolff, H. G., and Goodell, H.: Studies on Pain: The Analgesic Action of Morphine and Codeine in Man. Am. J. Physiol., **129**, 375, 1940.

[2] Drinker, C. K.: Carbon Monoxide Asphyxia. Oxford University Press, New York, 1938.

[3] Faxon, N. W., and Churchill, E. D.: The Cocoanut Grove Disaster in Boston. J. A. M. A., **120**, 1385–1388, 1942.