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OFFICE OF NAVAL RESEARCH

Final Report

BIOMEDICAL ASPECTS OF AIRCRAFT ESCAPE AND SURVIVAL UNDER COMBAT CONDITIONS

March 1976

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BioTechnology, Inc.
3027 ROSEMARY LANE • FALLS CHURCH, VIRGINIA

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Final Report

BIOMEDICAL ASPECTS OF AIRCRAFT ESCAPE AND SURVIVAL UNDER COMBAT CONDITIONS

by

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BioTechnology, Inc.
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FOREWORD AND ACKNOWLEDGMENTS

This study is part of a program for the Office of Naval Research to examine the problems of combat escape and survival for Navy aircrewmen. This phase was undertaken to respond to operational requirements identified by Captain Frank H. Austin, Jr., MC, USN, Director, Aerospace Medicine Division, Bureau of Medicine and Surgery, and Program Coordinator for the Life Support Systems Office of the Deputy Chief of Naval Operations (Air Warfare), Washington, D.C. Dr. Arthur B. Callahan, Program Director, Medicine and Dentistry Program, Biological and Medical Sciences Division, Office of Naval Research, served as Technical Monitor during the course of the project.

The purpose of the study was to combine Navy prisoner of war escape and survival event data, collected during an earlier phase, with detailed injury information associated with specific mishaps. The combined data were analyzed to determine the etiology of escape injuries as well as their consequences during later survival phases.

Special thanks must go to the 106 repatriated prisoners of war who took the time and effort to supply the event information about their mishaps, and to Captain Robert E. Mitchell, MC, USN, and his staff at the Naval Aerospace Medical Research Laboratory, Pensacola, Florida. Dr. Mitchell's time, patience, and medical records were invaluable in our obtaining the type of detailed injury information necessary for this study.

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INTRODUCTION

The experiences of Navy aircrewmen forced to eject during combat operations in Southeast Asia represent a unique and invaluable data bank against which to evaluate the procedures and equipment used for aircraft escape, survival, and rescue. Missions flown by these aircrewmen frequently were into heavily fortified regions of hostile territory during which aircraft losses were significant. The ultimate outcome of these aircraft losses for the aircrewmen who were involved is shown in Table 1.

Table 1
Status of Navy Aircrewmen
Following Ejection Over Southeast Asia

Recovered	Prisoner of War	Missing or Killed in Action
39%	28%	33%

The numbers in Table 1 present a somber picture. Close to two-thirds of the aircrewmen forced to leave their aircraft either became prisoners of war or were subsequently listed as missing or killed in action. Less than 40 percent were recovered and, of these, 29 percent suffered major injuries. For an aviator forced to abandon a disabled aircraft in combat, the chances of returning with either minor or no injuries were less than 30 percent.

The combat figure contrasts greatly with peace-time statistics (CY 1973) in which 87 percent of all ejections were successful, in terms of the aviator being alive, and, of these, only 12 percent involved major injury. For an aviator forced to abandon a disabled aircraft in peace-time, the chances of returning with either minor or no injuries are slightly less than 80 percent. The difference between an 80-percent satisfactory outcome in peace-time versus a 30-percent satisfactory outcome in combat is striking. This provides ample justification for a critical review of the combat use of procedures and equipment required for aircraft escape, and for the survival and rescue of crewmen.

In October 1971, BioTechnology, Inc., under contract to the Office of Naval Research, with technical guidance provided by the Bureau of Medicine and Surgery, initiated a study program to analyze problems of combat escape and survival. The principal objectives of the program were to: (1) identify unique biomedical problems associated with the escape and survival of Navy aircrewmen under combat conditions in Southeast Asia, and (2) develop a computerized data base for use in detailed studies of specific biomedical issues, especially those relating to ejection and survival injuries, escape equipment, personal protective equipment, rescue problems, and prisoner of war survival. The following technical reports were prepared earlier as part of this effort:

Every, M.G., & Parker, J.F., Jr. A review of problems encountered in the recovery of Navy aircrewmen under combat conditions. Prepared for the Bureau of Medicine and Surgery, Department of the Navy, Washington, D.C., June 1973.

Every, M.G., & Parker, J.F., Jr. Aircraft escape and survival experiences of Navy prisoners of war. Prepared for the Bureau of Medicine and Surgery, Department of the Navy, Washington, D.C., August 1974.

The data summarized in these reports delineate the escape conditions and types of injuries associated with ejection and survival following an air combat mishap in Southeast Asia. From analyses of these data, it was evident that the conditions of a combat ejection and the resulting injuries are, on the average, appreciably more severe than those normally encountered by aircrewmen during noncombat (operational) ejections. The severity of combat ejection injuries was often compounded during the landing, escape, and evasion phases of the survival. In many cases, these injuries made it extremely difficult to operate life support and signaling equipment, and in some cases, were so severe as to remove any possibility of evading the enemy and effecting a successful recovery. In many instances, the increased hover time necessary to locate and recover severely injured aircrewmen added to the risk for search and rescue (SAR) helicopters and crews.

Project Objectives

Earlier analyses of combat escape data showed the need for more specific injury information in order to establish precise injury cause-and-effect relationships during high speed escape. Using detailed injury data, specific injury causal agents in ejection equipment or in escape procedures might be identified. A precise specification of injuries sustained during the escape and survival phases could be used to evaluate the adequacy of life support, signaling, and rescue equipment. These injury data would further serve design engineers in their efforts to improve high speed ejection procedures and combat survival probabilities. The specific objectives of this project were to:

1. Draw upon and expand the data base developed earlier at BioTechnology, Inc. dealing with the specific circumstances of a large number of combat escapes from Navy aircraft. This information is referred to as the *event* data.

2. Work with the Naval Aerospace Medical Institute to use the very detailed medical information being obtained by that facility which describes the site and nature of specific injuries suffered by Navy prisoners of war. This information is referred to as the *medical data*.
3. Relate medical data to event data so that inferences might be drawn concerning the causal agents in combat escape which produce particular injury patterns.
4. Develop tabular and graphic presentations for the event/injury relationships, for individual cases and for group summaries, which might be used by military planners and by design engineers concerned with the development and evaluation of procedures and equipment for combat escape, survival, and rescue.

PROCEDURES

The first part of the project period was spent in updating and expanding the event data file developed by BioTechnology, Inc. as part of earlier efforts. This included adding questionnaires completed by some survivors who were solicited as part of the earlier project but whose responses were received too late to be of value at the time. Additional data describing ejection circumstances was obtained from the records maintained by the Center for Naval Analyses, Washington, D.C. Information concerning specific ejection seat use in the different combat aircraft was obtained through the offices of the Crew Systems Division of the Naval Air Systems Command.

Pensacola Prisoner of War Program

Data describing the precise injuries suffered by Navy POW aircrewmen was obtained principally from the medical files developed at the Naval Aerospace Medical Institute (NAMI), Pensacola, Florida, as part of the "Repatriated Prisoner of War Program." This program, in Pensacola, under the direction of Captain Robert E. Mitchell, MC, USN, is a joint effort between NAMI and the Center for Prisoner of War Studies, San Diego, California. The program was started in 1972 as a long-term prospective study regarding the cause and prognosis of disease in former prisoners of war.

Because no long-term data are available, a decision was made by the Department of Defense to follow the present group of repatriated prisoners annually for at least five years. Programs similar to that being carried on by the Navy are also being conducted by the Army and the Air Force.

The Naval Aerospace Medical Institute was selected as the most logical place for the conduct of this study for several reasons: first, the majority of the men were or had been aviation personnel; second, personnel at this facility have experience in following a similar group, the "Thousand Aviators," in a longitudinal medical examination of aviation personnel extending over a 34-year period; third, because of the need for uniformity of the examinations if the data are to be meaningful; fourth, because the records on each man will be concentrated in one place; fifth, because, hopefully, there will be some degree of continuity of examining personnel.

The annual follow-up examination of each man is including essentially the same studies as were performed in the initial examination, with deletion only of those tests which were done to detect captivity-related abnormalities. In an attempt to determine whether the results obtained in the repatriated group are related to the captivity experience, a control group of men matched by such variables as age, etc. will be started in April 1976.

The prisoner of war repatriates consisted of 141 Navy or ex-Navy men and 37 Marine Corps or ex-Marine Corps men, 140 of whom are or were aviation personnel. Tests conducted on these men included a searching interim history to determine how the man had fared in the interval since repatriation; a thorough physical examination; a complete battery of blood studies, including serologies for malaria and other Southeast Asia parasites, the latter being done by the Center for Disease Control in Atlanta; special x-rays; stress studies for heart disease; studies of lung functions; and studies of the organs of balance. The psychiatry half of the study, in addition to the usual psychiatric interviews, included extensive psychological testing. Special consultations were done on each man including dental, ear, nose and throat, eye, hearing, and such other specialties as were indicated. For orthopedics, surgery, dermatology, and urology, the man was referred to the Naval Hospital.

For those technical studies where feasible, documentation was by means of tape for computer analysis. Code sheets and mark-sense sheets were also used for computerized data processing. All records are being preserved on microfilm.

BioTechnology Data Retrieval

As the injury data were taken by BioTechnology personnel from NAMI files, each injury was coded in terms of the following: description, site, specific location, time, severity, and probable cause of the injury. The section of the BTI coding manual used in this process is presented in Appendix A. The coded medical data was then transferred onto 80-column punch cards and combined with prisoner of war event data already on file (see aviation casualty report Form BTI-73). The type, location, and degree of injury was cross-tallied with escape event data to determine relevant injury pattern relationships. In some cases, the injury data from recovered aircrewmen were combined with prisoner of war data. These instances will be noted, where appropriate, in this report.

When injury analyses comparing prisoner of war and recovered data were conducted, it was found that there were significantly fewer minor injuries recorded for the prisoner of war group. In all probability, this was due to the fact that the prisoner of war group sustained a much higher number of major injuries which led them to disregard minor injuries and also to the long period of imprisonment for many of the POW survivors which resulted in their forgetting the less significant injuries.

Injury classifications throughout this report were made using the instruction under Injury Classification of OPNAV INST 3750.6G (see Appendix B).

RESULTS AND CONCLUSIONS

Escape Conditions

This section summarizes escape conditions encountered during Southeast Asia air combat mishaps. Table 2 compares the ratios of aircraft type used in this study with total losses in Southeast Asia. It can be seen that the study sample closely approximates the actual ratios of Navy combat aircraft losses. The two groups in this study were composed of 104 recovered and 106 prisoner of war aircrewmen.

Table 2
Comparison of Total Navy Aircraft POW and Recovered Southeast Asia Losses with Aircraft Ratios Making up Study Group

Aircraft	Total Navy POW/REC Losses – SE Asia	BioTechnology Study Group Cases (POW & REC)
A-4	33%	39%
A-6	11%	10%
A-7	9%	7%
F-4	26%	24%
F-8	14%	13%
RA-5C	7%	7%

The mean speed at the time of initial aircraft damage for the recovered and POW groups was very similar. One major difference during the initial phase of the mishap, was the greater degree of structural damage suffered by POW group aircraft. The severity of this damage allowed POW aircrewmen much less time to slow and control the aircraft before initiating ejection (Table 3). The various aircraft attitudes at time of ejection are shown in Table 4. The higher number of adverse attitudes in the POW group attest to this group having less control over their aircraft at the time of ejection, and is significantly related to problems associated with body position at time of ejection.

If the 0- to 500-foot (takeoff and landing mishap) category is omitted (Figure 1), altitudes at the time of ejection for the prisoner of war group is similar to that for both the recovered and noncombat groups. Speed at time of ejection, however, shows very dissimilar curves (Figure 2). These differences are especially relevant in the high speed, critical injury range above 400 KIAS. A listing of ejection speed by aircraft type for the prisoner of war group and a comparison with recovered and noncombat ejection speed ranges is given in Table 5. It can be seen from the data in this table that over 60 percent of the prisoners of war ejected at speeds greater than 400 knots, while only 5 percent of the operational (noncombat) group ejected at speeds that high. Eight percent of the prisoner of war group ejected at speeds in excess of 600 knots. Mean ejection speed by aircraft type for the POW group is presented in Table 6. The overall mean ejection speed for the entire POW group was 407 knots. This compares with an overall speed of 302 knots for aircrewmen recovered in combat and a speed of approximately 213 knots for noncombat ejections occurring during approximately the same time period.

Table 3

Mean Times From Aircraft Damage Until Ejection

Type	Recovered Aircrewmen Mean Time (Min)	Prisoner of War Mean Time (Min)
A–4	10.3	1.0
A–6	13.8	.5
A–7	2.4	1.0
F–4	18.6	1.6
F–8	10.6	.5
RA–5C	2.1	.2

Table 4

Aircraft Attitude at Time of Escape

Attitude	Number of Times Reported	
	Recovered Group (104 Cases)	POW Group (106 Cases)
Nose down	32	57
Rolling	13	31
Right bank	11	13
Left bank	13	12
Tumbling	2	12
Inverted	6	9
Disintegration	1	9
Straight and level	29	7
Nose up	30	6
Nose down spin	0	7
Oscillating spin	0	3
Flat spin	1	2
Mushing	3	0

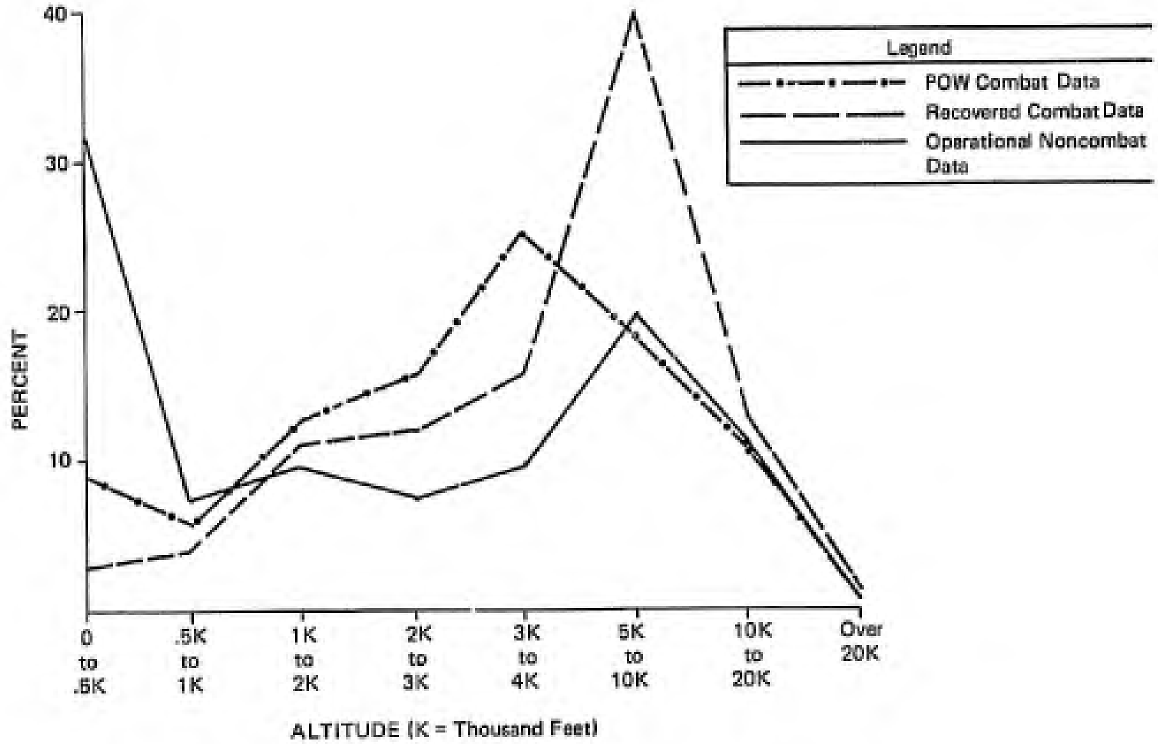


Figure 1. Combat versus operational ejection altitudes.

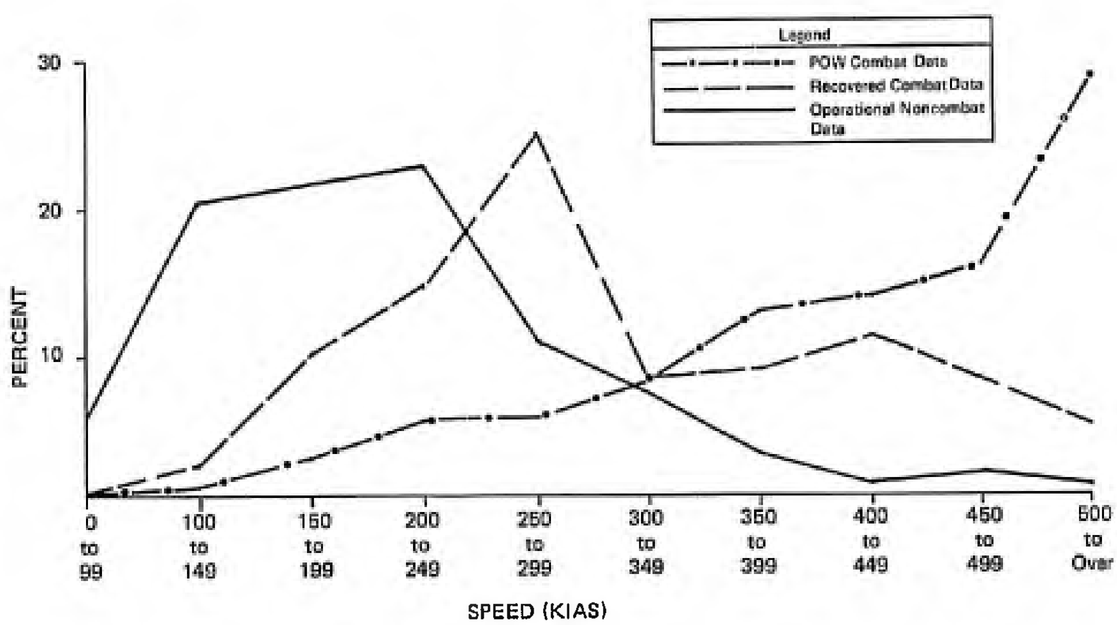


Figure 2. Combat versus operational ejection speeds.

Table 5

Ejection Speeds for Nonfatal Mishaps

Speed (KIAS)	Prisoner of War Aircraft Type						Percent		
	A–4	A–6	A–7	RA–5C	F–4	F–8	POW Combat 1964 – 1973 (97 cases)	Recovered Combat 1966 – 1972 (102 cases)	Operational 1966 – 1970 (794 cases)
0 – 99							0	0	6.4
100 – 149					1		1.0	2.9	20.7
150 – 199	2					1	3.1	10.8	22.0
200 – 249	3		1		2		6.2	15.7	23.3
250 – 299	3		1		2		6.2	25.5	11.2
300 – 349	4		1		3	1	7.3	8.8	7.7
350 – 399	5	4			2	2	13.4	9.8	3.7
400 – 449	4	5	2	1	2		14.4	11.8	1.5
450 – 499	6	2	1		5	3	17.5	8.8	2.4
500 & over	8	1		7	8	4	28.8	5.9	1.1

Table 6

Mean Ejection Speed by Aircraft Type
(POW Group)

Aircraft Type	A-4	A-6	A-7	F-4	F-8	RA-5C
Mean Ejection Speed (KIAS)	378	408	337	403	420	588

Aircraft Escape Injuries

Table 7 gives a breakdown of major and minor injuries by location of injury and phase of the mishap in which the injury occurred. While serious injuries occurred during every phase of escape and survival, almost 90 percent of the major injuries (Table 8) were inflicted during the relatively few seconds between initial aircraft damage and parachute deployment. Ejection injuries, especially to the spine, extremities, and torso (torso injuries in this case are mostly shoulder injuries from flailing), comprise almost two-thirds of those incurred during the entire mishap.

Table 7

Location of Major and Minor Injuries Incurred by Prisoner of War Study Group During All Phases of Mishap (106 Cases)

	Head and Face	Neck	Upper Ext.	Spine	Torso*	Lower Ext.	General Overall	Total	Percent
Pre-Ejection	9	5	14	0	3	11	0	42	18
During Ejection	15	6	36	33	26	40	4	160	69
During Descent	0	3	0	1	0	2	0	6	3
During Landing	0	1	0	3	1	16	0	21	9
During Survival	1	1	0	0	0	1	0	3	1
Total	25	16	50	37	30	70	4	232	
Percent	11	7	22	16	13	30	2		

*Torso Injuries are predominantly shoulder injuries.

Nonfatal injury rates obtained from POW, recovered, operational, and Air Force data are compared in Table 9. The probable causes of the prisoner of war injuries (major and minor) are shown in Table 10. Enemy-inflicted and burn injuries were predominantly "in the cockpit" or pre-ejection injuries. Ejection seat "G" forces, extremity flail, and striking objects during escape caused the more serious as well as the greatest number of injuries. Parachute landings were responsible for a high number of injuries including fractures, dislocations, and severe sprains to the lower extremities. Unfortunately, it cannot be ascertained from these data the extent to which existing injuries were compounded during landing or escape and evasion. Considering the high number of severe injuries encountered during ejection, however, there is a likelihood that landing impact further disabled individuals, perhaps to the point of making survival impossible. This would be especially true if an injured aircrewman did not receive immediate emergency care either self-administered, from rescue personnel, or from his captors. Table 11 lists the types of major injuries sustained by the prisoner of war group during their mishap. Fractures and dislocations, most of which were incurred during the ejection sequence, were, by far, the most prevalent types of major injury.

Table 8

Major Injury Summary
(POW Group)

Escape Phase	Number of POW's Suffering at Least One Major Injury During Phase*	Total Major Injuries During Phase	Location of Major Injuries					
			Head and Face	Neck	Upper Extremities	Spine	Torso	Lower Extremities
Pre-Ejection	8	13	3	2	5		1	2
During or Probably During Ejection	44	60	1		17	12	12**	18
During Descent	1	1						1
During Landing	6	6				1		5
After Landing – Before Capture	0	0						

*2 pilots not included on this table suffered major injury during an unknown phase of the mishap.

**Predominantly shoulder area injuries – associated with arm flailing.

Table 9

Nonfatal Injury Comparison

	Major	Minor	None
Navy POW Combat	53%	24%	23%
Navy Recovered Combat[1]	29%	43%	28%
Navy Operational[2]	19%	37%	44%
Air Force Recovered Combat[3]	15–25%	–	–
Air Force POW Combat[4]	38%	42%	20%

[1]Every & Parker, 1973.
[2]Naval Safety Center, 1973.
[3]Till & Shannon, 1970.
[4]Shannon, 1974.

Table 10

Probable Cause of Known Injury (POW Group)

	Percent
Flail	33
Enemy Inflicted	17
Ejection Seat G Forces	14
Struck Object	13
Parachute Landing	11
Fire	10
Parachute Opening Shock	2

Table 11

Nature of Major Escape Injuries (106 Cases all Phases)

Major Injury	Number of Times Occurring
Amputation of Thumb	1
Burns	6
Contusions (Severe)	3
Dislocations	22
Simple Fractures	32
Compound Fractures	9
Spinal Compression Fractures	16
Severe Sprains	6
Torn Muscle or Ligament	9
Gunshot Wound	8
Severe Lacerations	3

Injury Occurrence by Phase of Escape

Pre-Ejection

The period of time from initial aircraft damage until ejection seat initiation is the pre-ejection phase. Table 8 in the previous section gave the location of injuries for the eight prisoners of war who sustained major injuries during this phase. The cause of four of these injuries was fire in the cockpit; the other four injuries were from gunshot or shrapnel wounds. All of these injuries were the direct result of enemy-inflicted damage.

Combining the minor pre-ejection injuries with the major injuries (Table 12) results in 42 injuries reported by the POW group for this phase. Seventeen of these injuries resulted from fire in the cockpit and 25 as a direct result of wounds caused by enemy ordnance.

Table 12

Location of Major and Minor Pre-Ejection Injuries
(POW Group)

Head and Face	Neck	Upper Ext.	Spine	Torso	Lower Ext.
9	5	14	0	3	11

There were no reports from the POW group of these injuries causing significant difficulties with ejection seat initiation. There were, however, some difficulties reported by the recovered group (Every & Parker, 1973), and preliminary examination of some MIA and KIA data indicates there are cases where nonsuccessful escape attempts may be linked to pre-ejection injury.

For both the prisoner of war group and the recovered group, the more severe lacerations and burns caused some problems during escape and evasion. Gunshot wounds and burns were particularly painful and troublesome during prisoner of war captivity.

Ejection

For those not familiar with some of the basic characteristics of the ejection seats which will be discussed in this section, Appendix C gives a brief description of each of the seat types utilized in the aircraft comprising this study.

The vast majority of serious injuries occurred during the ejection phase. Figure 3 shows the percent of prisoner of war survivors sustaining major ejection injuries at various ejection speeds. Typically, the more severe, multiple major injuries occurred during ejections executed in the upper speed ranges. Primary causes of these major injuries were:

- Flail 60 percent
- G forces 15 percent
- Striking equipment 8 percent
- Unknown or other causes 17 percent

Many survivors who reported "cause unknown" could not state the exact cause of their injury because they were unconscious at the time of its occurrence.

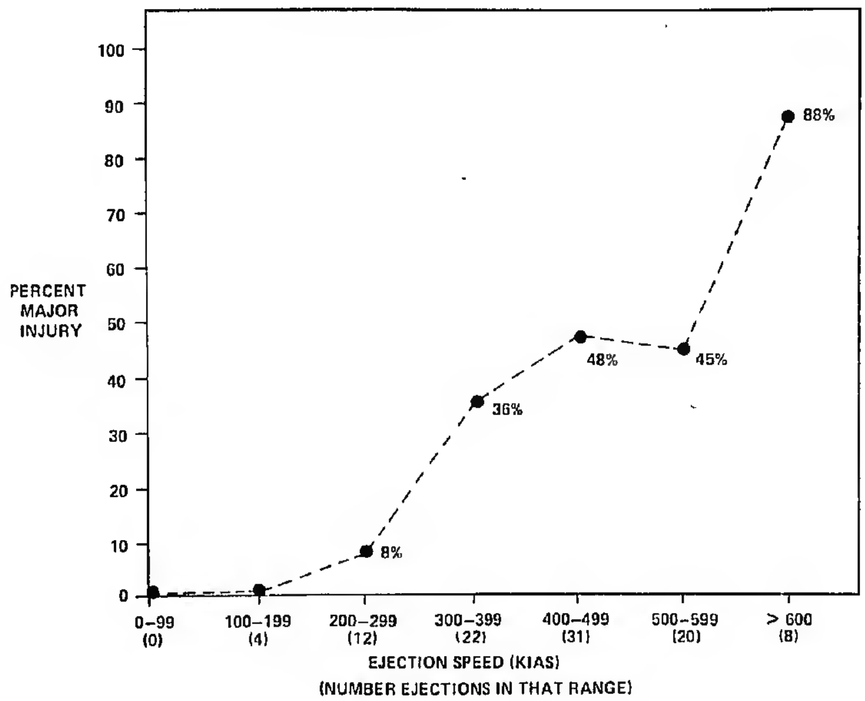


Figure 3. Percent of survivors sustaining a major injury v/s ejection speed.

The rate and severity of ejection injury showed some measure of fluctuation depending on aircraft type (Table 13). While injury rate was related to variables such as aircraft attitude at time of ejection, ejection seat "G" forces, and whether or not the canopy was jettisoned prior to ejection, the dominant cause was extremity flail. Each of these ejection problems will be discussed in turn.

Table 13

Major Ejection Injury by Aircraft Type

Aircraft	Number of Ejections	Number of Persons Sustaining a Known Major Ejection Injury (A)	Total Number of Major Ejection Injuries Sustained (B)	Major Ejection Injury Rate B/A
A-4	40	18	51	2.8
A-6	12	6	5	.8
A-7	6	2	2	1.0
F-4	27	9	15	1.7
F-8	11	3	3	1.0
RA-5C	10	6	13	2.2

Flail Injury. Figure 4 shows the increase in flail injury with increase in ejection speed in the prisoner of war group. As was found in the recovered group study, the 300- and 400-knot range seems to be the point where the injury curve rises sharply.

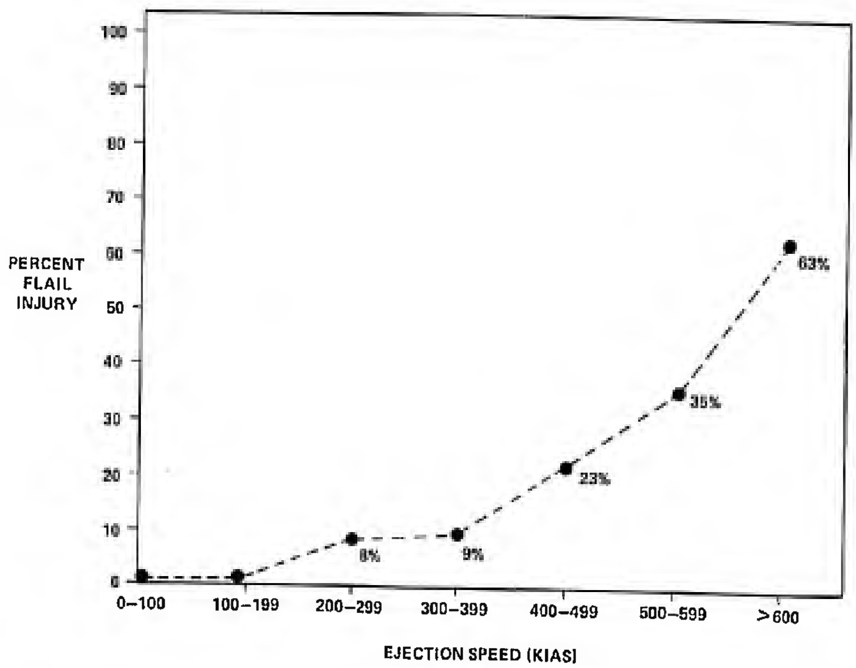


Figure 4. Incidence of major flail injury v/s ejection speed.

Windblast-induced flailing of extremities produced the greatest number of major injuries during the entire escape sequence. Windblast, also referred to as ram pressure or Q force, varies with the density of the airstream and, therefore, for the same true air speed, is reduced as altitude increases.

It is thus related to indicated airspeed rather than true airspeed and varies with the square of the velocity. The following formula for Q forces is from Ring (1975):

$$Q = \frac{1}{2}\rho V^2$$

Q = dynamic air pressure in Newtons/meter^2 (N/m^2)

ρ = air density in Kg/m^2

V = velocity in m/second

This relationship is expressed in Figure 5. Gillies (1965) states that the effects of these Q forces can be divided into those produced by direct pressure on the body, such as petechial and subconjunctival hemorrhages, and those produced by flailing of the head and extremities. Head flailing may cause unconsciousness or fatal brain damage, while flailing of the arms and legs can lead to fractures or joint dislocations. When the body is unsupported, a Q force of approximately 3×10^4 N/m^2 or more can lead to flailing that cannot be controlled by muscular effort. The onset of flailing can be so rapid that muscular reflex action is ineffectual even at Q values below 3×10^4 N/m^2. At Q values of 3.7×10^4 N/m^2, full abduction of the hip joints can take place in 1/10 second; at greater speeds, the loads of unsupported limbs may exceed the strength of the major joints. Where relevant, Q forces will be listed with ejection speeds through the remainder of this report so that comparisons can be made with other studies in the literature.

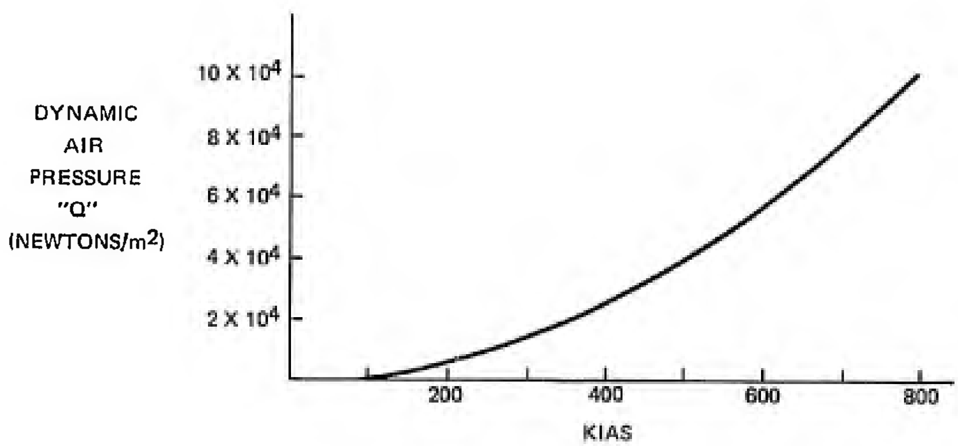


Figure 5. Dynamic air pressure vs. airspeed. (Ring, 1975)

It is important to note that it is not the Q force per se that causes the injuries associated with high speed ejection. Payne (1975) cites examples of persons exposed to 4.8×10^4 N/m^2 to 14.4×10^4 N/m^2 without serious injury. The problem lies in the two distinctive injury patterns associated with higher Q forces. The first, generally referred to as true windblast, normally results in only minor injury to soft tissue. The second type, commonly referred to as flail injury, results from the summation of forces over larger areas producing differential decelerations of the extremity relative to the torso and seat (Ring, Brinkley, & Noyes, 1975). The sudden stop of the extremity as a result of striking the seat structure or reaching the limit of the joint often results in severe extremity dislocation and/or fracture, examples of which are shown in Figures 6 and 7.

Major ejection flail injuries sustained by prisoners of war are listed in Table 14 by speed and Q force at the time of ejection. Eighty-two percent of this group reported ejection speeds of 400 knots or greater. Survivors who ejected at speeds below 450 knots sustained an average of 1.5 major flail injuries during ejection, while those ejecting at speeds above 450 knots had an average of 2.4 major flail injuries per ejection. Two ejection speeds were unknown due to unconsciousness at time of ejection. A summary of major ejection and flail injury types is shown in Table 15. The nonflail injuries are primarily attributable to striking some object during ejection. The general locations of major flail injuries are shown in Figure 8. Figure 9 presents the specific location of all known major ejection injuries sustained by the musculoskeletal system.

Appendix D lists ejection Q forces, ejection speed, method of initiating ejection, and degree of ejection injury sustained by all prisoners of war in this study. It is apparent from this listing that 50 percent of the survivors received major ejection injuries at Q forces above the value of 4.4×10^4 N/m^2, and 75 percent of the aircrewmen received major wounds ejection at Q forces above the value of 6.2×10^4 N/m^2.

Table 16 compares flail injury and aircraft type. The high mean ejection speed encountered by RA-5C aircrewmen accounts for the large number of flail injuries (50 percent). Both the A-4 and A-7 aircraft, however, show lower mean ejection speed than other aircraft, yet major flail injury rates for those two aircraft were relatively high. The A-4 and A-7 aircraft both use the Douglas Escapac ejection seat, which does not have lower leg restraints.

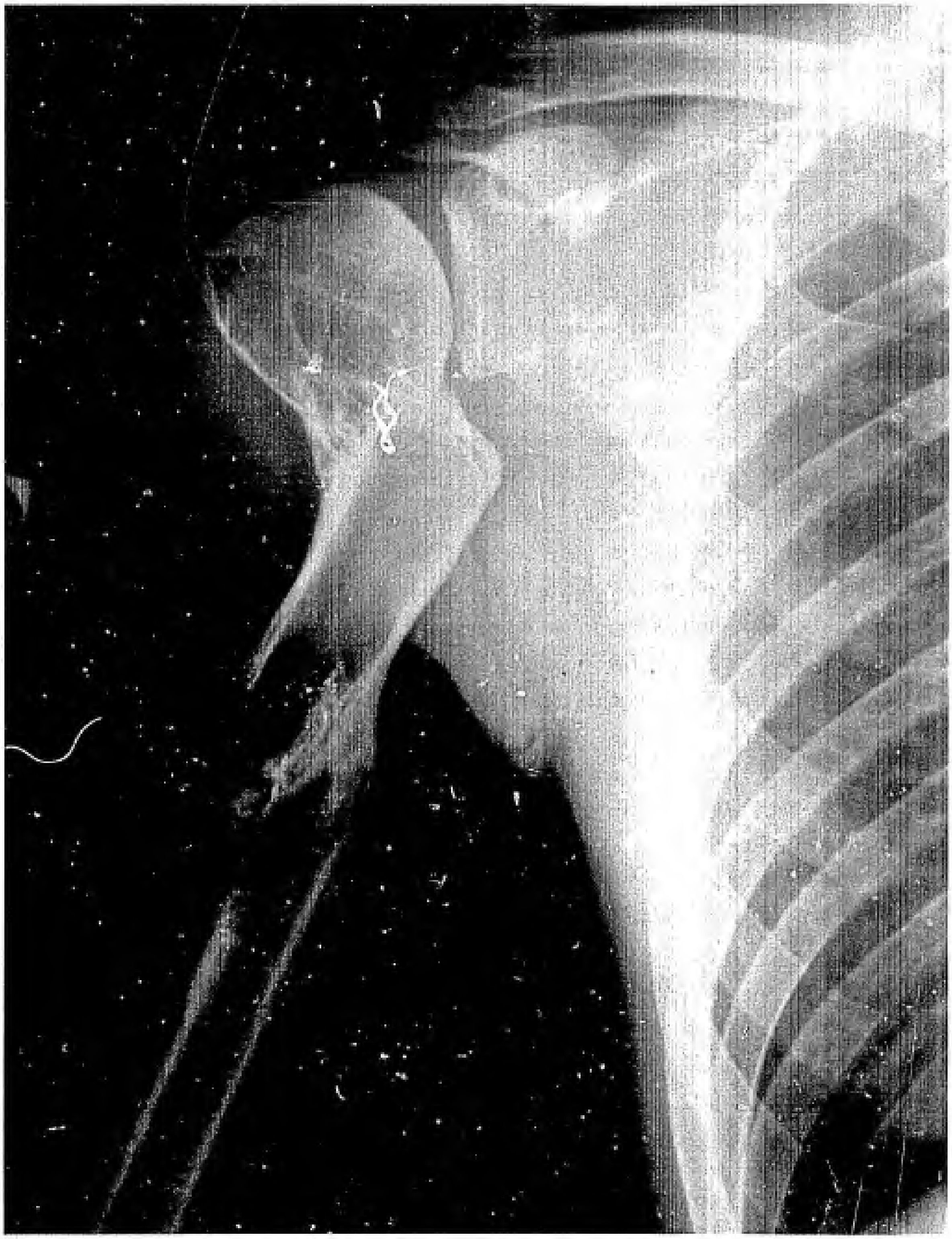


Figure 6. (Case 072) Injury – Segmental fracture of right humerus (healed with angulation).
Cause – Flail during ejection.

Figure 7. (Case 074) Injury – Fracture dislocation of left shoulder (healed with displacement).
Cause – Out of position during ejection, followed by extremity flail.

Table 14

Prisoners of War Sustaining a Known Major Ejection Flail Injury*

BTI #	Ejection Speed KIAS	Ejection Q Force $\times 10^4$ N/m^2	Aircraft Type	Major Flail Injury Description
56	735	8.7	RA-5C	Left shoulder dislocated, fracture neck left humerus, fracture left ulna
54	640	6.6	RA-5C	Torn ligaments left shoulder
24	620	6.2	RA-5C	Dislocation and fracture right elbow, fracture of ulna, unconscious
34	600	5.8	F-4	Dislocated left knee with torn medial ligament, dislocation right elbow
100	600	5.8	RA-5C	Fracture right humerus, unconscious
4	550	5.0	A-4	Torn ligaments right knee, possible fracture right tibia and right fibula
20	500	4.1	A-4	Bilateral shoulder dislocations, bilateral fractures upper humerus, fracture fibula
32	500	4.1	F-4	Bilateral elbow dislocations
42	500	4.1	A-4	Bilateral shoulder dislocations, fracture right humerus, knee dislocated, fracture left fifth metacarpal, unconscious, possible fracture at left knee
57	500	4.1	RA-5C	Two vertebrae in neck injured, severe strain neck muscles and tendons
72	500	4.1	A-4	Comminuted fracture left humerus, fracture right humerus, torn ligaments right knee, fracture femoral condyle
115	500	4.1	A-4	Right knee dislocated with torn ligaments
66	490	3.9	A-4	Right shoulder dislocated, fracture right humerus, dislocation right knee, laceration right knee
114	475	3.7	A-4	Fractured scapula, possible fracture left humeral head
74	450	3.3	A-4	Left shoulder dislocated, fracture left humerus, fracture left knee, dislocation left knee
96	450	3.3	A-7	Torn ligaments left knee, dislocated left knee
36	420	2.9	F-4	Fracture right elbow
117	420	2.9	A-6	Fracture right humerus
78	400	2.6	A-4	Torn ligaments in both knees, unconscious
125	350	2.0	A-4	Fracture left humerus
26	300	1.5	A-4	Right shoulder dislocation, fracture anterior neck right humerus
91	250	1.0	A-4	Left shoulder dislocation
89	Unk	Unk	A-4	Fracture dislocation left shoulder, unconscious
122	Unk	Unk	A-4	Fracture left shoulder, fractured ribs

*Eight individuals, not included in this table, sustained major flail type injuries. These cases were not included; however, because in six of the cases the aircrewmen was unconscious during the entire escape event and in the other two cases there was an equal probability that the injuries may have been caused by some other agent than flail.

Table 15

Types and Frequencies of Major POW Flail and Ejection Injuries*

Type of Injury	Flail Only Frequency	All Ejection Injuries
Dislocations	20	21
Fractures		
Simple	20	31
Compound	4	5
Torn ligaments or muscles or severe sprains	9	9

*Includes only known flail and ejection injuries; excludes all spinal-compression fractures.

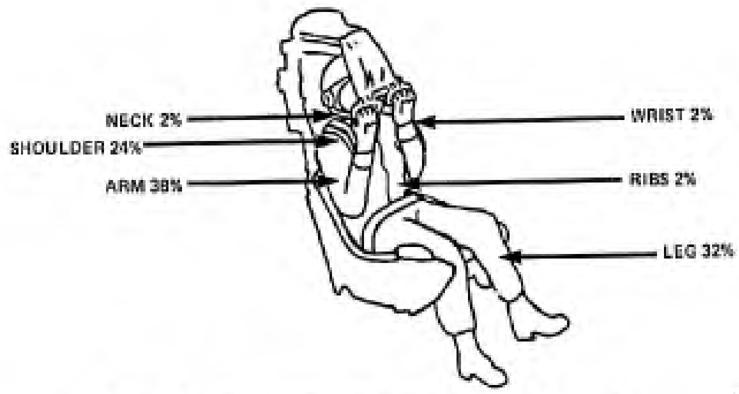
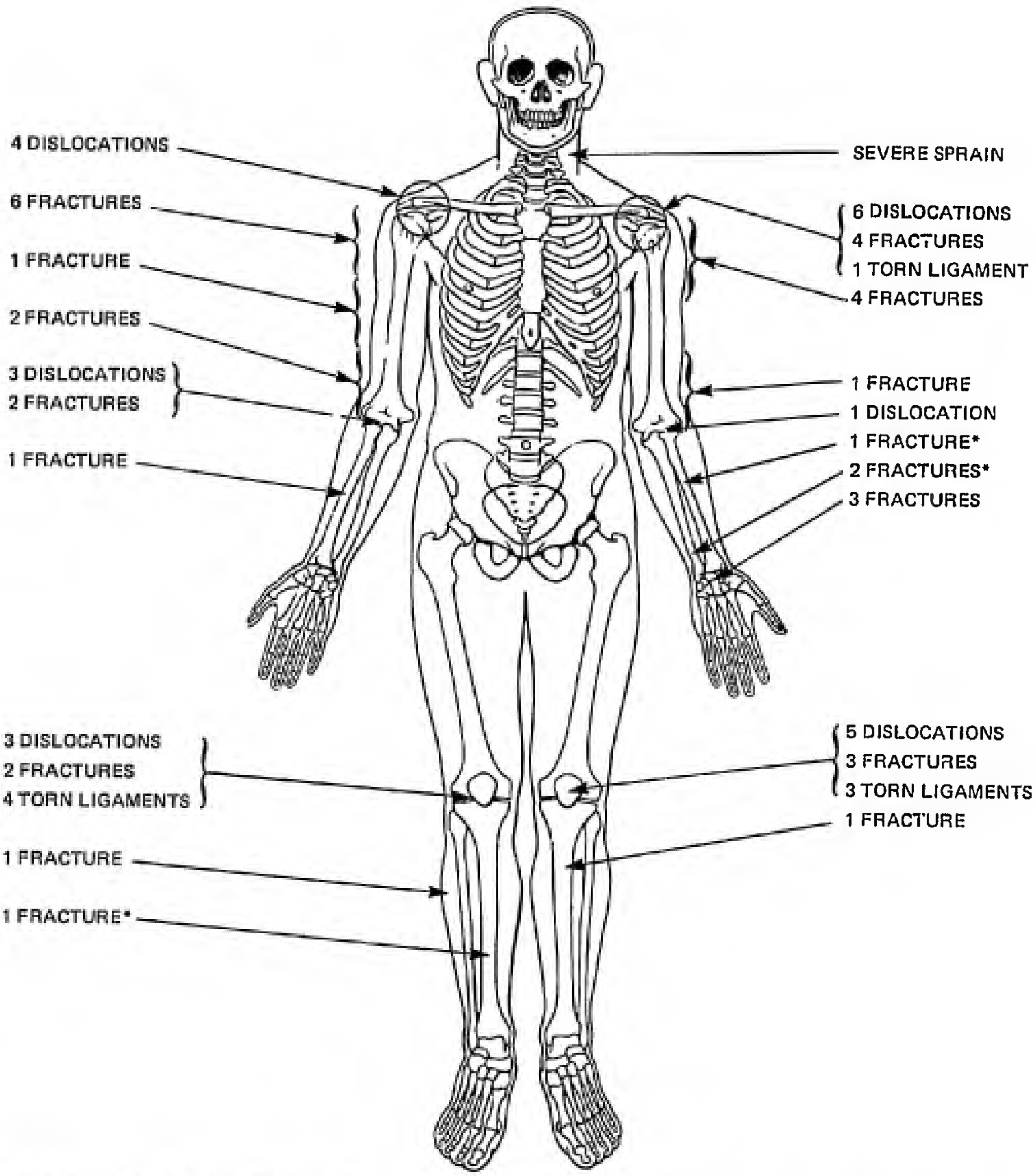


Figure 8. General location of major flail injuries.

When flail injuries are classified by upper and lower extremity and compared against ejection seat type (see Table 17), it again appears that those seats with lower extremity restraints do offer more anti-flail protection than those without, especially at the higher speeds normally associated with combat escape. When similar comparisons of seat type versus degree of injury sustained over ejection speed ranges are compared, the results again favor those seats with lower extremity restraints (Table 18).

A Chi-square statistical test was made of the relationship between the two types of seats and severity of injury. The results of this comparison show a significant difference between the two seats (see Table 19). In all probability, the lower incidence of lower extremity flail (Table 17) is attributable to the lower extremity restraints on the Martin-Baker seat. The reason for the lower incidence of upper extremity flail with the Martin-Baker seat is unclear.

Specific Location of all Non-Vertebral Musculo-skeletal Major Ejection Injuries



* INDICATES EXACT AREA UNKNOWN.

Figure 9. Specific locations of all non-vertebral musculoskeletal major ejection flail injuries (composite from 24 POW's reporting known flail injuries).

Table 16

Percent of POW Survivors Sustaining Major Flail Injury by Aircraft Type

Aircraft Type	Mean Ejection Speed (KIAS)	Type Ejection Seat	Percent of Ejectees Sustaining A Major Flail Injury
A-4	378	D	36
A-6	408	M-B	9
A-7	337	D	17
F-4	403	M-B	11
F-8	420	M-B	0
RA-5C	588	N.A.	50

D = Douglas Escapac Seat
M-B = Martin-Baker Seat
N.A. = North American Seat

Table 17

POW Ejection Extremity Flail Injury Rates*

	Douglas Seat A-4 & A-7 45 Ejections	Martin-Baker F-4, A-6 & F-8 49 Ejections	North American RA-5C 10 Ejections
Upper Extremity Flail Rate	24%	8%	40%
Lower Extremity Flail Rate	20%	4%	0%

$$^{*}\% = \left(\frac{\text{Number of persons suffering major flail injury}}{\text{Number of persons ejecting with a specific seat}}\right)$$

Table 18

Comparison of POW Ejection Seat Major Flail Injury Rate by Air Speed

Ejection Speed KIAS	Percent Major Flail, by Ejection Seat Type	
	Martin-Baker 48 Cases	Douglas 41 Cases
0-300	0	14.3
301-450	8	25
451+	13	64
All Speeds	8	32

Table 19

Severity of Ejection Flail Injury Versus Ejection Seat Type

Ejection Flail Injury Severity	Douglas	Martin-Baker
Major	13	4
Minor or None	28	44

$X^2 = 7.81, p < .01$

The method of initiating ejection (face curtain or seat pan handle) was also compared against type and frequency of major ejection flail injuries sustained by the prisoners of war (Table 20). The incidence of major flail injuries among the prisoners of war was the same regardless of the ejection seat initiation method used. However, the incidence of *multiple* major flail injury was somewhat higher in aircrewmen who initiated ejection utilizing the secondary handle. While it is recognized that a number of causal factors go into making up the various types of escape injury, having the body out of proper position at time of ejection appears to increase the likelihood of injury occurrence or severity.

Table 20

Major Flail Injury Versus Method of Ejection Seat Initiation (POW Group)

Method	No. Using	Major Flail Injury Rate (Percent)	Percent Sustaining Multiple Major Flail Injuries
Face Curtain	60	22	12
Seat Pan Handle	36	22	17

Injury Due to Striking Objects During Ejection. A number of aircrewmen reported striking cockpit structures during ejection. While most of these injuries were minor, two groups appear to have had a somewhat higher major injury rate: (1) the RIOs and RANs in the backseat of two-place aircraft, who often were not ready for ejection and had extremities extended to strike objects; and (2) those aircrewmen ejecting through-the-canopy from the A-6 aircraft. This latter group appears to have had a disproportionate number of severe injuries. Combining prisoner of war and recovered group data from survivors utilizing this method of escape reveals that, of the 16 through-the-canopy (primary sequence) ejections, 50 percent resulted in major injuries. Many of these involved severe lacerations. Of the five who jettisoned the canopy in this aircraft prior to ejection, there were no major injuries (see Table 21).

Table 21

Degree of Ejection Injury Versus Mode of Ejection for A–6 Combat (Recovered & POW) Mishaps

	Mean Speed	Degree of Ejection Injury		
		Major	Minor	None
Thru-the-Canopy (N = 16)	360	50%	25%	25%
Jettison Canopy (N = 5)	317	0%	60%	40%

Injuries Due to Ejection Seat G_z Forces. When an aviator is catapulted from an aircraft during emergency ejection, he experiences a high rate of change of acceleration. The peak accelerative force imparted to the aircrewman, while primarily related to the type of seat charge propelling the seat, varies as a result of a number of factors including the weight of the man - seat assembly, aircraft attitude, temperature, position of the man in the seat, etc.

The effects of accelerations of short duration with rapid onset such as those experienced in ejection seat firing are difficult to predict. The response of bone and organs to deformation or shearing varies greatly and injuries are not necessarily most severe at the site of application of the force (West, Every, & Parker, 1972). Spinal compression injuries are the most common spinal injury resulting from these forces (see Figure 10). This is primarily because the center of gravity of the upper trunk lies in the front of the spine and a bending movement is applied to the spine during ejection. The anterior lips of the lumbar or thoracic vertebrae are the most susceptible to fracture.

Sixteen of the prisoners of war sustained some measure of spinal compression fracture during the escape (Table 22). It is almost impossible to establish precise cause relationships for this type of injury. However, it appears that body position is one of the more important variables. Spinal fractures occurred almost twice as frequently in those initiating ejection with the seat pan handle as in persons using the face curtain. The incidence of *multiple* spinal compression fracture was higher by a factor of over five for those using the seat pan handle when compared with personnel using the

Figure 10. (Case 133) Injury – Compression fracture T-12 and L-1.
Cause – Out of position at time of ejection.

face curtain. It must be noted, however, that in some cases the secondary handle was used in an extreme situation or when negative G's or some other adverse circumstance forced the survivor out of optimum ejection position. Table 23 summarizes spinal compression injury frequency by aircraft type.

Table 22

Known Spinal Compression Injuries Sustained During Ejection
(POW Group, 106 Cases)

Aircraft	Ejection Speed KIAS	Method of Ejection Seat Initiation	Seat Mod.	Spinal Compression Fractures Vertebrae Injured (Severity)*
RA-5C	550	Face Curtain	HS-1**	T-8(2)
RA-5C	Unk.	Sec. Handle	HS-1	T-10(2)
RA-5C	600	Unknown	HS-1	T-9(1)
F-8	350	Face Curtain	MK-F5	T-12(2)
F-4	420	Sec. Handle	MK-H7	Unk. (2)
F-4	300	Face Curtain	MK-H7	T-12(2); L-1(2)
F-4	Unk.	Unknown	MK-H5	T-11(1); T-12(1)
A-7	325	Sec. Handle	IC-2	L-1(1); L-5(2)
A-6	400	Face Curtain	GRU-5	L-4(2)
A-6	360	Face Curtain	GRU-5	T-10(2)
A-6	400	Face Curtain	GRU-5	T-8(1)
A-4	450	Sec. Handle	Unk.	T-12(1); L-1(1)
A-4	435	Face Curtain	Unk.	L-1(1)
A-4	450	Sec. Handle	Unk.	T-6(1); T-12(1); L-1(1)
A-4	450	Sec. Handle	Unk.	T-11(1); T-12(1)
A-4	300	Sec. Handle	Unk.	T-8(1); T-9(2)
A-4	350	Sec. Handle	Unk.	T-7(2)

*Severity: (1) Major Injury; (2) Minor Injury.
**See Appendix C for seat descriptions. (Unk. = Unknown).

Table 23

Spinal Compression Fractures
During Ejection by Aircraft Type
(106 POW's)

Aircraft Type	Number of Ejections	Spinal Compression Fractures	
		Percent Major or Minor	Percent Major
A-4	40	15	13
A-6	12	17	8
A-7	6	17	17
F-4	27	11	4
F-8	11	9	0
RA-5C	10	30	10

In the prisoner of war group, there were no major double upper extremity injuries which would have made it difficult to initiate ejection. During the ejection through landing phases, however, almost eight percent received major injuries to both upper extremities. The difficulties caused by these injuries were especially critical during the survival and escape and evasion phases, and will be discussed in following sections.

Sixteen of the prisoners of war reported losing their helmets during some phase of the ejection, while three reported removing their helmets during parachute descent. Several of the aircrewmen who lost their helmets suffered minor cuts or facial abrasions, possibly attributable to windblast. None suffered any major facial injuries. The mean ejection speed for those losing their helmets during ejection was approximately 470 knots.

Parachute Opening, Descent, and Landing

There is evidence in several cases that fracture of the jaw, severe face and head riser slap, unconsciousness, and neck injury may have been incurred during parachute deployment. The exact cause of many of these injuries remains unclear and probably will continue so due to difficulties in reporting the exact sequence of events at this time.

Opening shock was the cause of eight individuals sustaining missing or severely torn parachute panels. Six of these aviators, who knew their ejection speed, reported ejecting at speeds greater than 475 knots. The major landing injury rate for survivors sustaining missing or torn parachute panels was approximately 3½ times the rate of those with minimal or no damage to the parachute. Major landing injuries consisted of fractures, sprains, or dislocations to the legs or ankles, some quite severe (see Figure 11). One individual suffered a major double spinal compression fracture (L1 and L3) from landing impact. The relatively low rate of landing injury was perhaps due to the fact that many of the survivors made soft landings in water or water-filled rice paddies.

Escape and Evasion

The period of time between parachute landing and recovery, capture, or death represents the escape and evasion phase. This time interval is shown graphically in Figure 12 for the recovered group and in Figure 13 for the prisoner of war group. For the survivor coming down over land, the first few minutes of escape and evasion are crucial. In the recovered group, the fastest land rescue took 25 minutes. In approximately the same period of time, almost 90 percent of the prisoners of war had been captured. The most frequent cause of capture, which is unfortunately beyond the

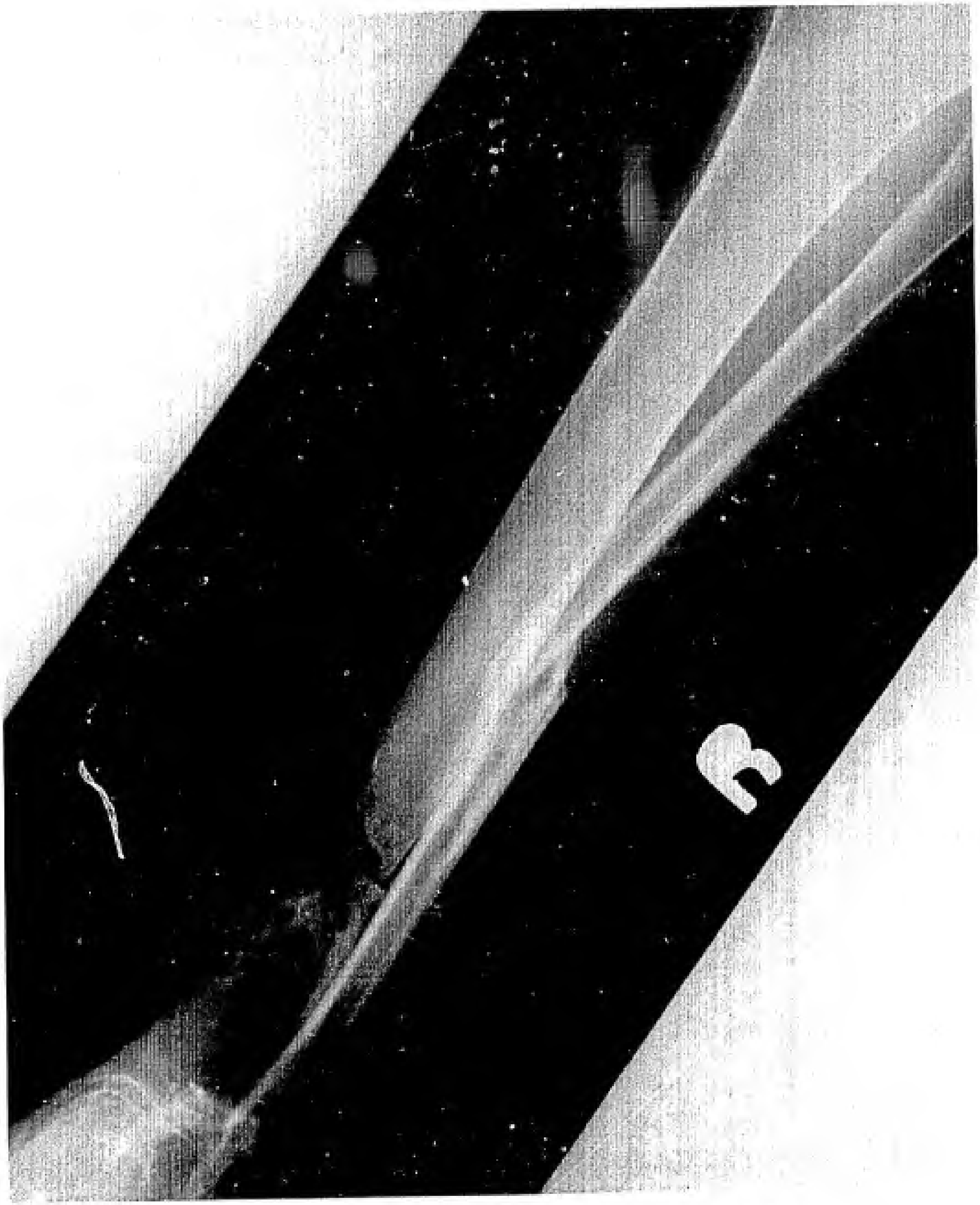
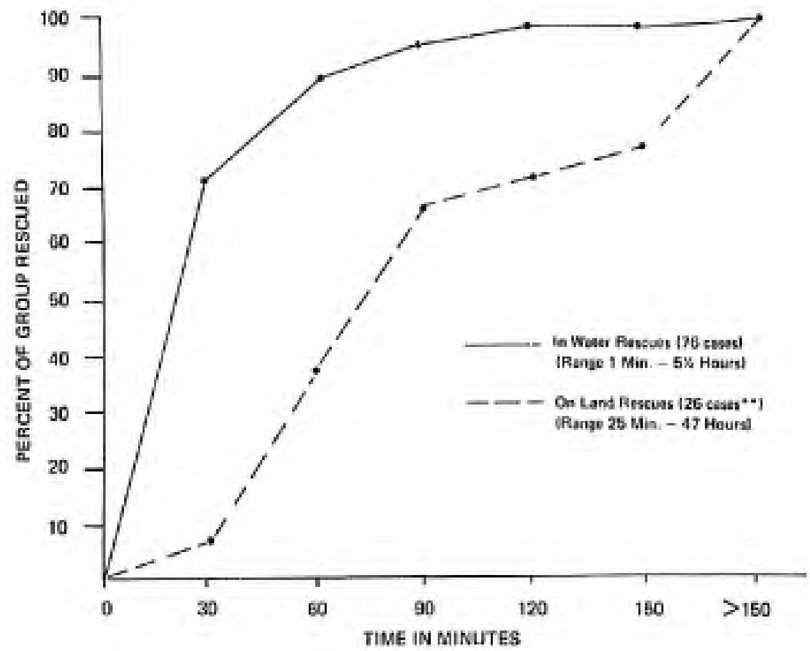


Figure 11. (Case 107) Injury – Double compound fracture of right leg.
Cause – Parachute landing on rocky terrain under windy conditions.

aircrewman's control, is the safeness of the area over which he is forced to eject following a mishap. Ejection location influences several survival factors including distance from friendly rescue vessels, enemy population density, type of terrain, amount of ground cover, and degree of air control.



**Excludes two escaped POW's who were part of this study group.

Figure 12. Comparison of time to effect land rescue versus time to effect water rescue.

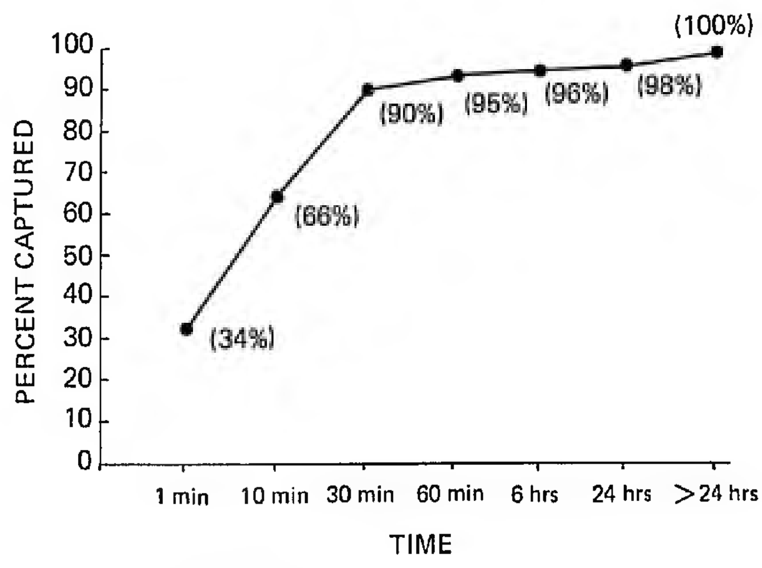


Figure 13. Time until capture for prisoner of war group.

An important variable in escape, that could in theory be more effectively controlled in the future, is the degree of injury sustained by the survivor. This factor has a significant influence on an aircrewman's ability to effectively escape and evade, particularly during the first few minutes after parachute landing.

Unconsciousness may be the most important injury in terms of survival. Nine percent of the recovered group and 16 percent of the prisoner of war group reported being unconscious or dazed during the egress phase of the mishap. Fortunately, most of these individuals came down over land or regained consciousness prior to landing in the water. There are no statistics indicating how many did not regain consciousness or had major injuries to both upper extremities, landed in the water, and drowned because of their inability to inflate life preservers or clear themselves from parachute entanglement.

The large number of lower extremity injuries incurred during the ejection phase of a mishap limited many of the survivors in their ability to effectively escape and evade. Upper extremity injuries caused difficulty for survivors in inflating flotation equipment, extracting themselves from parachutes and anti-G suits, operating signaling equipment, and administering first aid. This was especially true in the prisoner of war group where almost eight percent of the survivors sustained major injuries to both upper extremities.

Any severely injured survivor in enemy territory greatly increases the hazard for search and rescue (SAR) aircraft and crews. During prolonged search and recovery operations, these crews can be subjected to heavy hostile fire. This situation intensifies when a survivor has sustained an injury which renders him unable to assist during the actual recovery. The very nature of combat recovery under "quick in – quick out" conditions exposes injured survivors to a situation where existing injuries may be compounded during the recovery process.

For the captured survivor, any injury takes on special significance, particularly under the conditions that were found in Southeast Asia. Medical treatment to major wounds, if given at all, was generally substandard. Many times, wounds were used for the purposes of torture and, in all probability, many aircrewmen died from what would normally be considered a nonfatal injury. Many of these injuries were so severe that prisoners of war experienced years of agonizing pain, serious infection, and, ultimately, permanent disability. Consequently, when capture and imprisonment are a possible outcome of combat operations, it is important to do whatever one can before the fact to minimize the potential for injury during aircraft escape.

SUMMARY

The combat ejection results in an appreciably higher rate of major injury than does operational escape. Combat injuries are predominantly fractures and dislocations of the extremities due to the Q forces associated with the high speed, relatively low altitude ejection. These injuries, while serious in themselves, also serve to complicate escape and rescue. If evasion is attempted, it frequently results only in compounding the injury.

The extent of ejection injury was compared for the various types of ejection seats used for escape. There was, among the various seat types, a significant difference in the severity of ejection flail injury, which tends to support the need for extremity restraints during high speed escape. The method of initiating ejection appears to have no significant effect on the percent sustaining flail injury. Those aircrewmen using the seat pan handle rather than the face curtain did have an increased injury rate for *multiple* flail injuries and almost twice the rate for spinal compression fractures. Ejection through the canopy resulted in a disproportionate number of severe lacerations. Lacerations and burns seem highly susceptible to infection, especially during escape and evasion in the jungle and during the early stages of captivity.

This study has shown that injuries associated with air combat escape have, both for recovered and prisoner of war groups, resulted in disabilities which adversely affected the use of survival and communication equipment, limited escape and evasion, and jeopardized rescue operations. In an earlier study, it was found that, for pilots fortunate enough to be recovered, over 25 percent could not be returned to flying status before 30 days due to the time necessary for recuperation from injuries. For aircrewmen who became prisoners of war, the consequences of injury were even more severe. In many cases, because of the lack of proper medical attention, they were forced to experience years of pain and, in some cases, permanent disability. But these groups were the successful ones. Undoubtedly, ejection-related injuries were responsible for many of the aircrewmen now classified as missing or killed in action. Many of the injuries to this latter group might well not have been classified even as severe had they occurred under operational conditions. Such injuries, however, in combination with the hostile conditions found in Southeast Asia combat, could easily prove fatal.

Results of this investigation demonstrate that the conditions under which a disabled aircraft is abandoned in combat are appreciably different from those found in noncombat operational flying. As a consequence, combat injuries are more serious and more extensive. The increased injury pattern, in turn, lessens the likelihood of successful evasion and rescue. Therefore, for moral as well as economic reasons, every consideration must be given to improving the conditions responsible for combat escape injuries in order to better the chances of survival for Navy aircrewmen.

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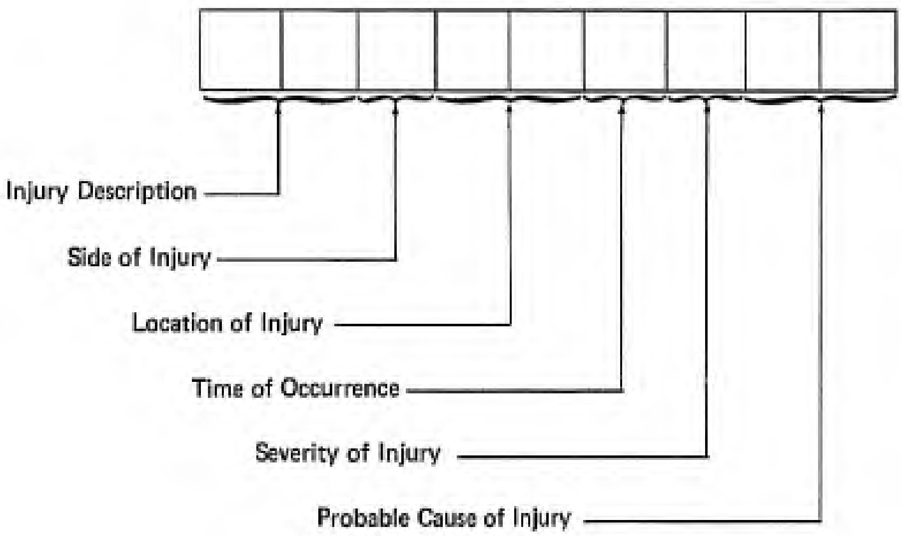
APPENDIX A

MEDICAL CODING FORMAT

Escape injuries were coded utilizing the following information



Injury Description

Abrasions	01	Fracture, Compound (displaced)	14
Amputation	02	Lacerations	15
Bite	03	Shock	16
Blindness	04	Sprain or Strain	17
Burn	05	Tear of Muscle or Tendon	18
Blast Injury	06	Tear of Ligament	19
Concussion	07	Unconsciousness	20
Contusion or Bruise	08	Wound, Gunshot or Fragment	21
Crushing Injury	09	Wound, Other	22
Cuts and Scratches	10	Spinal Compression Fracture	23
Dislocation	11	Unknown	98
Division of Nerves	12	No Answer or None	99
Fracture, Simple (undisplaced or unknown)	13		

Side of Injury

Right	1	Both	4
Left	2	No Answer	9
Not Applicable	3		

Specific Location

Head, Cranium	0100
Face	0200
Neck, nonvertebral	0300
Vertebral (column) (Vert. Not Spec.)	0400
Cervical (7)	0401 – 0407
Thoracic (12)	0408 – 0419
Lumbar (5)	0420 – 0424
Coccyx or Sacrum	0427
Shoulder (Clavical Scupula Area)	0500
Chest or Back	0600
Ribs or Sternum	0700
Arm (Specific Area Unknown)	0800
Humerus	081
Elbow	0820
Radius	083
Ulna	084
Wrist	0900
Fingers or Hand	1000
Hip (Ilium and Ischium)	1100
Leg (Specific Area Unknown)	1200
Femur	121
Knee	1220
Tibia	123
Fibula	124
Ankle	1300
Foot Bones or Foot	1400
Back (Torso)	1500
Front (Torso)	1600
General (All Over)	7777
Not Applicable	8888
No Answer or None	9999

See Vert. Col. Code Next Page

Proximal	1
Medial	2
Distal	3
No Ans.	4

Vertebral Column Codes

Cervical	Thoracic
C – 1 = 0401	T – 1 = 0408
C – 2 = 0402	T – 2 = 0409
C – 3 = 0403	T – 3 = 0410
C – 4 = 0404	T – 4 = 0411
C – 5 = 0405	T – 5 = 0412
C – 6 = 0406	T – 6 = 0413
C – 7 = 0407	T – 7 = 0414
Lumbar	T – 8 = 0415
L – 1 = 0420	T – 9 = 0416
L – 2 = 0421	T – 10 = 0417
L – 3 = 0422	T – 11 = 0418
L – 4 = 0423	T – 12 = 0419
L – 5 = 0424	

Time of Injury

Pre-Ejection	1	After Landing During Survival	5
During Ejection (Prior to Chute Deploy)	2	During Capture	6
		Unknown	7
During Descent (Prior to Landing)	3	Unknown — Probable During Ejection	8
During Landing (Prior to Getting Rid of Chute)	4	No Answer	9

Severity of Injury

Major	1	None	3
Minor	2	No Answer or Unknown	9

Probable Cause of Injury

Ejection Seat Rocket "G" Forces	01	Parachute Entanglement	09
Struck Equipment	02	Impact with Ground	10
Equipment Malfunction	03	Fire in Cockpit	96
Loss of Equipment	04	Enemy Inflicted	97
Flail	05	Unknown	98
Parachute Opening Shock	06	No Answer	99

APPENDIX B

CRITERIA USED FOR INJURY CLASSIFICATION
(Extracted from OPNAVINST 3750.6G)

INJURY CLASSIFICATIONS

(To be used with Form BTI 72-No.)

Major Injury – Any injury requiring five days or more hospitalization and/or "sick in quarters." Also any of the following, regardless of hospitalization/sick in quarters time:

1. Unconsciousness due to head trauma (transient unconsciousness due to hypoxia, hyperventilation, G Forces, etc., are not to be classified as injury).

2. Fractures of any bone except simple fracture of nose or phalanges.

3. Traumatic dislocation of major joints/internal derangement, of the knee.

4. Moderate to severe lacerations resulting in severe hemorrhage, or extensive surgical repair.

5. Injury to any internal organ.

6. Any third degree burns. Any second degree burns involving more than five (5) percent of the body surface. Any friction burn regardless of degree that requires less than five days hospitalization or "sick in quarters" is classified as a minor injury.

Minor Injury – Any injury less than major which:

1. Results in the loss of 24 hours from full performance of regularly assigned duties, but less than five days.

2. Results in loss of regular working time for civilians beyond the day or shift on which injury occurs.

3. Hospitalization for observation not to exceed 48 hours from the time of admission is not classified as an injury.

No Injury – Minimal injuries which do not meet the criteria for minor injury.

APPENDIX C

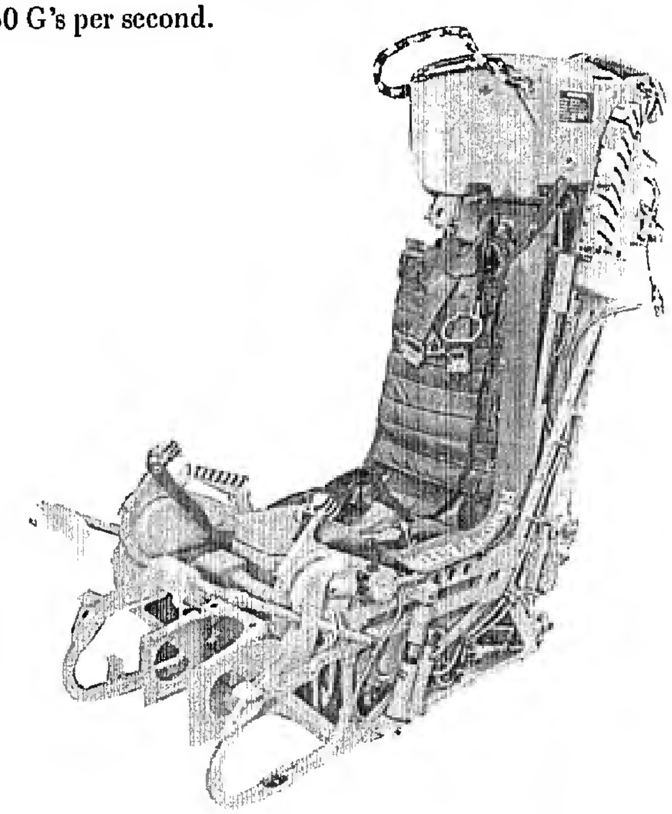
DESCRIPTIONS OF EJECTION SEATS UTILIZED IN AIRCRAFT DISCUSSED IN THIS STUDY

North American Rockwell Ejection Seat, HS-1 and HS-1A

North American Rockwell HS-1 and HS-1A ejection seats currently used in the RA-5C aircraft provide an escape envelope at ground-level from speeds of zero velocity to 750 KIAS. The ejection thrust of the HS-1 seat is provided by a single-unit catapult rocket. During ejection, the catapult portion fires first, thrusting the seat clear of the cockpit; the rocket portion then ignites to provide continued thrust. Positive parachute extraction is provided with the NB-7E parachute which has been modified to incorporate the Stencil ballistic spreader gun.

The North American Rockwell seat possesses a rigid leg restraint system. During the initial phase of seat ejection, leg positioning and restraint and positioning of the lower torso are accomplished by lowering the seat bucket to bottom, lifting the knees, and locking the feet in foot wells. The knee-raising bar contacts the legs behind the knees. As the knees are lifted, the feet fall into the foot wells which are closed by hooks. If acceleration is being experienced, such that the feet will not fall into the wells, the closure hooks contact the lower legs pushing the feet into the wells.

In order to increase the trajectory altitude during straight and level flight, the catapult portion of the rocket in the HS-1A seat has been modified, increasing the impulse. This modification increases maximum acceleration from 12 to 20 G's. The rate of acceleration onset increases to approximately 250 G's per second.

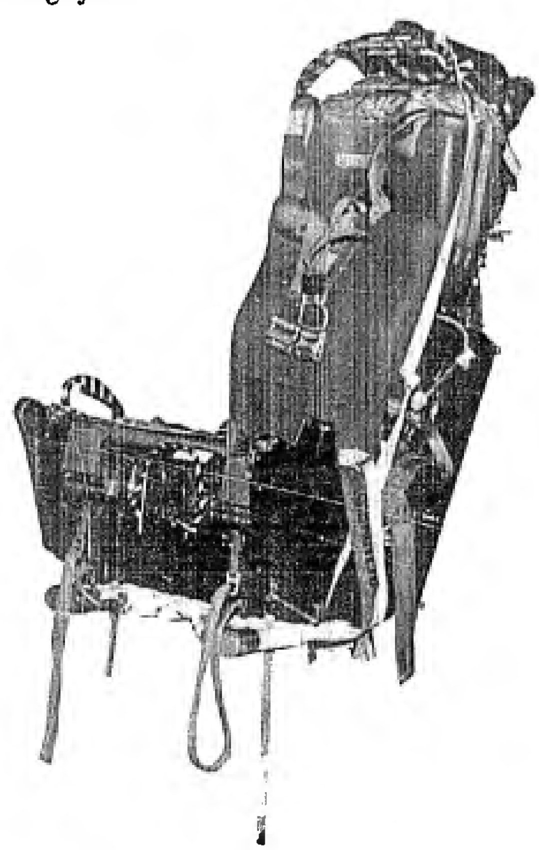


Martin-Baker Ejection Seat, MK-5 and MK-7

Aircraft	Cartridge System	Rocket Pack
F-4	MK-H5	MK-H7
F-8	MK-F5	MK-F7
A-6	MK-GRU5	MK-GRU7

The low-level capability of the Martin-Baker MK-5 ejection seat is obtained through the use of a three-cartridge pyrotechnic, telescoping, long-stroke ejection gun which achieves an 80-foot per second seat ejection with maximum accelerations of 15 to 18 G's. Drogue parachutes are used to stabilize and decelerate the seat and to deploy the main parachute. This parachute, manufactured by Martin-Baker, has a 28-foot canopy and is positioned behind the crewman's shoulders. The leg restraint system consists of a garter worn by crewmembers, leg restraint lines with lock pins, snubber unit, and shear fitting secured to the floor.

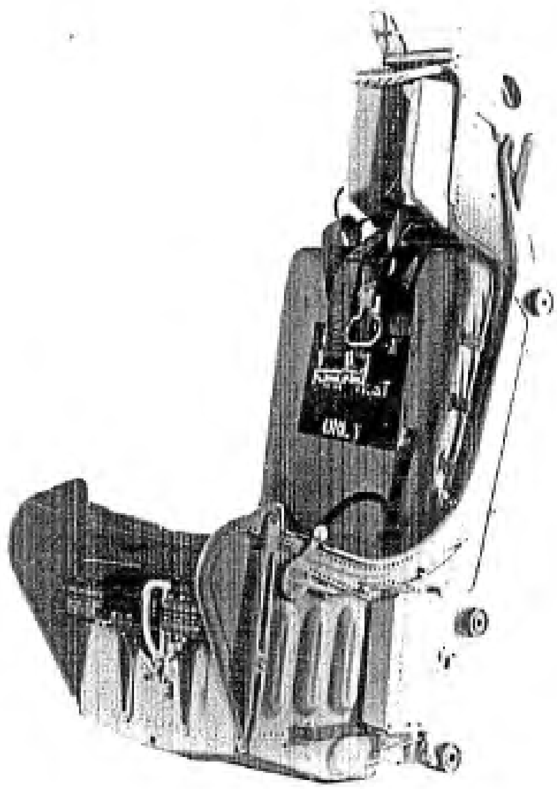
The MK-7 seats differ from the MK-5 primarily through the addition of a rocket pack. The ejection gun used in the initial catapult contains cartridges of reduced charge to lessen acceleration forces acting on the spine during ejection.



Douglas Escapac Ejection Seat, Series 1A through 1G

The Series 1C Escapac seat was the predominant seat used in A-4 and A-7 aircraft during Southeast Asia operations. This seat allows escape, during level-flight conditions, from zero altitude and from zero speed through 600 KIAS. The seat's ejection thrust is provided by a two-stage rocket catapult. Maximum acceleration with this system is approximately 12 to 15 G's. The rate of acceleration onset is approximately 250 G's per second. the NB-10 parachute has a 28-foot flat, circular canopy and is opened with an automatic release opener. Seat system stabilization is achieved during the initial part of the trajectory through a system consisting of two braking devices attached to the seat bottom which maintain constant tension on the nylon lanyards being played out as the seat rises. No Douglas Escapac seats are equipped with arm or leg restraints.

The primary differences between the currently-used 1G seat and the older 1C seat are that the 1G seat uses a lower impulse rocket catapult, employs a ballistic spreader gun in the parachute and has a rocket seat separator instead of nitrogen-inflated bladders.



APPENDIX D

COMPUTER PRINTOUT OF SEVERITY OF EJECTION FLAIL INJURIES VERSUS ESCAPE CONDITIONS

(POW's with known escape speeds)

Injury Codes

Injury = Degree of Ejection Flail Injury

1 = Major

2 = Minor

3 = None

Q-Forces = Newtons/M^2

EJ METH: Method of Ejection Seat Initiation

2 = Face Curtain

3 = Seat Pan Handle

9998 = Unknown

IAS = Ejection Speed in KIAS.

POW DATA---EJECT Q-FORCES IN DEC. ORDER

RTI NUM	INJURY*	EJECT-Q	MISHAP-Q	A/C TYPE	EJ METH	I.A.S.
56	1	87396.	87420.	RA-5C	3	735
131	3	67897.	49151.	F-4	3	645
54	1	66282.	72673.	RA-5C	2	640
24	1	62253.	40698.	RA-5C	2	620
28	3	61616.	61616.	RA-5C	9998	615
44	2	59421.	83906.	RA-5C	3?	600
100	1	58302.	58617.	RA-5C	8	600
34	1	58302.	58265.	F-4	3	600
111	3	53562.	12240.	F-8	2	575
4	1	49664.	49664.	A-4	2	550
85	3	44397.	77229.	F-8	2	500
77	3	43766.	43822.	F-8	3	520
71	3	42972.	28682.	A-4	2	515
63	2	40863.	44904.	F-4	2	500
132	3	40685.	40464.	F-4	3	500
73	3	40501.	21276.	A-6	2	500
42	1	40501.	40572.	A-4	2	500
72	1	40497.	40455.	A-4	2	500
105	2	40497.	19827.	A-4	3	500
115	1	40497.	40501.	A-4	3	500
47	3	40473.	40444.	F-8	2	500
95	3	40464.	40928.	F-4	2	500
6	3	40464.	40867.	F-4	3	500
20	1	40462.	32795.	A-4	2	500
83	3	40462.	26194.	F-4	3	500
57	1	40454.	58493.	RA-5C	2	500
5	3	40454.	40454.	A-4	2	500
32	1	40444.	40462.	F-4	3	500
130	3	39812.	40650.	F-4	2	495
66	1	38870.	38843.	A-4	3	490
62	3	37314.	40455.	F-4	3	480
114	1	36574.	32769.	A-4	9998	475
43	3	36540.	32795.	A-4	2	475
41	3	33152.	38893.	F-4	2	450
2	3	33012.	33152.	A-4	3	450
134	3	33012.	33052.	F-4	2	450
64	3	32863.	32902.	F-4	3	450
31	3	32825.	25936.	F-8	2	450
101	3	32809.	32809.	A-5	2	450

*Two (2) Major Flail Injuries were incurred where ejection speed was unknown.

POW DATA---EJECT Q-FORCES IN DEC. ORDER

BTI NUM	INJURY*	EJECT-Q	MISHAP-Q	A/C TYPE	EJ METH	I.A.S.
74	1	32795.	32795.	A-4	3	450
17	3	32795.	33425.	A-4	3	450
88	3	32783.	32825.	F-8	2	450
50	3	32776.	32776.	A-6	2	450
30	3	32769.	32774.	F-8	2	450
96	1	32760.	25923.	A-7	2	450
15	3	30652.	29242.	A-4	2	435
36	1	28915.	35961.	F-4	3	420
117	1	28797.	28797.	A-6	2	420
82	3	28716.	28961.	A-5	2	420
14	3	28577.	28550.	A-5	2	420
3	3	27320.	28569.	F-4	2	410
12	3	26409.	25891.	A-6	2	400
78	1	26126.	19997.	A-4	2	400
102	3	26120.	27370.	A-7	2	400
37	3	26072.	29425.	A-6	2	400
129	3	25920.	40462.	PA-5C	2	400
138	3	25920.	22244.	A-7	2	400
10	3	25912.	99999.	A-4	9998	400
121	3	25903.	25920.	A-4	3	400
39	3	23479.	23479.	F-4	3	380
29	3	23361.	23361.	A-6	2	380
46	3	22774.	25884.	A-4	3	375
49	3	20993.	20996.	F-4	2	360
25	3	20966.	20966.	A-6	2	360
107	3	20004.	99999.	A-4	3	350
33	3	19960.	19960.	A-4	2	350
135	3	19904.	19918.	F-8	2	350
137	3	19857.	17114.	A-5	9999	350
112	3	19857.	19845.	A-4	2	350
110	3	19839.	19839.	F-8	2	350
125	1	19839.	27598.	A-4	3	350
22	3	19823.	19827.	A-6	2	350
128	3	17195.	36574.	F-4	2	325
92	3	17092.	40464.	A-7	3	325
76	3	14856.	14664.	A-4	3	300
113	3	14691.	17210.	F-4	2	300
80	3	14623.	6567.	A-4	3	300
11	3	14586.	22750.	F-8	2	300
136	3	14586.	40462.	F-4	2	300

*Two (2) Major Flail Injuries were incurred where ejection speed was unknown.

POW DATA---EJECT Q-FORCES IN DEC. ORDER

RTI NUM	INJURY*	EJECT-Q	MISHAP-Q	A/C TYPE	EJ METH	I.A.S.
106	3	14579.	32774.	A-4	3	300
26	1	14560.	25912.	A-4	2	300
58	3	12251.	14589.	A-4	2	275
99	3	11988.	99999.	A-7	2	250
91	1	10118.	32769.	A-4	2	250
8	3	10116.	19960.	F-4	2	250
27	3	10115.	19823.	A-4	2	250
120	3	10114.	14741.	F-4	3	250
84	3	8106.	28600.	F-4	3	225
126	3	7887.	32825.	A-4	3	220
87	3	7171.	15326.	A-4	3	210
65	3	6530.	32810.	A-4	3	200
51	3	6518.	14735.	A-7	2	200
109	3	6499.	33056.	F-4	3	200
61	3	5850.	26410.	A-4	2	190
48	3	5348.	20993.	F-8	3	180
97	3	5243.	32819.	A-4	2	180
67	3	1620.	26070.	F-4	2	100

*Two (2) Major Flail Injuries were incurred when ejection speed was unknown.

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Navy Prisoners of War
Air Combat Escape
Aircraft Ejection
Southeast Asia Air Combat
Aircraft Escape Equipment
Aircraft Escape Injuries

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

in Southeast Asia

The experiences of aircrewmen forced to eject during combat operations in Southeast Asia represent a unique and invaluable data bank against which to evaluate the procedures and equipment used for aircraft escape, survival, and rescue. Detailed event conditions and, to the extent possible, specific medical injury data now have been collected for Navy aircrewmen who ejected and were recovered, or became Prisoners of War. Initial analyses (previously reported) show the combat ejection, and consequently the associated injuries, to be appreciably more severe than encountered during non-combat operations.

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Additional analyses now have been conducted, primarily with repatriated Navy Prisoners of War, to establish some precise cause and effect injury relationships associated with high speed escape. The effect of escape injuries on subsequent evasion and survival is examined.

Special attention is given to the effectiveness of escape, personal protective, and life support equipment. The adequacy of this equipment is evaluated in terms of an individual's injury condition and his success in using such equipment under the arduous conditions of combat escape, survival, rescue and capture.