

CRASH INJURIES

THE INTEGRATED MEDICAL ASPECTS OF
AUTOMOBILE INJURIES AND DEATHS

By

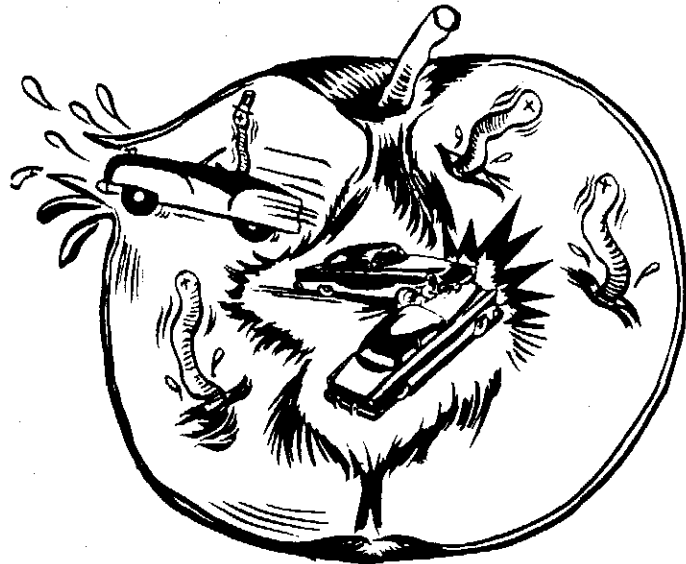
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*I heartily beg that what I have here done may be read
with forbearance; and that my labors in a subject so
difficult may be examined, not so much with the view
to censure, as to remedy their defects.*

—NEWTON's Preface to the *Principia*, 1686

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To My Parents
Lina A. Kulowski
and
Meyer Kulowski
and my son, Gerald B. Kaye

(1) The Unknown Is Knowable (2) Advance by Trial and Error (3) Measurement and Theory Are Inseparable (4) Analogy Gives Insight (5) New Truth Connects With Old Truth (6) Complementarity Guards Against Contradiction (7) Great Consequences Spring From Lowly Sources.

(From Wheeler, J. A.: A Septet of Sibyls: Aids in the Search for Truth, *American Scientist*, 44:360, 1956.)

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PREFACE

ACCORDING to Baldwin* the first motor vehicle accident of which there is any record in the United States occurred in New York City in 1899. A passenger stepping off a trolley was struck by a passing motor vehicle and died in a hospital on the following day. Some 52 years later, in December, 1951, the millionth traffic victim died as a result of a motor vehicle traffic accident in the United States. By the end of 1954 another 100,000 people had been killed. From 1906, when traffic deaths had been estimated to be 400, deaths spiraled to a peak of almost 40,000 in 1941.

Stated another way† this means that 100 people in this country become accident vital statistics and another 6,000 receive injuries every day. The time during which the decelerations and forces generated in a collision are of sufficient magnitude to cause a fatality is very short. In fact, the total time consumed in a whole day involves less than 30 seconds to produce these deaths, and only about 30 minutes to inflict this multitude of injuries.

The individual automobile collision has been characterized, by D. M. Severy, "as an extremely complicated phenomenon of a very brief duration ending in destruction"*** (Fig. A).

The epidemic frequency of these accidental injuries and deaths is thought to derive from biomechanical and pathomechanical stress-strain patterns of behavior peculiar to the age of power and speed in which we live, work and play. This attribute, of course, is also shared by air traffic. Efforts to improve these situations are in progress along mass statistical, laboratory and full-scale crash lines of investigation (Figs. B, C). How does automotive ground

* Baldwin, D. M.: Motor vehicle traffic accident facts, 1955, *Medical Aspects of Traffic Accidents* (Elliott), Sun Life Assurance Company of Canada, Montreal, p. 41.

† Haynes, A. L., et al.: *Automotive Collision Impact Phenomena*, Highway Research Board, National Academy of Sciences, N.R.C., Jan. 19, 1956.

*** Severy, D. M.: Photographic instrumentation for collision injury research, *Journal of the Society of Motion Picture and Television Engineers*, 67:69, 1958.

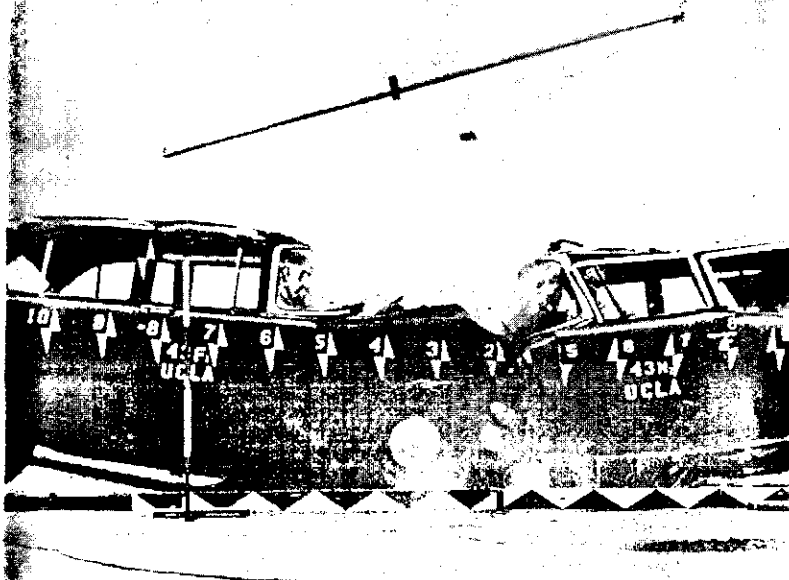


FIG. A. Head-on experimental collision at 50 miles per hour (mph). Photograph, courtesy of Derwyn M. Severy, Institute of Transportation and Traffic Engineering (ITTE), University of California at Los Angeles.

transport stack up with that of aviation in this respect? What are the reasons for differences, if any? There appear to be two reasons for the phenomenal advances in aviation and the apparent lag in comparable areas by automotive ground transport.

First of all, there has been simultaneity of progress in aviation with regard to medicine, biology, engineering, and adjacent fields of human endeavor. This kind of growth, until very recent times, has been lacking in regard to automotive ground transport. Another influence, impugns grave errors of perspective and judgment on the part of the public which has been "seeing one thing too large" and "something else too small." For example, whereas advances in aviation—now probing the fringes of outer space—have always been widely acclaimed and fostered by public opinion, those of automotive engineering have been accepted as a simple fact of life. However, in this one respect, the score is evened.

STATISTICS SHOW - SINCE 1930

PASSENGER CAR AVERAGE HORSEPOWER INCREASED 65%
TOTAL TRAFFIC FATALITY RATE DECREASED OVER 55%

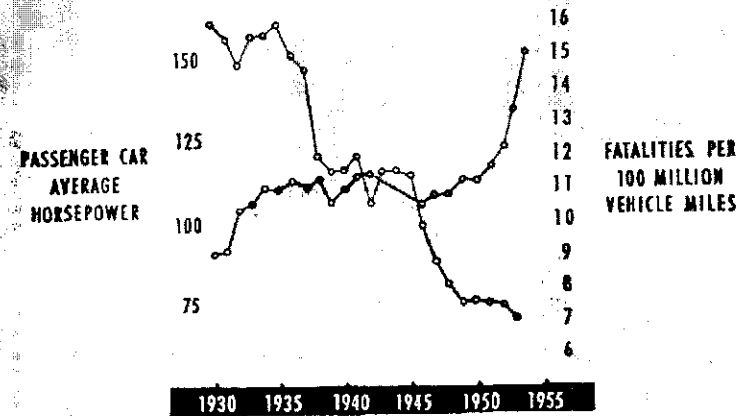


FIG. B. This is the statistical point of view.



FIG. C. This is the field and clinical story.

communication across the departmental walls which tend to isolate the professions and specialties from one another"; and, thus achieve a degree of sequential cross fertilization of ideas from these intersecting sources. For this reason the book aims at an audience "beyond the confines of specialization" in medicine and related fields.

This book is also an attempt to stimulate further researches as well as improved understanding among scientists in medicine and allied disciplines. For this reason attention is drawn to broadening perspectives and changing attitudes in variously related phases of the life and death cycle of motoring. In order to project objectively some of these ideas it was necessary to overcome two major obstructions of my own, both in accordance with the wisdom of know it first, not to mention the emotional factor. The first was the difficulty of technical comprehension; the second was "in the resistance of human attitudes to change (for example, medical screening of drivers)." When the first obstacle had been hurdled—to a degree of course—the second loomed even larger, because it stems from an understandable resistance to compulsion in any form—even though every physician knows that "the doctrine of health by compulsion has been extraordinarily successful" in all other fields of public health.*

The very success of health by compulsion and the convincing arguments for ranking highway safety high as a value should logically justify still further restrictions upon the individual as an operator of a motor vehicle. The line of health by compulsion may be extended to this point, where the driver's unfitness obviously threatens the safety and health of someone else. By the same token, "The automobile industry is like the maker of a very useful but potentially dangerous drug. The privilege of making and selling automobiles carries with it an obligation to be tireless to improve safety and to refrain from qualities which make them potentially dangerous to health"† (Fig. E).

It should be remembered in regard to this particular value—

* Garland, T. O.: Health in perspective. *British Journal of Clinical Practice*, 12:396, 1958.

† Noves, Dorothy: America's No. 1 health problem: automobile accidents. *Connecticut State M. J.*, 22:183, 1958.



- | | |
|-----|-----|
| (1) | (4) |
| (2) | (5) |
| (3) | (6) |

FIG. F. Non-union of the tibia: showing the various steps in a sliding bone graft: (1) site of non-union has been cleared; (2) preparation of the proximal graft; (3) lifting it out; (4) the graft from the distal portion has been placed proximally and the proximal portion has been rotated 180 degrees and bridges the site of non-union; (5) securing the graft with metal screws; and (6) grafts secured.

the liberty of the individual versus the group—that this rather primitive, perpetual and universal conflict has been transposed into a “do-as-you-would-be-done-by ethic”—one of the major attainments of mankind.

Resistance to change, as in any stage of transition, is evidenced herein in the fact that current changes in ideas and in practices have not yet been crystallized; terminology is not well established; and, the extent of new methods is not well known.

In any case, once accepted, the wealth of data already accumulated in this book represent definitive assurances that automotive safety—i.e., including accident prevention, reduction of injury, and recovery—is ready to take its rightful place alongside of advances being made in the age of speed and power in which we live.

For the physician this book should fill an important need. It contains an account of the “available” scientific and empiric knowledge of our time which he needs to meet the challenges of patient “total” care engendered by injury-producing motor vehicle traffic accidents. It may also help him to decide what proportion of medical effort should be put into shaping attitudes to automotive safety alongside of human salvage (Fig. F).

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GENERAL INTRODUCTION

In our present age of rapid technological progress, the frightening discrepancy between our technical “know-how” and our philosophical incomprehension, in general, of basic scientific conceptions seriously endangers the integrity of our intellectual outlook.

—MAX JAMMER

THE magnitude of automotive injuries and deaths is generating new fraternal problems for medicine, engineering, and related sciences, disciplines, groups and individuals. Mass statistical, laboratory and full-scale crash investigators are asking for more medical data to direct these researches. One purpose of this book is to help close this gap between related clinical and extraclinical activities. This means compressing, channelling and integrating properly evaluated medical data with pre-impact, impact and post-impact factors which govern the life history of motoring as a whole.

The fact is that motor vehicle accidents present an opportunity for the study of trauma which is ordinarily afforded by combat as it occurs in war. Yet, this traffic scourge which has killed more people than have all the wars in which this republic has been involved and kills and injures more people off the job than occurs on the job has not given results of medical study comparable to war medicine and industrial medicine. Since these accidents strike down victims of all ages and both sexes, here indeed is a daily battleground for the study of trauma the results of which may better condition us to meet other imminent catastrophic threats (Figs. G, H, I).

Moreover, while much is being achieved by the experimental method of study in medicine by controlled experiments in animals with extrapolation to traumatic conditions observed in man, these methods can supplement but not supplant direct clinical, laboratory and autopsy examinations of crash victims, in a category separate from accidental injuries of mechanical origin in general.



FIG. G. This access road looks ominous from every angle.

The benefits of accumulated vital statistics from autopsy investigations would be of inestimable value for diagnosis and treatment. Moreover, valuable contributions to safety could come from relating accessory findings disclosed by autopsy to their probable roles in accident causation and predisposition to injury from crash forces. Paradoxical as it may seem, this introduction of more variables to the problem of crash and upset conditions would clarify rather than complicate the situation further.

The book is separated into seven sections which deal consecutively with Biomechanics, Pathomechanics, Autopsy Pathology, Clinical (Hospital) Pathology or Pathological Anatomy, Delayed Complications and Residual Disabilities, Human Salvage, and concludes with chapters which are intended to unify and integrate the medical aspects of the problem. Some points of departure from

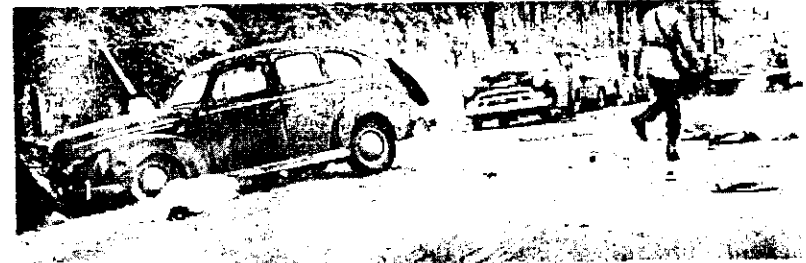


FIG. H. Just before the pictures were made for Figure G, the car above came onto the belt highway to be struck by a trailer-truck; ejecting the mother and two children—whose mangled bodies have been covered by the officer.

ANNUAL VEHICLE REGISTRATION, TRAVEL MILEAGE AND HIGHWAY MILEAGE AVAILABLE

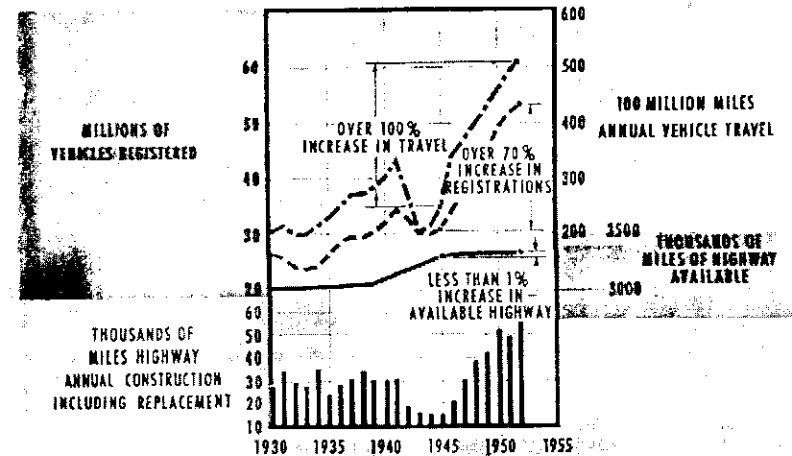


FIG. 1. The road bed—the most easily controlled component of highway transport is woefully inadequate to meet modern demands.

traditional medical considerations and categorizations call for an introductory outline of the general plan of this book.

BIOMECHANICS AND PATHOMECHANICS

It is logical to assume or imply that to a useful degree man's anatomical, and psycho-physiological characteristics can be expressed in the systematic terms of engineering, and that the nature, source, and magnitude of the stresses set up by man-machine combinations, under both normal and abnormal conditions, can be identified and measured—and even anticipated in the course of design—so that the operator (and passenger) will not be subjected to greater stresses than his body can tolerate without failure of one or more parts. *In this way the same laws which govern engineering practice may be applied by engineers to the physical laws which govern man's physical capacity and tolerances to external (and inertial) stresses.* By the same token, anatomists, physiologists and physicians may reduce and explain their special spheres of knowledge by analogy in the idiom of basic engineering.

There are apparent and hidden stress-strain interrelationships and interactions involved in normal and abnormal motoring conditions. The first is illustrated by the difficulty encountered in getting in and out of overly low designs; the other by the absorption of vehicular vibrations which can lead to backache and fatigue. These more or less normal or basic situations are multiplied and distorted under accident or pathological conditions. Thus, the switch or transition from biomechanics* to pathomechanics is quantitative not qualitative. The same equation exists between human engineering and crash-impact or crash safety engineering. Neither one of these applied sciences is actually new because engineers had already pioneered in areas of physiology when it became apparent that psychological and physiological

* Charles M. Gratz (1942) defined human biomechanics as "that branch of biological engineering herewith principally concerned with the study and co-relation of the physical properties of human muscles, fibrous and ligamentous structures and bone with their function." (From a memorandum to George B. Karelitz, August 7, 1942.) By inference, pathomechanics implies abnormal biological engineering; i.e., from either biological or mechanical standpoints or both.

stresses of higher orders were being created by progressive elimination or lessening of physical stresses in industry (automation).

Human engineering—having sprung from the parent field of "ergonomics"—now draws upon a variety of basic biological and biophysical sciences to define the pattern of human behavior in responses to man-machine or man-at-work stress for determining man's capabilities and limitations in dealing with such stress (Table A).*

From this standpoint crash safety engineering begins where human engineering leaves off. One fool-proofs against accidents; the other crash-proofs against injuries in "unavoidable accidents." In other words, crash safety engineering is the distinctive art of delethalizing automobiles and aircraft in order to raise the level of survival in "survivable accidents" (Hasbrook). This new approach in combatting deaths and injury on the highway stems from the concept that a certain number of automobile collisions are inevitable but that the resulting injuries are, to a large extent, preventable. This (secondary) concept of automotive safety is not, therefore, in conflict with the primary one that injuries are prevented by preventing accidents in the first place. Rather, crash-safety engineering simply recognizes the limitations (under current conditions) of accident prevention measures and deals instead with the consequent important issue, the reduction of motorist injuries through engineering revisions of injury potentialities of current automotive design.

It is well to remember, in this connection, that in engineering many factors besides the basic scientific principles are involved in applying any new technique or material. There are organizational, managerial, marketing, legal and even personal equations to be solved. On the research side, with respect to crash studies in particular, the financial burdens need to be equally appreciated.

* Hatch defines human engineering as the "application of the principles, laws and quantitative relationships which govern man's response to external stress, to the analysis and design of machines and other engineering structures, so that the operator of such equipment will not be stressed beyond his proper limit or the machine forced to operate at less than its full capacity, in order for the operator to stay within acceptable limits of human capabilities."

Hatch, T. F.: Proposed Program in Ergonomics . . . Human Engineering, *Mech. Engr.*, May, 1955, p. 394.

TABLE A

NOMENCLATURE OF HUMAN FACTORS ENGINEERING

<i>Title</i>	<i>Typical Activities</i>	<i>Related Areas or Job Titles</i>
Human Factors Engineering	The field of activities wherein special emphasis is placed on determining optimum mode of interaction between man and machine systems of which he is a part	Human engineering Ergonomics Engineering psychology Biomechanics Psychotechnology Applied experimental psychology Biotechnology Aviation psychology
Human Factors Engineer	A professionally trained engineer with special human factors training and/or experience	Mechanical engineer Automotive engineer Industrial engineer Electronics engineer Electrical engineer Chemical engineer Aeronautical engineer
Human Factors Consultant	A professionally trained scientist, not an engineer, who is primarily engaged in consulting activities relating to the applied aspects of human factors engineering	Physician Flight surgeon Biophysicist Physicist Sociologist Anthropologist Physiologist Mathematical statistician Psychologist (experimental, physiological, industrial, systems analysis, or human factors)
Human Factors Research Specialist	A research scientist concerned primarily with experimental design and accumulation of basic research data relating to the field of human factors engineering	Any of the above occupational specialties

Adapted from Peters, G. A., and Seminara, J. L.: Alias the human engineer (as reviewed in *Nav. Human Engineering Bull.*, 25:1, Feb., 1957). (From Peters: *Internat. Rec. Med.*, 171:558, 1958.)

D. M. Severy has recently alluded to the difficulties of instrumentation of these destructive experiments. Therefore, "Experiments which eat up research funds at a rate of \$40,000 a second require extremely careful planning and particular attention to operational details to minimize the chance of loss of data through any one of a multitude of system failure potentialities."*

I believe it to be true that crash-impact engineering is a mirror image of human-engineering (Fig. J). To separate these concepts—as alternating schizophrenic counterparts—cancels out the basic equivalence which exists between them. Stated differently, it means that neither idea should be given pre-eminence or be dissociated from the other; lest overzealous or dissociated activity in one should cancel out the intent and efficiency of the other. These biomechanical and pathomechanical interrelationships and interactions are fundamental, derived and empirical. It is a fundamental fact, for example, that motor vehicle traffic accidents occur in time, space and motion. On the other hand, most pathomechanical behavior patterns are derived from physical laws which govern inertia, acceleration, deceleration, and dissipation or absorption of kinetic energy, as they occur in the automobile compartment.

New points of departure concerning the "stress-raiser" effects of human failures with respect to greater-than-chance accident causation and injury production emerge more convincingly from these standpoints, and are further developed in later clinical chapters.

AUTOPSY PATHOLOGY

A study of autopsy materials indicates that just below the range of impact which causes sudden death, there is a narrow range of impact which may produce serious injuries and permits survival. This is the range of over-all maximum tolerance of the body to force. Just above this category or level are those who die on im-

* Particular attention is invited, in this regard, to the Institute of Transportation and Traffic Engineering, University of California, where full-scale automobile crash experiments originated in 1948, and have been in progress since that time. Similar recognition is given the more recent achievements of the Ford Motor Company along these lines.



Fig. J. A characteristic experimental collision performance of steering wheel and column. (From Severy, Mathewson and Siegel: Presented at the Society of Automotive Engineers (SAE) National Passenger Car, Body and Materials Meeting, March, 1958).

part or at the scene of accident whose bodies had been stressed beyond the elastic limits of the body structures and vital functional capacity to compensate for these limits of factors of safety.

A third class dies at varying intervals of time after impact. Here, actually, are introduced still more variables consisting of secondary complications, which are entities apart from the effects of application of force. Their significance in relation to human salvage is stressed. Secondary complications often multiply quite rapidly under a combination of unfavorable conditions and death, though delayed, is frequently inevitable. These events epitomize what I imply by the term *fractionality of death*. In these cases *autopsy examinations show that the effects of injury and its complications are multiple and continuous so long as bleeding, infection, fear, pain, exposure, and poor response to treatment go undetected or are allowed to pursue a downhill course.*

The time factor influence in laboratory investigations of hemorrhagic or traumatic shock led to the discovery of the "properdin system" of the body. Figure K illustrates the standard experiment employed in the study of hemorrhagic shock. H=hemorrhage; T=transfusion of the blood remaining in the reservoir after the period of "taking up." (From Frank *et al.*: *Surgical Forum*, American College of Surgeons, Philadelphia, W. B. Saunders Co., 1951, p. 522.) The femoral artery bleeds into an elevated reservoir until the blood pressure reaches 80 mm. Mercury and remains there. Eventually blood runs back from the reservoir to the artery. If, after two hours, the femoral artery is shut off and returns all the blood still in the reservoir to the femoral vein, the pressor response is prompt and adequate, and the recovery rate is about 90%. If, instead, transfusion is withheld until about half of the total shed volume has returned to the animal, the pressor response is transient and death occurs soon thereafter in an average of six hours after bleeding has started.

The difference in results is explained on the basis of collapse

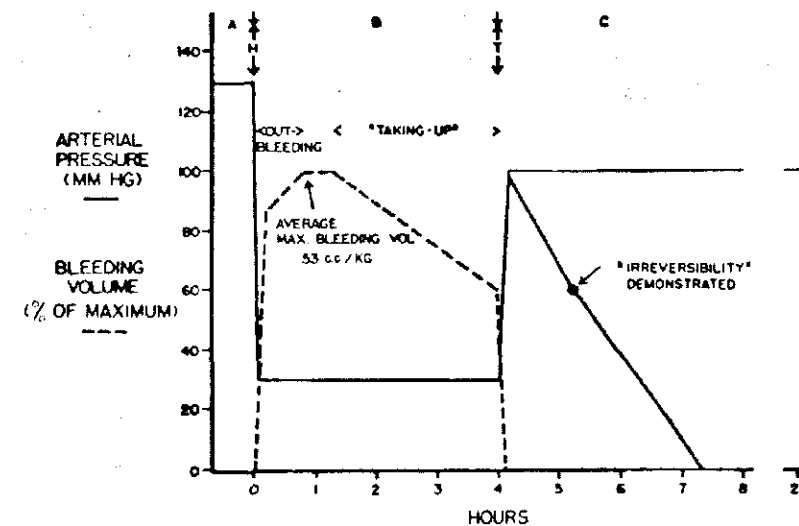


Fig. K. Standard experiment employed in study of hemorrhagic shock. Full explanation in text. (Frank *et al.*: *Surgical Forum*, American College of Surgeons, Philadelphia, W. B. Saunders Co., 1951, p. 522.)

of the bacterial mechanisms and the subsequent liberation of toxins which paralyze the peripheral circulation (Fine, 1957).^{*} In other words, early shock death is not "bacterial" while the late death is "bacterial." According to Fine the state of shock results in tissue damage, and injury to tissue enzymes—especially a breakdown of the "properdin" system (consisting of properdin, complement and magnesium). More specifically, polysaccharides are liberated (zymosan) from tissue damage, which combines with properdin and alters the total antibacterial potential of the animal. Thus properdin could be an index of the total amount of tissue damage. It is believed that properdin is made in the bone marrow (Pillemer),^{*} and is only found in mammalian serum. During the phase of low properdin levels, animals are very susceptible to infection; however, during the period of high properdin titers, animals are very resistant to infection. *Therefore, the timing of shock therapy is of tremendous importance in the therapeutic result of transfusion.*

CLINICAL PATHOLOGY OR PATHOLOGICAL ANATOMY

The acute clinical results are evaluated with regard to various criteria of bodily behavior in response to crash forces. The residual crash disabilities are related to pre-impact, impact, and post-impact factors which governed their production, clinical behavior, and complications. In both of these categories pre-existing disease or other physical deficiency seemed to play more important roles than has hitherto been suspected, in regard to respective clinical life histories reviewed. *It seems odd that despite the fact that every physician has treated accident patients in whom there existed some concomitant disease state not produced by the trauma, that the most recent literature (available to me) contains so few references to the role of such pre-existing conditions in the production and management of accidental injury.*

^{*} Fine, J.: The bacterial factor in experimental shock. *Shock and Circulatory Homeostasis*, Transactions of the Fifth Conference, 1955, The Josiah Macy, Jr. Foundation, 1957, New York, N. Y.

Pillemer, in discussing and participating in Fine's paper felt that properdin is either bound to some substance that is exposed in the tissues following shock, or that tissue products appear in the serum which combine with properdin.

For medical groups this spells out the need for some medical control of the human variables involved in crash injuries; which have been assumed in the past to be a fixed and uncontrollable quality and quantity (Fig. 1).

MEDICAL ASPECTS OF PROPHYLAXIS OR PREVENTION

The basic responsibility of medicine is to maintain methods of human salvage at the highest possible level. In addition there is



FIG. 1. Are these the automotive hands of "Mr. Ottermole"?

the challenge of medical screening for driver licensure. Other aspects of prevention consider the prevention of avoidable post-impact complications through improved First Aid, Emergency Care, and the ultimate in Definitive Diagnosis and Treatment.

It is becoming increasingly evident that accidents occur in close proximity to human psychosomatic failures. The connections, however, are not always clear and convincing; and, in some cases may be wholly fortuitous. If any causal relationship does exist, the

mechanism may not be known and must therefore be postulated. The proneness of drivers with psychosomatic deficiencies to additional accidents is becoming well known. Less well known, perhaps, is the fragility of such riders under accident force conditions, and to initial hazardous diagnostic procedures in the hospital. Also, less well known are the additional diagnostic and therapeutic problems they present (not to mention the medicolegal complications).

TOWARD A UNITED MEDICAL CONCEPT AND INTEGRATED REPORT

The problem of motor vehicle traffic safety is pulling together three closely related and older disciplines, i.e., medicine, engineering and law. It is imperative that they converge simultaneously upon their respective guardianships respecting health, safety and rehabilitation in regard to their individual patients, clients, community at large, and the state.

The recurrent theme of this book is dichotomous. The first concerns integrating physical and clinical aspects of injury-producing motor vehicle traffic accidents with the life history of motoring as a whole. Here clinical and more or less extraclinical points of view are blended. The second involves clinical considerations of motorists injuries and deaths as a part of the broad spectrum of trauma of mechanical origin in general, keeping in mind the large and specific forces involved in motor vehicle traffic accidents. In either case, this book is an informal approach—not a systematic account—to a great reservoir of scientific, empirical, pathological and clinical materials.

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ACKNOWLEDGMENTS

I WELCOME this chance to thank Mr. Payne Thomas for the invitation to write this book, and the care and skill given to its issue by the publisher.

Behind every medical student and professional physician stands the *teacher*, biologist, physiologist, chemist, pathologist, radiologist, anthropologist, engineer, physicist, mathematician, psychologist, sociologist, and man of God. My particular teacher, Doctor Arthur Steindler, passed quietly away on July 21, 1959. For now, and in the future, I shall continue ". . . to consider dear to me . . . him who taught me this art: . . ."

At my side have stood and still stand a host of technicians, nurses, nurses aids, orderlies, first aid workers, ambulance drivers and attendants. The Daughters of Charity of St. Vincent dePaul, and professional colleagues. Among the latter, I remember most fondly Doctors Harry S. Conrad and Frank X. Hartigan. There are others, too numerous to mention in this brief note, for which I apologize.

Most of the illustrative materials in this book were selected from my private office and hospital practice. The professional photographs were made by Mr. Frank O'Konski. The professional art work was done by Mr. Carlyle Hadley and Mr. Carl Brill. The amateurish photographs and art work are mine. Other source materials are gratefully noted in the text (not all of which so generously supplied could be used at this time).

My wife Margaret prepared the manuscript for final typing and did much of that also. Medical Librarians, Miss Ruth McNulty and Miss Genevieve Cunningham (and their assistants), came up with hospital records. My office assistant, Miss Alberta Breit, R.N., spotted office records and aided in locating hospital ones.

Lastly, I would acknowledge with gratitude, my wife's equa-

nimity and forbearance during the active period of writing, which was a constant source of strength and inspiration for me.

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