Human Factors in Aerospace Pathology

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IN RELATING pathology to aircraft accident prevention it seems obvious that the most logical and mutually profitable field to explore is that which involves common areas of interest. The primary interest of the Directorate of Flight and Missile Safety Research is the prevention of aircraft accidents from human cause factors and that of the Armed Forces Institute of Pathology (AFIP) is the demonstration of pathologic changes which may affect human performance. These areas of interest obviously bear a close relationship.

Accomplishing the prevention of an aircraft accident is a nebulous thing. How does one know when he has prevented an accident? It is quite as intangible as the purchase of national security. The investigation of an aircraft accident is really an admission of the defeat of a primary objective. However, in establishing accident cause factors it may be possible to lower the accident potential from the same or similar causes. Pathologic studies have been a great help to the accident prevention effort and will doubtless continue to grow in usefulness as the body of knowledge and experience enlarges. Pathologists and accident investigators must work together closely and enjoy mutual understanding.

Rather than employing a purely statistical approach, this exposition will identify definite or probable human cause factors and relate them to the varying degrees of competence to deal with them. Perhaps in this way requirements for emphasis, timeliness, or applied research can be identified. Most of the areas have been noted before. This fact serves to emphasize the persistence of technical inadequacies and gray areas in the body of knowledge available to the art.

In the epidemiologic treatment of accident cause factors the standard technique of identifying major groupings and then classifying together the smaller or statistically invalid factors either as "miscellaneous" or "other" is perhaps not completely correct when dealing in human cause factors of accidents. This is for the reason that the prevention somewhere, sometime, somehow of a single major aircraft accident may well repay in public funds for the entire career of the individual who has been responsible for its prevention—to say nothing of the prevention of injury or fatality. Therefore, the consideration of some human cause factors which are actually statistically insignificant or invalid may serve to prevent an accident. It will be profitable later to explore the major cause factor groupings which have a connotation to pathology and which may or may not be amendable to demonstration ante or postmortem. It probably would not be particularly profitable to deal in rates or absolute

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numbers although these will be indicated in general terms regarding factor occurrence probability.

The continuing review of current aircraft accident records is a considerable task and the research of stored records involves sometimes tremendous exertions. These efforts have, however, in the human factors area, been a traditional function of the Aero Medical Safety Division almost since its inception. The wealth of data is immense. The objective is to use these data in the prevention of accidents or towards the minimization of injury, or both. The problem is one of man hours to compile, analyze, conclude, and act in consonance with the findings.

Some relatively rare conditions will be mentioned which are amenable to both clinical and pathologic detection and which have been definite, probable, or possible causes of either aircraft accidents or incidents but in small numbers or on very isolated occasions.

Thyroiditis—a relatively rare and isolated condition compromising flying safety—was a finding in the recently reported aircraft accident from the R.C.A.F. Institute of Aviation Medicine. It is a condition about which one would not ordinarily think in the investigation of an aircraft accident. This is mentioned to point up the fact that there may well have been missed not necessarily the same but similar cases in the past through lack of routine postmortem pathologic examinations. This condition is possible to detect if close medical supervision of flying personnel is maintained on an individual basis. In these times of personnel austerity this is seldom possible. Sarcoidosis is also an isolated and rare finding in the active aircrew population. The fact that the presence of this condition was the probable cause of an aircraft accident is significant and should put the medical contingent on guard at least to keep these things in the backs of their minds when medically evaluating fitness for flying on a day-to-day basis. Although rare at this time the paroxysmal onset of a *latent malaria* has been recorded as the cause of several aggravated incidents which might well have led to a major accident had not help been available. *Sickle cell disease*—essentially a racial dyscrasia—has also been described as a hazard to aviation because of predisposing its victims to the hypoxia hazards of lower oxygen tensions. It is a point to keep in mind when dealing with pilots of racial origins susceptible to the condition.

So much for a few of the relatively rare and perhaps exotic conditions which may affect safety of flight but not on a major-grouping basis; next, to examine more commonly occurring conditions which still do not exhibit a frequency necessarily significant from a purely statistical viewpoint.

Some of these conditions fall under the heading of sudden severe incapacitation. *Myocardial infarction* or *coronary insufficiency* are conditions often mentioned as a possible or probable cause of aircrew member incapacitation. The resulting lesions are usually demonstrable both clinically and pathologically. The aircrew population is aging. Coronary atherosclerosis is apparently a rather serious problem even in younger individuals of a generally overfed and overweight population. Adequate early detection is the problem. Annual or special electrocardiographic determinations seem to be the

best tool immediately available. A much better one is required. Perhaps pathology along with the research-minded clinician can provide a more adequate tool.

The significance of *high blood cholesterol* levels is incompletely explained. We shall have to depend no doubt on nutrition research and the clinician to suggest treatment but it seems reasonable to suppose that pathology may be able to provide guide-lines and forecasts for the significance of this laboratory finding. Along this same line another and long-range investigation in which pathology can be of prognostic value is the providing of additional information on the deleterious effects of obesity.

Cerebro-vascular accidents of various kinds and degrees have been reported occurring in flight in both pilots and passengers. It has been reasonably suspected that negative G forces were a factor in a few. In others the flight environment did not seem in any way to influence the occurrence. Detection of susceptibility to such episodes poses a clinical problem that is not easily amenable to solution. One can only apply the generally known factor of age in relation to other known predisposing factors. In any case this category of incapacitation has not been a problem of any magnitude but it is of pathologic interest.

Incapacitation from the *inhalation of noxious fumes* is always a possibility in the aviation environment. How much and what kind of fumes can incapacitate is the same old question. Everyone has looked to pathology and toxicology (as closely related fields) to provide answers in this area. There remain to be developed (or refined) more adequate techniques for sampling, detection, and analysis (both qualitative and quantitative) of noxious fumes and perhaps better techniques for postmortem determinations in tissues or tissue fluids to provide answers to the obvious questions.

There is a requirement from the accident investigator's standpoint to have much more and better information on the biochemical and, indeed, demonstrable tissue responses to prolonged *stress*. Ketosteroid studies appeared at one time to be promising but this effort seems to have straggled, and further investigations in fields already proved unprofitable have consumed time and funds unproductive of constructive or useful information. The development of microanalytic techniques offers great promise if only we knew for what we should analyze. In general terms the same things apply to *physiologic fatigue*. How is it defined, demonstrated, and its parameters established? How can its antemortem presence in dangerous degree be determined by postmortem examination?

An aging population has been mentioned. The demonstrable changes in aging tissues are in the province of pathology. Their significance in terms of function is doubtless an individual affair but it would seem profitable to correlate, using statistically significant numbers of cases, pathologically demonstrable changes with functional capacity or capability. AFIP can contribute a considerable share to this general area. It is known clinically that physiologic aging is concomitant with, among other things, a slowing reaction time and a decreasing ability to perform precise physical manipulations. This fact has quite a connotation to aviation safety everywhere but it is in an emotionally loaded area

and it has and will continue to generate contumacious argument.

One can hardly refrain from mentioning *excessive smoking* as a possible contributing cause in aircraft accidents. This is extremely difficult to pin down—especially at present when the proponents of smoking contend that a full life is impossible without it and the opponents attribute all bad things to it. It should be obvious that, physiologically, smoking does no one any good and it may do harm. Certainly it can aggravate an existing hypoxia. It provides for inhalation of carbon monoxide along with other irritating and physiologically active vapors. Reactors to this sort of thing can conceivably add to an already existing relative incapacity so that the demands of a situation exceed the operator's capacity to cope. This is speculation but not without reason. Does the field of pathology have a contribution in this area?

Detection of *various drugs*—usually, but not always, those of the diverse "go" group (amphetamines and like drugs) or "no go", "stop" groups (barbiturates or tranquilizers) suspected of being factors in accidents or incidents, generally falls into the field of pathology. Although some detection methods are good, drug intoxication as a factor in aircraft accidents remains a very doubt-filled area. There is great awareness of the danger of self-medication and, although not amenable to proof, it is quite probable that medication has been at least a contributing cause in a number of aircraft accidents.

Larval idiopathic epilepsy has been suspected frequently as a primary factor in otherwise "cause undetermined" accidents. Precipitation of seizures from previous larval epilepsy has been reported to have occurred in an aircraft cabin by light flicker through an idling propeller and in a cockpit by flight through bright sunlight and broken clouds. Hardly enough is known of borderline EEG tracings to make consistently sound judgments. The critical nature of high performance equipment demands that any error of interpretation be made on the safe side. *Post-traumatic epilepsy* is always to be suspected following significant head injury. The presently applicable degree criterion of duration of unconsciousness being directly proportional to probability of sequelae is well founded on the basis of experience. History of head trauma and unconsciousness is no doubt often concealed for various reasons. Usually, however, the characteristic focal patterns in an EEG are well correlated with operative or postmortem findings.

In considering more frequently occurring physical and physiologic factors relating to aircraft accidents or incidents the figures for 1959 are of some interest. These were definite, probable, or possible factors in the occurrence of either accidents or reportable incidents during 1959. Some of them have been mentioned earlier.

Aeroembolism	3
Carbon monoxide	4
Fumes, smoke, excess heat	18
Rapid/explosive decompression	23
Disorientation/vertigo	24
Hypoxia	9

Incapacitating dysbarism, a long-known potential hazard, deserves some consideration in view of the extreme altitudes now possible of attainment with manned vehicles. The factors which dispose to dysbarism in an uncommonly susceptible individual are usually detected on altitude indoctrination and yet day-to-day physio-

logic variation as a result of subclinical infections, fatigue, or stress, can cause remarkable variations in the same individual's predisposition. The presence of clinically demonstrable residuals either temporary or permanent and the postmortem findings of demonstrable changes or abnormality continue to be of primary importance to those in the accident prevention effort.

The question of *fatigue* also deserves more attention than it received in the brief mention made of it previously. It has been a contributing if not a primary cause factor in a great number of accidents some of which have occurred in the recent past. It would be extremely helpful if there were available some simple test for its presence to a dangerous degree other than subjective feeling or empiric observation.

Hypoxia continues to be a potential threat and a real hazard when it occurs. Perhaps it is not of primary pathologic interest but certainly the hypoxic state is significant from the standpoint of incapacitation. It is a fact that hyperventilation is quite apt to follow episodes of hypoxia and take over as the primary incapacitating mechanism. In a very recent fatal accident involving a high performance single-place aircraft on a practice intercept mission, the pilot was thought to have been incapacitated as the result of hypoxia. His fatal injuries were of the multiple extreme type. It would be most helpful if it could be established that hypoxia was in fact the primary cause of his difficulty. The mechanical hazards of the equipment he wore can be estimated by an examination of the same equipment on other individuals and in different aircraft. But to establish the fact that hypoxia was the primary cause of this accident would be of great help in the accident prevention program.

Establishing the fact of pre-impact *fire,* or *explosion,* or both, is of primary importance in the cause determination of aircraft accidents. Although it may seem dramatic and somewhat cloak-and-daggerish, the possibility of sabotage in military aircraft should never be overlooked. This is particularly true in special mission aircraft of whatever sort. Although many precautions are taken to prevent this sort of thing it is conceivable that it can happen. Postmortem examinations by the trained pathologist can often establish the fact of an explosion prior to the crash. This was recently dramatically demonstrated in a widely publicized civil airlines accident.

Just how much the pathologist can assist in the very real hazard of *disorientation* and *vertigo* in the operators of high performance aircraft and helicopters has not been determined. There is insufficient acquaintance with the detailed literature of pathology to know whether or not there is any correlation between susceptibility to disorientation or vertigo as the result of any but a few of demonstrable pathologic conditions and diseases. It is recognized that the investigation of such an area would entail tremendous efforts and long periods of time.

There is another major human cause factor of aircraft accidents in an area in which it is extremely doubtful if help can proceed from pathology, *per se.* This is the area of *human judgments*—not only involving correct or incorrect decisions—but also the time required to arrive at a decision and take what is deemed to be effective action.

Perhaps there is some connection with pathology. One may reflect again on the aging pilot population and the demonstrated presence in young individuals of atherosclerosis. It is not beyond the realm of possibility that cerebral atherosclerosis may sometimes be a factor in faulty judgment, delayed decision, or both.

If, by making accident investigation information available to this group so that thought has been stimulated to point up profitable areas for investigation, this time has been well spent. None of the things mentioned is new. All are old and recurring, and bringing them up again merely serves to emphasize that our knowledge is incomplete and the final fixes are not yet available. The always willing assistance of the AFIP in the investigation of aircraft accidents is greatly appreciated. This assistance is of the same high quality and helpfulness which characterizes other activities of the organization. Everyone in the accident prevention effort is more appreciative of these efforts than the time and opportunity they ordinarily take to express.

Science and Society

Scientists have a special responsibility to provide citizens with the knowledge required to make informed decisions on public issues related to science.

A report released last month by the American Association for the Advancement of Science (AAAS) Committee on Science in the Promotion of Human Welfare urged the scientific community to assume the obligation for providing the general public with objective facts and estimates of the effects of alternate policies. A citizenry thus informed, the committee noted, is a chief assurance that science will be devoted to the promotion of human welfare.

The committee also warned against growing pressures for relaxation of the traditional rules of science. Decried was a public tendency to comprehend science only in terms of immediate practical results with an insufficient appreciation of the significance of basic research.

Said the committee: "We are witnessing an unprecedented and accelerating rate of growth in man's power over his environment. Science, the instrument which produces this power, is being consciously exploited for industrial, military, and political purposes. At the same time, there is little recognition of the internal needs of science, or of its purposes as a discipline of the human mind."

Proposals. Suggested was that AAAS follow these steps:

Stimulate discussion, within the scientific community, of issues relating science and human welfare to identify those issues regarded as of most immediate interest.

Prepare a detailed report for scientists on each issue with relevant data, a discussion of assumptions and sources of error, and a description of expected consequences of alternative courses of action. The report would be made widely available to scientists and would not recommend a specific course of action. The contents of the report should then be translated into forms suitable for distribution to the public through all available channels.

Develop liaison between scientists and the public on a local basis. Many scientists already report an increasing demand from local civic groups for lectures on contemporary issues.—*M.D.*, August, 1960.