Excerpts from a talk by Dr. G. Rainey Williams, professor of surgery and chief of the division of thoracic surgery at the University of Oklahoma Medical Center, Oklahoma City.

I plan to talk about the ways in which chest injury alters the physiology of patients. If we understand these mechanisms, the ill effects of chest injury can either be prevented or to some extent reversed. This seems to be an appropriate subject for several reasons: The first is simply that chest injuries are terribly common; the second is my general impression that physicians understand the basic physiology of most other systems somewhat better than they do the pulmonary system; and third, there is relatively new information that is important in the management of chest injuries, and I think this merits review from time to time.

Initial management of chest injuries should not fall, for the most part, to any particular specialty group. The reason for this, of course, is that rapid action is essential in treating chest injuries; there is no time to get a thoracic surgeon to the patient with life-threatening trauma. Furthermore, patients with untreated chest injuries are among the poorest of all travelers. They cannot simply be shipped off before appropriate resuscitative and supportive measures have been taken, so their management must be carried out where they are first seen in order to prevent mortality. And finally, only a very small percentage of patients with chest injury require open thoracotomy. So there really is little necessity for the vast majority of chest-injury patients to be seen by a specialist in chest disease or in thoracic surgery. In my opinion, the quickest way to insure poor management of a multiply-injured patient is to call a specialist for each area that is injured.

I would like to review the physiological pathways of chest injury. Two things happen to patients with chest injuries: respiratory failure and shock. All of you are aware that these two influence each other. They are not separate mechanisms. Respiratory failure is frequently an effect of shock, and furthermore, many chest injuries produce both.

Pulmonary function can be considered in two phases: ventilation—the mechanism whereby oxygen gets to the lungs; and gas exchange—the mechanism whereby oxygen gets into the blood and carbon dioxide gets out. If we think in terms of ventilation and gas exchange as being the necessary components to insure pulmonary function, failure of either one obviously results in pulmonary insufficiency.

To break the ventilatory problem down a little further, we can conveniently think of it as depending on three things. First, in order to have adequate ventilation, one has to have adequate lung volume. Second, this lung volume has to be filled and emptied over a period of time—and we'll talk about this as minute ventilation or tidal volume. The third component is that of lung chest components, the point being that one can have adequate lung volume and one can have, in terms of capacity, adequate tidal volume, but if the patient is unable or if the work effort involved in actually moving this minute volume is not adequate—in other words, if the compliance becomes extremely low—then we have pulmonary insufficiency. I'll say no more about compliance because it is not commonly of real importance in the initial management of chest injuries. Rather, it enters into the subsequent management of the patient once he or she has left the emergency room.

There are several entities which reduce lung volume, among them pneumothorax, hemothorax, and diaphragmatic rupture with herniation of abdominal viscera into the chest. All of these simply cut down on the volume of lung which can be ventilated and when this reaches 20 to 25%, the patient is in respiratory failure. Reduced minute ventilation or tidal volume is most often caused by upper respiratory tract obstruction; vomitus, blood, and foreign bodies of all sorts are relatively common in patients with massive injuries. The classic entity, of course, that reduces minute volume is the flail chest, which results from multiple rib fractures. This causes an area of the chest wall to move paradoxically with respirations, preventing effective minute ventilation. The sucking wound of the chest will do the same thing, provided the wound in the chest wall is sufficiently large to prevent effective ventilation of the lungs.

The second component of pulmonary function that we talked about is gas exchange. Ventilation without it is really not very important. There are two points about gas exchange that we need to explain. One of them is the fact that ventilation and blood flow have to be together in order to produce gas exchange. We refer to this as ventilation/perfusion ratio. The second important aspect of gas exchange is that the membrane across which gas...
diffuses has to be efficient. If this membrane is not working, it doesn't make much difference what kind of ventilation/perfusion ratio you have and it makes absolutely no difference what sort of ventilation you have. Normally, ventilation-to-flow ratio is about 3:5.

If we have adequate ventilation, but inadequate perfusion, then we have an increase in physiologic dead space which is rarely encountered in patients with injuries. A more commonly encountered situation is one in which there is decreased ventilation and normal or even increased blood flow, and this gives us what we refer to as a shunt. This shunt is probably not an anatomic thing. It's a physiologic concept that blood which is going through the lungs is not oxygenated and is simply returned to the left side of the heart. Thus, unoxgenated blood is dumped back into the circulation.

For practical purposes in the emergency room, the entities that produce abnormalities of the ventilation/perfusion ratio are such things as bronchial obstruction, pneumothorax or hemothorax, and, of course, bronchial rupture. There are many other things that effect ventilation/perfusion ratio, such as the position of the patient, but for practical purposes these are the entities we fear and which, if severe enough, result in respiratory failure.

Reduction of membrane efficiency is understood least of all, but, needless to say, it occurs rapidly in aspiration pneumonia, and it may also result from overinfusion of fluid. Shock may also reduce membrane efficiency and produce anoxia by mechanisms that are slowly being understood.

Shock may be due either to hemorrhage—principally from intercostal vessels, from the lung itself, from the mediastinal vessels, or some combination of these—or to pump problems. Hemorrhage is one of the feared aspects of chest injury, as it can be torrential and life-threatening in a very few minutes after the patient is brought in.

With regard to pump problems, one of the causative mechanisms is reduction in venous return on either side, principally systemic. This occurs, of course, in large hemothorax or pneumothorax in which mediastinal structures are shifted markedly and venous return is impeded. It also occurs in cardiac tamponade when blood enters the pericardial cavity in such quantities that the heart simply cannot fill in diastole and, therefore, cardiac output falls. The patient is in clinical shock with a high venous pressure—about the only situation in the emergency room in which one encounters that combination.

Finally, myocardial injury can result in inadequate pumping. We are seeing some of these particularly with steering-wheel injuries of the chest.

Now, pulmonary physiologists who understand the mechanisms well would almost certainly be useless in the emergency room because the principal problem in the management of chest injury is to recognize it. Detection of the chest injury is not always simple. If a patient is cyanotic when he is admitted, everybody can make the diagnosis of some sort of respiratory insufficiency, but the important concept is that the patient can be in borderline respiratory insufficiency and have normal color.

I'm impressed with the simple system that Rutherford and Gott described several years ago in which one does three things. The first one is simply to look at the color of the skin and nail beds and so forth. The second is to put an ear close to the nose or mouth of the patient, and the third is to watch the chest and feel the pulse at the same time. One can quickly ascertain whether or not there is adequate ventilation by the volume of exhaled air. If there is not adequate ventilation one can frequently get an idea of why it is inadequate by watching the chest at the same time. And, of course, palpation of the pulse is important in terms of at least suspecting that the patient is or is shortly going to be in shock. This is a quick way of making at least an initial assessment of respiratory function.

Second only to getting too many specialists in the game early, I consider that more errors in the management of emergency room patients come from inadequate examination than perhaps from any other single thing. It is important that an adequate physical examination be done, and the principal reason this is not done is the problem of getting the patient undressed. In my opinion, a relatively automatic, non-physician-initiated system of getting the patient undressed in an area where you can do an adequate physical examination should be routine. Unfortunately, it is not rare to see patients sent to wards, still in their winter clothing, with flail chests and adequate color, but in undetected pulmonary insufficiency. Such patients may well quietly expire a short time after admission to the hospital.

One of the real advances in the clinical management of patients in the last several years is the availability of equipment which will very quickly allow us to measure the pH, the pO_2, and the pCO_2 of arterial blood. I think these determinations should be done relatively early in the emergency room on every seriously injured patient.

Whether you detect chest injury or not, virtually any serious injury has a chest component, and early blood-gas readings are of considerable value to the managing physician when the patient is sent upstairs. Blood-gas determinations ought to be available on a 24-hour basis. The apparatus is no longer expensive and anybody can run it with a very little bit of instruction.

The third major error is sending patients to x-ray too early. I am aware of the problems in having x-ray equip-
ment in the emergency room. The usual solution is to try to set up the radiography department adjacent to the emergency room so that a patient can be moved for x-ray examination without really leaving the emergency department. The safe availability of x-ray facilities should be considered when chest x-rays are ordered.

When chest injury is recognized, management consists of these relatively simple maneuvers: First, ventilate the patient; second, expand lung that is not expanded; third, relieve pericardial tamponade; and finally, treat shock.

After suctioning, the second step in ventilating the patient is the use of a mask and bag for several minutes as a prelude to intratracheal intubation. The technique of intratracheal intubation—a relatively simple procedure—should be mastered by everyone working in the emergency room. The availability of a variety of intratracheal tubes and of a laryngoscope with an appropriate and functioning light is extremely important.

Tracheostomy, in my opinion, is not an emergency room procedure. Tracheostomy is simple only under ideal operating conditions, and that means light, suction, and help. If one has to do a tracheostomy in the emergency room—and such situations do arise—I think that the cricothyroid membrane tracheostomy is indicated, with the understanding that it will be changed in a very short time, actually in a matter of hours. It is simple, it can be done rapidly, it can be done without all of the things that we talked about, and I think it should replace tracheostomy as an emergency-room procedure.

And finally, the use of ventilators ought to be mentioned. I think that ventilators should be available in the emergency room along with people who know something about the ventilators. If one must do a tracheostomy, we like to see double-balloon rubber tubes inserted so that the patient can be placed on a ventilator. This may be changed within a few hours if one determines that the ventilator is not necessary, but generally if a tracheostomy is necessary the patient is going to be on a ventilator for some period of time, so we prefer to see this sort of tube placed. The only other thing I'd say about tracheostomy is that the Silastic tubes for infants really appear to be an immense improvement over the old tracheostomy tubes.

The decision to put a patient on a ventilator is based simply upon his blood gases and clinical appearance. We consider a patient in respiratory insufficiency to be in urgent need of therapy any time his pO2 drops below 70. At this level, of course, he won't be cyanotic, but if the pO2 is below 70 we think about getting something done, because in the acutely injured patient it's going to get worse, almost invariably.

Turning to the question of expanding the lung, many of you learned that needle aspiration was a good idea. I think needle aspiration is fine in the patient who arrives in serious respiratory trouble with an obviously big pneumothorax, and you don't have more than a few minutes to get something done. But needle aspiration is not without its drawbacks, and to add a pneumothorax—which is easy to do—to a patient who already has multiple injuries is a pretty high price to pay for needle aspiration. In general, I think that it should not be done.

A much safer procedure is tube thoracostomy. For some reason this is a procedure that many people have been reluctant to do. It is very simple to perform. It has almost no serious complications, provided one realizes that there are subclavian vessels at the top of the chest and assorted vessels inside at varying depths. How to connect the chest tube depends upon your particular emergency-room setup.

Usually the valve will be replaced with some form of pleural suction. For this, you can use a packaged, disposable, sterile chest tube available in at least two sizes. It is a clear, relatively soft plastic tube with a radiopaque stripe, a metal stilet, and a blunt point. We've been very pleased with this tube; it's very easy to insert after you make a small incision in the anterior chest. We invariably use the big one. When you need a chest tube you need a big one, and the physiological price is no greater for a big tube than for a little one.

Pericardial tamponade is the only situation you may encounter in which the patient has a low peripheral arterial pressure and a high systemic venous pressure. This high systemic venous pressure can be determined clinically by the observation of distended neck veins, or it can be determined by a simple venous-pressure measurement with a saline manometer. But when those two conditions coexist in an injured patient, pericardial tamponade is almost a certainty. If there is any suggestion of pericardial tamponade, aspiration of the pericardium is not a very hazardous procedure. I think it is less hazardous than aspirating the chest cavity if you don't know that a pneumothorax exists. We do it through the left parasternal fifth or sixth interspace, and we encourage its performance in the emergency room when there is any suspicion of pericardial tamponade.

Now, if all has gone well, our patient is stable: He has an intratracheal tube in. He is on a respirator. He has one or two or three chest tubes connected to an Emerson respirator. He's had a specimen drawn for testing blood gases. He's been treated for shock, and at this point you are in the happy position of sending him off to one of the other units for somebody else to worry about. His course from this point on will probably not be a smooth one, with problems of oxygen intoxication, decreasing pulmonary surfactant, shock or post-traumatic lung and other complications still looming for the physicians who will subsequently manage him. Nevertheless, without the steps we've talked about, the chances are the patient would never have gotten that far. Systematic emergency management of seriously injured patients is the only approach that is likely to improve our over-all salvage of this very difficult group of patients.