Physiologic Principles of Surgery

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Preface

THE PRACTICE of Surgery has long passed beyond its earlier preoccupation with anatomic derangements. It concerns itself importantly with disturbances of function. The physiologic and chemical alterations in the organism occasioned by injury and disease, the effects produced by anesthesia and operation, and the maintenance of an optimal internal environment are all of daily and intimate concern to the surgeon. The current enthusiasm for experimental surgical research is directed, almost entirely, to problems in the field of surgical physiology. The Forum on Fundamental Surgical Subjects, which has become so important a feature of the annual Clinical Conferences of the American College of Surgeons, brings forth the efforts of eager young surgeons from every laboratory in the country, in an experimental attack on the physiologic and chemical problems in surgical practice.

Despite these evidences of the importance of applied physiology in the rapidly advancing forefront of modern surgery, there has been a curious dearth of books published in this field. With the most limited exceptions, there is no place where one can find, between the covers of a single book, an authoritative statement of the current status of the various physiologic problems in surgery. The candidate for American Board Certification, the resident on the wards, and the surgeon in practice have felt this want. An attempt to fill this need was the intent of the authors, in projecting this book. We have tried to meet it by imposing on our collaborators and on ourselves the necessity not only to appraise critically our present knowledge of physiologic process, but to found this appraisal on clinical observation and to direct its statement toward the practical reality of use in surgery. We believe that a point has been reached in the advance of knowledge where it is possible to extend basic contributions of the laboratory to the everyday procedure of sound surgical practice.

In order to meet the needs of clinical surgeons, it seemed, first, that a collaborative effort of a surgeon and physiologist was required. In the second place, a work designed to meet the requirements described would have to be a multiple-author book. No one person could be expected to have sufficiently broad knowledge to cover authoritatively all phases of

surgery. Furthermore, in the time required for a single author to prepare a book of this type, the earlier material would become obsolete before the later were finished, so rapid is the progress being made.

There are two hazards in multiple authorship: lack of equality in merit and style, and hiatuses or overlapping of the material. These disadvantages the authors have attempted to avoid by careful editing, without at the same time altering the thoughts or the style of the several contributors. Brief editorial notes are appended to certain chapters to indicate to the reader in what other sections of the book he will find closely related material. In the interest of readability, we have requested the authors to eliminate lengthy historical introductions and extensive citations of the literature. We have selected, as contributors, authorities in the various subjects who have evaluated the material, and whose judgment can be accepted without documentation. A short working bibliography of the most important references follows each chapter.

The contributors to this book are, in the main, active and busy persons, who are engaged in practice, research, teaching and writing. For their cooperation, we are profoundly thankful. Whatever merits the book possesses are attributed to their efforts. We are also grateful to the Publishers, the W. B. Saunders Company, for unfailing patience, encouragement and many helpful suggestions.

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Contents

CHAPTER 1

Metabolic Changes Associated with Injury

By STANLEY M. LEVENSON, M. D.
LT. COL. EDWIN J. PULASKI, M. D.
and CAPT. HAROLD L. UPJOHN, M. D.

FIGURE 1 shows a young man about 8 weeks after he had been severely injured. His hospital course had been stormy. At the time the pictures were taken he weighed 100 pounds; his pre-injury weight had been 175. When such rapid nutritional deterioration develops in patients with severe injury (operative or traumatic), important complications ensue—weakness; easy fatigability; increased susceptibility to anesthesia, shock and infection; altered gastrointestinal and liver function, and impaired wound healing. Among such patients, operative deaths are more frequent than in those not suffering rapid nutritional deterioration, convalescence is prolonged and mortality increased.

The post-injury nutritional problem, important in day-to-day civilian life, becomes magnified in time of war. Among a group of patients with severe battle wounds and renal failure treated during the Korean War in 1952–1953, weight losses of 20 to 30 pounds in two to four weeks were common, and losses up to 45 pounds in the same period of time occurred. Mortality was high—50 per cent. The following case report is indicative of the complexity of the problem:

A 26-year-old American soldier was severely wounded by mortar shell fragments. His injuries included lacerations of the scalp, cerebral concussion, penetrating wounds of the abdomen, traumatic amputation of the right thigh, and multiple soft-tissue injuries. He was in severe shock during the first 3 hours after injury, despite the administration of

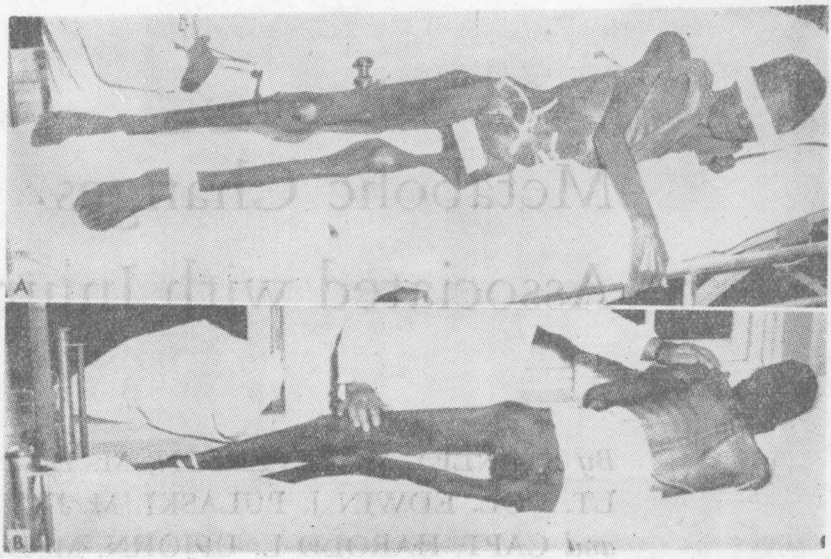

Figure 1. Nutritional deterioration in severely injured patient, 8 weeks following injury. (Armed Forces Institute of Pathology, Walter Reed Army Medical Center.)

2500 cc. of blood, 350 cc. of 25 per cent albumin, and 1500 cc. of isotonic saline solution. His right leg was amputated without anesthesia in the emergency room. In the next 4 hours, he was given an additional 2500 cc. of blood. His blood pressure gradually rose to normal, but his pulse remained rapid. Operation was delayed for 3 more hours because he had not regained consciousness. During this time, he received another liter of blood. His blood pressure remained stable at about 130/80.

Operation, under atropine, Pentothal, and nitrous oxide anesthesia, was begun 10 hours after injury. The patient's blood pressure immediately fell, and remained low throughout most of the operation, despite the infusion of an additional 3500 cc. of blood. Estimated operative blood loss was 3000 cc. The operation lasted 3 hours and consisted of exploratory laparotomy, drainage of the liver and kidney perforations, re-amputation of the thigh, and débridement of many soft-tissue injuries.

The postoperative course was complicated by profound and persistent renal failure, jaundice, pneumonia, wound infections, and considerable weight loss. Extracorporeal hemodialysis by a Kolff-type artificial kidney was necessitated on the fifth, ninth and fifteenth days because of progressive hyperkalemia and uremia. Temporary improvement followed each dialysis, but the course was progressively downhill. The patient died on the nineteenth post-injury day.

At autopsy, the entire body showed evidence of marked wasting. The amputation site of the right thigh showed extensive necrosis and infection of the skin flaps, muscle and fascia. There was a severe bacterial pericarditis, focal edema and necrosis of the myocardium, bronchiolar pneumonia, severe central necrosis of the liver, lower nephron nephrosis, hypertrophy of the parathyroids, and necrosis of the occipital poles of the cerebral cortex.

Nutritional disturbances may occur in any seriously injured patient. These result from profound metabolic changes consequent to severe trauma. Lesser trauma is followed by less dramatic changes and by fewer complications, but the basic metabolic changes are qualitatively similar.

Our intent is, first, to present some of the known facts of the metabolic

responses to injury (with particular emphasis on the so-called "catabolic" period) and, second, to point out the gaps in our present knowledge of the mechanisms and significance of these responses with the hope of stimulating interest and investigation in this area.

Metabolic Reaction to Injury

In the young healthy adult, a complicated series of interrelated metabolic reactions is going on in a manner which results in a relatively steady, albeit dynamic, state. Although it has been customary to talk of protein, carbohydrate and fat metabolism separately, it is evident that this practice is one of historical convenience. Proteins, fats and carbohydrates are so interconnected that any separation, in a sense, is artificial. Further, their reactions take place in water and are affected by vitamins, hormones and minerals. Something happens after injury which disturbs these interrelationships and thereby modifies the steady metabolic state characteristic of the healthy adult; there are widespread disturbances in the behavior of all metabolites so far studied. In general, these changes are qualitatively similar in patients with a wide variety of injuries or illnesses.[6, 8, 14, 28, 31, 35, 44, 59, 61, 70, 77, 80, 89, 97, 123]

The intensity and duration of this period of metabolic disturbances depend on a number of factors, among which are the extent of the injury and the state of the individual at the time of injury. It is the young adult male, previously healthy, who shows the greatest upset; the reaction is less in females, children, the elderly and the malnourished. Although considerable descriptive data of plasma concentrations and urinary excretions of various metabolites have been accumulated, there are significant gaps in the available data and many fundamental questions remain unanswered.

Protein Metabolism

Protein metabolism, in particular, has been extensively studied. The healthy adult male usually eats about 2500 to 3000 calories and 60 to 100 gm. of protein per day. In terms of nitrogen, this represents 10 to 15 gm. He loses 1 to 2 gm. of nitrogen each day in his stools and excretes 9 to 13 gm. in his urine; thereby, he is in nitrogen equilibrium. Following injury, fecal nitrogen excretion is unchanged (unless there is specific gastrointestinal tract damage), but the urinary nitrogen excretion increases, at times to as much as 45 gm. of nitrogen daily in extreme cases. Urea is usually the chief component; in the absence of renal disease, proteinuria is minimal. The increased urinary nitrogen excretion begins soon after injury, reaches a peak at about 5 to 7 days, and may continue for 3 to 7 weeks. During this time the injured patient is in negative nitrogen balance and there is a gradual depletion of his body protein.[10, 25, 48, 105] Thereafter, as the patient recovers, the urinary nitrogen excretion falls and, as the patient's nutrient intake is often high at this time, he is in positive nitrogen balance. This continues until his recovery is complete and the body tissues are restored.

The extent of the metabolic imbalance parallels, roughly, the severity of the injury, and, as mentioned, is most marked in the previously healthy young adult male.

Patients with thermal burns have been among the most frequently studied. They constitute one of the largest groups of very extensively injured individuals encountered in peacetime—and such patients will constitute the largest group of injured patients in any war in which nuclear weapons are used. (Burns were responsible for more than half of the fatal casualties and probably for about three-quarters of all the casualties at Hiroshima and Nagasaki.) The burned patient, in addition to losing excessive amounts of nitrogen in the urine, loses a variable amount of nitrogenous compounds from the burned area depending upon: (1) depth of burn, (2) extent of burn and (3) infection.

Early following weeping superficial burns, there is a large outpouring of plasma-like fluid from the injured skin. This fluid contains a high proportion of protein. Similarly, protein is transiently trapped in the dermal and subcutaneous edema fluid of both superficial and deep burns. If the burn is deep and the surface relatively dry, the amount of nitrogenous compounds lost in the first days through the skin is considerably less than that lost into and under the skin. Later, during the sloughing and granulating stages of deeper burns, there is a steady and considerable loss of protein from the surface. The loss varies directly with the extent of the area involved, and the degree of infection. During the period of maximum wound slough and purulent discharge, the surface nitrogen may constitute 25 to 30 per cent of the total nitrogen loss. These losses continue until healing is complete.

Figure 2 depicts data of a 41-year-old man with a severe burn, 35 per cent total, 25 per cent third degree. During the first 7 weeks, he had a minimum nitrogen loss of about 250 gm., as judged by measurements of urinary and fecal nitrogen excretions and nitrogen intake. This corresponds to a loss of about 1.6 kg. of protein or about 7 kg. of fat-free body tissue. The nitrogen lost from the burned areas was not measured. After the fiftieth day, he went into positive nitrogen balance and, by the one hundredth day, had retained an amount of nitrogen equal to his earlier minimum loss. As indicated on the graph, he continued to retain nitrogen (100 gm.) for another 2 weeks; this reflects the nitrogen previously lost from the burned areas, which, as mentioned, had not been directly measured. At the end of this time, he was back at his pre-injury body weight.

The characteristic increase in urinary nitrogen excretion after injury was described about 25 years ago by Cuthbertson, but we are still not entirely clear as to its basic mechanisms. Does the excess urinary nitrogen reflect increased tissue breakdown or does it reflect decreased tissue build-up? What tissues are involved, and to what extent? Madden and his associates[71] became interested in this problem several years ago and, using S^{35} labeled methionine, investigated the effect of turpentine abscesses on the urinary excretion of sulfur and its incorporation into the plasma protein and various other tissue proteins of dogs. The organic nitrogen and sulfur