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Positions Brace Passengers for Impact To Reduce Injuries and Fatalities

Flight attendants can help passengers survive aircraft accidents with less serious injuries if they properly brief them on the recommended brace positions and urge the passengers to use the positions during a real emergency. Evidence indicates that the brace positions can make the difference between surviving or not surviving an aircraft crash.

by

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The importance of brace positions in reducing injuries during aircraft accidents has been well documented. The positive effects of "brace-for-impact' positions are evident in the following three accidents that involve the DeHavilland DHC-6 Twin Otter.

The aircraft carrying eight passengers and two crewmembers, crashed on approach to Cape May County Airport, N.J., U.S., on Dec. 12,1976. There was no warning prior to impact. A 19 year-old passenger, seated in the second row of seats, had lowered his head between his legs because he was airsick. He sustained only minor injuries while three passengers, seated beside him and in the row in front of him, suffered fatal head and chest injuries during the impact.

Another accident occurred on Dec. 4, 1978, when the aircraft, carrying 20 passengers and two crewmembers, crashed into snow-covered mountains near Steamboat Springs, Colo., U.S. One passenger and one crewmember died, while 14 other occupants sustained serious impact injuries. Although there was no warning, a frightened 26-year-old passenger seated in the center of the cabin took a brace position. She received only minor injuries; several other passengers seated nearby were seriously injured.

The third accident occurred on approach to the Knox County Regional Airport, near Rockland, Maine, U.S., on May 30, 1979. The aircraft was carrying 16 passengers and two crewmembers. Again, no warning was given. A 16-year-old boy seated near the rear of the plane was looking out the window, and saw that the aircraft was going to crash into the trees. He immediately lowered his head and took a brace position. His seat, along with most of the other seats on the plane, was torn loose from the floor during the impact. However, he suffered only a fractured wrist and leg, and a scalp wound. The other 17 occupants were killed.

Following these accidents, the U.S. National Transportation Safety Board (NTSB) recommended that the U.S. Federal Aviation Administration (FAA):

1. Establish a research project to determine the optimal brace position for various seat designs and seating configurations used in passenger-carrying operations.

2. Issue guidance information to the air carriers to insure that crewmember training includes information on the appropriate passenger brace positions and that the appropriate emergency brace positions are described on the passenger briefing card (1).

Research Aims At Prepositioning The Body

FAA has performed extensive research on brace-for-impact positions with the use of anthropomorphic dummies. Secondary impact, the impact involving a body segment, such as a head, and whatever it comes into contact with has also been thoroughly studied (2).

Simply stated, the goal of the brace-for-impact position is to pre-position the body against whatever it is most likely to hit during the crash, and prevent a secondary impact. Although this goal is simple, the conditions that can exist in aircraft operations have resulted in misunderstandings, and doubts, and have raised many questions regarding the best brace-for-impact positions.

Richard F. Chandler, Chief of the Protection and Survival Laboratory at the FAA's Civil Aeromedical Institute, recently addressed many of these questions in *a paper, Brace-for-impact* Positions.

Best Position Varies

According to Chandler, the best brace-for-impact position for each occupant of an aircraft will depend on many factors, such as the environment of the crash (magnitude, direction and sequence of crash forces), the layout of the interior configuration of the aircraft within the strike envelope of the occupant, the design and use of the seat-restraint system provided to the occupant, and the size and physical characteristics of the occupant. Obviously, with so many factors involved, it is impossible to describe a single, simple brace-for-impact position which would be best in every case. Fortunately, it is possible to identify a few general principles which will allow an appropriate brace-for-impact position to be selected on the basis of those factors which can be predetermined.

Positions Aimed To Avoid Secondary Impact

Chandler further "plains that the primary goal for the brace for-impact position is to reduce the effect of secondary impact of the body with the interior of the aircraft. Secondary impact can be reduced by pre-positioning the body, or individual body segments like the head, against whatever interior surface it would be likely to impact during the crash. The effects of flailing can be reduced by having occupants pre-position their bodies in the direction their bodies are likely to be driven by inertia during the impact.

Understanding these two principles, and making a careful assessment of the environment around the occupant, will aid in selecting an appropriate brace-for-impact position for any configuration.

Chandler reminds us that certain basic guidelines still apply to all configurations. The seat belt should always be located low on the torso, just above the legs. It should be adjusted after the occupant has pushed back in the seat so that the lower torso is firmly against the seat back. The more tightly the seat belt is adjusted, the better restraint it will provide.

The occupant's feet (unless the occupant is a crew member who must use the feet for aircraft control) should be placed firmly on the floor, slightly in front of the edge of the seat. Passengers should not attempt to put their feet on the seat in front of them and brace with their legs, because this could double the loads acting on that seat. The seat is not designed to accept these additional loads and it would be likely to break. The legs should not be wedged under the seat in front because the legs may act as levers trying to pry the seat off the floor, and this could break the legs of the seat or the passenger, during impact.

Passengers should not use pillows or blankets between them and any object they would brace against unless they are designed for that purpose. Pillows and blankets are usually not designed to absorb energy or distribute impact loads over the body, and they could increase the likelihood of injury by giving a false impression that the body is being properly supported. Also, pillows and blankets may become loose during the impact, no matter how hard the passenger tries to hold on to them, and would create additional clutter in the aisles of the aircraft cabin which could impede an emergency evacuation.

Using the principles and guidelines described above, Chandler has defined the appropriate brace-for-impact positions for the following configurations.

Forward Facing Seats with Safety Belt Restraint

The occupant should bend forward, over the snug seat belt. Place the hands and arms so that they are between the head and any contact surface ie., the seat back or other part of the aircraft interior. This provides a "pad" to support the head (Figure 1).

Figure 1

As long as the hands and/or arms act as a pad to support the head their exact placement is not important.

Pushing on the seat back with out-stretched arms and head tucked is not sufficient. The arms won't support the head effectively and the upper torso is away from the structure which could provide it support. If resting against a seat back with a "break-over feature", the occupant may get slightly better support if the seat can be folded over until it stops or until it rests gently on the occupant in front. However, even if this is not done, good support will still be provided by the seat back as it folds forward of its own inertia during the impact, and is followed by the arms and head. The arms and head will slide down the seat back as it folds, but they shouldn't be seriously injured. Passengers must be cautioned against holding the edge of the seat back with their fingers.

If the seat is located so that the head will not contact any portion of the aircraft interior as the occupant bends forward over the seatbelt, the occupant should continue to bend forward and rest the upper torso against the upper legs. The head should be tucked down, and not twisted to one side. Twisting the head will twist the neck, and this reduces the ability of the neck to withstand the loads it will encounter during the impact. Flailing of arms may be reduced in low level impacts if the occupant grasps his/her ankles or legs (Figure 2 and Figure 3).

Figure 2

Figure 3

In some aircraft, the interior of the plane or the forward seat is too far away to provide a secure support for the head and upper body, but still be close enough to come into contact with the head during an impact. Data at CAMI show that the head strike envelope for a 95th percentile male will extend 40 inches to 42 inches in front of the intersection between the seat cushion and the seat back ("seat reference point'). For example, if the seat or interior is 38 inches away, it will be too far away to provide support for bracing for the impact, but will still be a potential source of secondary impact for the occupant. There is no completely satisfactory brace-for-impact position in this situation. Chandler suggests grasping ankles or legs and keeping the head well tucked in.

Rear Facing Seats with Seat Belt Restraint

Passengers in rear facing seats should push themselves back into the seat and tighten the seat belt. They should sit upright with their head firmly against the headrest. Their lower arms should be placed on the arm rests. This may help to support the upper body and reduce loads in the spinal column. If arm rests are not available, arms should be positioned with hands on thighs or clasped in front of the waist. Feet should rest flat on the floor. Clasping hands behind the head is not recommended because this may increase stress on the neck due to the mass of the arms and the hands as they react to the impact if the aircraft yaws during the impact.

Side Facing Seats with Seat Belt Restraint

Side facing seats without lateral support for the whole body, including legs, do not provide good protection from impact loads. Legs will twist sideways during impact, and twist the spinal column. The spinal column will also be bent sideways, and compressed as the torso flexes laterally and receives vertical impact forces.

This combination of loading can generate high stresses in the spinal column, perhaps causing fractures and spinal cord injury. It is difficult to reduce the injury potential of this seat configuration because the sideways twisting of the legs cannot be easily prevented. The best protection would be to sit facing forward in the seat and bend over the seat belt until the upper torso and head are resting on the legs, and wrap the arms around the legs. If there is not adequate space for this brace-for-impact position, then the passenger must lean towards the front of the aircraft, and rest the upper torso and head against whatever might be contacted.

Forward Facing Seat with Seat Belt and Shoulder Harness

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The occupant of a forward facing seat with a seat belt/shoulder harness restraint system should adjust the seat belt tightly after pushing back in the seat so that the lower torso is firmly against the seat back. If the shoulder harness has manual adjustments, it should then be adjusted so that it is tight. If non-locking retractors are used on the webbing, the webbing should be pulled all the way out, and adjusted with the manual adjustment fittings provided.

If non-automatic locking retractors are used, the webbing should be pulled out until the locking system is actuated, and then fed into the retractors until the restraint is tight. If the shoulder harness is equipped with automatic locking retractors (inertia reels), any extra slack in the webbing of the shoulder belts should be taken out and fed into the reel. The webbing should always be flat against the body, and not twisted as it goes into the retractor. The occupant's head should be tucked down as far as possible, to try to eliminate secondary impact of the shin with the sternum (Figure 4).

Figure 4

The occupant's hands can either be clasped and placed in the lap; clasped to the front edge of the seat (without locking the elbows or wrists); or the occupant can sit on the palms of the hands. According to Chandler, all of these hand positions are effective in most circumstances.

The occupant must not hold the restraint system with the hands. This can introduce slack into the system, especially if it is equipped with an automatic locking retractor, and any slack will tend to increase injury. Feet should be firmly placed flat on the floor slightly in front of the forward edge of the seat This will prevent the front edge of the seat from catching the back of the lower legs in the event that the clearance between the seat and floor is reduced during the impact.

Rear Facing Seat with Seat Belt and Shoulder Harness

Brace-for-impact position for the occupant of a rear facing seat with seat belt/shoulder harness restraint system is the same as for a forward facing seat with seat belt/shoulder harness restraint system, except that the head should be placed firmly against the head rest (Figure 5).

Figure 5

Side Facing Seat with Seat Belt and Shoulder Harness

Instructions provided earlier for side facing seats with seat belt restraint also apply here, except for the limitation in upper **torso** movement provided by the shoulder harness. Unless legs are given full support by a sufficient lateral support surface, which is part of the seat or aircraft interior, they are likely to twist sideways and compound the stress on the spinal column. No brace-for-impact position has been devised to prevent this movement. Possibly the only benefit that a brace position could provide is to move the head in the direction of the anticipated impact to help reduce head flailing.

Helicopter Seat/Restraint Installations

Occupants in seats in rotary wing aircraft should take the same brace-for-impact positions as they would in conventional **air**craft. The impact direction of a rotary wing aircraft is difficult to predict, so optimum brace-for-impact position is also difficult to establish. If the impact should generate extremely high vertical forces, serious injury may not be reduced by the brace position. Inertial reactions of the head or of internal body organs cannot be effectively controlled by bracing, and can cause serious or fatal injuries. Sophisticated energy absorbing seat/restraint systems can be used to reduce the probability of injuries due to vertical impact loads to some extent. However,

according to Chandler, these seat/restraint systems have not yet seen widespread use in civil aircraft.

Children

Children seated in passenger seats should follow the same procedures to brace-for-impact as previously described for adults. Because of their smaller stature, the flail envelope of children is smaller than that of adults and so they are less likely to suffer secondary impact with the interiors of the aircraft.

Seat belts in most passenger seats are installed so that they can provide effective restraint for the child with little chance of moving into the child's abdomen. The seat belt buckle is usually located so that it will be at the side of a small child when it is tightened, reducing the likelihood of injury from contact with the buckle. The belt should be placed low on the child's torso, just above the legs. If the seat belt cannot be adjusted so that it is tight on the child, pillows or blankets can be placed behind the child to aid in moving the child into the tightened belt.

It is important for small children to bend forward over the seat belt, and rest their head on the seat cushion between their legs, or to bend their head forward, over the edge of the cushion, as appropriate for their height. This is done to reduce head flailing, which might result in secondary head impact with the front or bottom of the seat.

Children seated in an approved child restraint systems should not be removed from those systems in preparation for a planned emergency landing. Children seated in approved child restraints should be braced in accordance with the instructions of the manufacturer of the child restraint, if any such instructions are provided. (Approved infant seats usually provide even support to the infant's torso and head, so no additional brace for-impact efforts are necessary.) Because of the wide variety of child restraints available, and because these restraints are usually provided by the child's parents, it should be sufficient to alert parents to the need for bracing so that they can instruct the child.

Children who are being held by adults should be held in a manner that will support the child's head and torso as evenly as possible. The adult should then bend forward, over the seat belt, so that the child is held in the space formed between the adult's torso, legs and the forward seatback. Both arms should hold the child to provide as much support as possible. While it is unlikely that a child could be safely held by an adult in a severe impact, there is presently little evidence to show that a child held by an adult is at unusual risk in an impact of a civil aircraft where the area surrounding the adult/child pair maintains a survivable environment.

According to Chandler, alternative brace-for-impact positions for a child have been used successfully in the past and would work if everything happened as planned. However, unplanned events could increase the possibility of injury to the child. For example, a frequent suggestion is that the child be rolled up in a blanket, and held supine at the intersection of a bulkhead and the floor. This technique would provide even load distribution over a large area of the child's body, and should help to reduce injury. However, if the adult holding the child in place were to transfer his own body inertia to the child during the impact, or if the impact had a lateral component of force which would cause the child to slide along the floor into the aisle, the child could be severely injured. An adult and child should not share the same seat belt because the adult may crush the child against the belt.

Special child belts and harnesses which attach to the adult's seat belt and are intended to position the child in the adult's lap generally do not protect the child from crushing between the adult's torso and legs as the adult flails over the seat belt. These child belts/harnesses can also concentrate the restraint forces on the child's abdomen, an area particularly sensitive to internal injuries. This situation is sometimes worsened by placing a conventional buckle on the child belt at a location where it could cause internal abdominal injuries to the child as the child bends around the belt. These devices provide no support for the child's head, and provide no protection from neck injuries which could result in head flailing. For these reasons, the use of these devices is not recommended and they are not currently considered to be approved child restraint systems.

Handicapped or Pregnant Passengers

The brace positions for handicapped or pregnant occupants of an airplane are the same as those recommended for other occupants. Assistance should be offered if necessary. Pregnant women should be instructed to place the seat belt low, below the abdomen, so that it applies its forces to the pelvis. If rearward facing passenger seats are available, handicapped or pregnant passengers should be relocated to those seats to take advantage of a brace position more effective for their condition.

References

1. Safety Recommendations (1979) A-79-76 through A79-78. National Transportation Safety Board. Washington, D.C., U.S. issued Oct. 4.

2. Swearingen, John J., (1966) "Evaluation of Head and Face Injury Potential of Current Airline Seats During Crash Decelerations." Report No. AM 66-18. Federal Aviation Administration, Office of Aviation Medicine, Civil Aeromedical Institute, Oklahoma City, Okla., U.S. June.

3. Air Carrier Operations Bulletin (1982) No. 224 (1-7623) "Brace-for-impact Positions". Federal Aviation Administration, Washington, D.C., U.S. Revised Nov. 18.

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