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A Unique Contact Lens-Related Airline Aircraft Accident

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16. Abstract

INTRODUCTION. The use of contact lenses to satisfy the distant visual acuity requirements for obtaining a civil airman medical certificate has been permitted since 1976. According to the Federal Aviation Administration's "Guide for Aviation Medical Examiners," the use of monovision contact lenses is not considered acceptable for aviation duties. An aviation accident involving the use of monovision contact lenses will be reviewed.

METHODS. A case report is presented utilizing information from a National Transportation Safety Board (NTSB) aircraft accident report (NTSB/AAR-97/03) of a nonfatal scheduled airline accident. Past studies that examined the use of contact lenses in the aviation environment are reviewed.

RESULTS. On October 19, 1996, a McDonnell Douglas MD-88 aircraft, Delta Airlines Flight 554, was substantially damaged in an undershoot approach while landing at LaGuardia Airport, Flushing, NY. Weather observations indicated a broken cloud layer at 800 feet, visibility between 1/2 and 1 mile in heavy rain and fog or mist, and easterly winds at 12 to 14 knots. The approach was over water to Runway 13 and the flight crew transitioned to visual references just above the decision height. As the airplane continued to descend, it struck an approach light structure and the end of the runway deck, shearing off the main landing gear and slid 2,700 feet down the runway. During an emergency evacuation, 3 passengers received minor injuries.

CONCLUSION. The NTSB determined that the probable cause of this accident was the inability of the pilot to overcome his misperception of the airplane's position relative to the runway, due to the use of monovision contact lenses. The adverse effects of wearing contact lenses in the aviation environment are discussed. Research is recommended to better understand the effects of environmental conditions on monovision to validate the current policy on such corrections.

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INTRODUCTION

The use of corrective ophthalmic lenses is more prevalent in older pilots. In a study of U.S. Air Force pilots, about 50% of aviators between the ages of 41 and 45 wore eyeglasses, while approximately 90% of those over age 45 wore spectacles (1). In 1977, airmen $\geq$ 40 years of age comprised only 38.8% of the civilian airman population, and about 42.8% had a vision restriction. By 1997, airmen age 40 and over comprised more than 59% of the population and 56.0% of airmen had a vision restriction for flying (2).

The use of eyeglasses to correct refractive error may have disadvantages for pilots. Spectacle frames can reduce the field of vision, be uncomfortable when not properly fit, displace during flight maneuvers (G-forces), and be incompatible with headsets and other communication devices as well as protective breathing equipment. Spectacle lenses may also become dislodged inflight and fogging can occur with changes in air temperature. Additionally, adapting to multifocal spectacle lenses may be difficult for the pilot, as the older aviator often requires special prescriptions for the unique visual demands of the cockpit.

Prior to 1976, civilian airmen were not allowed to use contact lenses while flying unless a waiver, i.e., Statement of Demonstrated Ability (SODA), was issued by the Federal Aviation Administration (FAA). As of December 21, 1976, Amendment 67-10 to the Federal Aviation Regulations permitted the routine use of contact lenses to satisfy the distant visual acuity requirements, eliminating the need for the SODA process (3). Contact lenses have inherent advantages for pilots, including: more natural vision, full field of vision, no lens fogging or water droplet accumulation, no discomfort due to weight, and no annoying obstruction from the frame or distracting reflections from the lenses. Military pilots have used contact lenses in harsh wartime environments and have reported them to be operationally superior to spectacles (4).

In 1998, within the United States, there were about 32.1 million contact lens wearers, about 19% of the 173 million eyewear users in this country (5). As the "baby-boomers" reach the age when presbyopia (an age-related reduction in accommodative ability) becomes more prevalent, interest in near vision correction contact lenses is expected to increase. Currently, monovision (one lens for distant vision and one lens for near vision) is the most successful method to correct presbyopia with contact lenses and is used in approximately 80% of all such presbyopic corrections (6). However, under Federal Aviation Regulations (7), the use of monovision contact lenses is prohibited since one eye would not meet the visual acuity standard. For example, first- and second-class airmen are required to have 20/20 or better Snellen visual acuity at distance in each eye separately, with or without corrective lenses. A pilot wearing monovision contact lenses in the near correcting eye may not meet this distant vision standard. According to the FAA's "Guide for Aviation Medical Examiners (3)," the use of monovision contact lenses is not considered acceptable for aviation duties (Note: Additionally, bifocal contact lenses are not considered acceptable for aviation duties.). In this paper, a case report of an aircraft accident is presented in which the use of monovision contact lenses was found to be a contributing factor.

METHODS & RESULTS

The National Transportation Safety Board (NTSB) aircraft accident report of the October 1996 Delta Air Lines Flight 554 was reviewed (8). The following is a summary of that report.

On October 19, 1996, Delta Air Lines Flight 554 departed Atlanta's Hartsfield International Airport bound for LaGuardia Airport at Flushing, NY. The crew consisted of two pilots and three flight attendants. There were 58 passengers on board the aircraft.

The McDonnell-Douglas MD-88, N914DL, was on approach to the ILS/DME-equipped (Instrument Landing System with Distance Measuring Equipment) Runway 13. Weather observations at LaGuardia indicated a broken cloud layer at 800 feet, visibility between ½ and 1 mile in heavy rain and fog or mist, and easterly winds at 12 to 14 knots. The flight encountered light to moderate precipitation as it descended below 3,000 feet. The crew was flying an approach that called for them to cross over Bowery Bay to the right of the extended runway centerline. The approach end of Runway 13 is built on a concrete deck about 15 feet above Bowery Bay. Approach lights are installed on a narrow pier extending out over the bay. The runway glideslope is unusable below 200 feet, and the runway has a decision height (altitude at which a decision is made to land or go-around during a precision approach) of 250 feet. When the flight reached the decision height, the approach continued with the crew transitioning to visual references. The airplane then landed short, resulting in the right wing striking the approach light structure and the runway deck closest to the approach end (see figure 1). The main landing gear assemblies were sheared off; the aircraft proceeded to slide 2,700 feet down the runway and rotated 180 degrees (see figure 2). With the odor of jet fuel present, an emergency evacuation was ordered, during which three passengers received minor injuries.

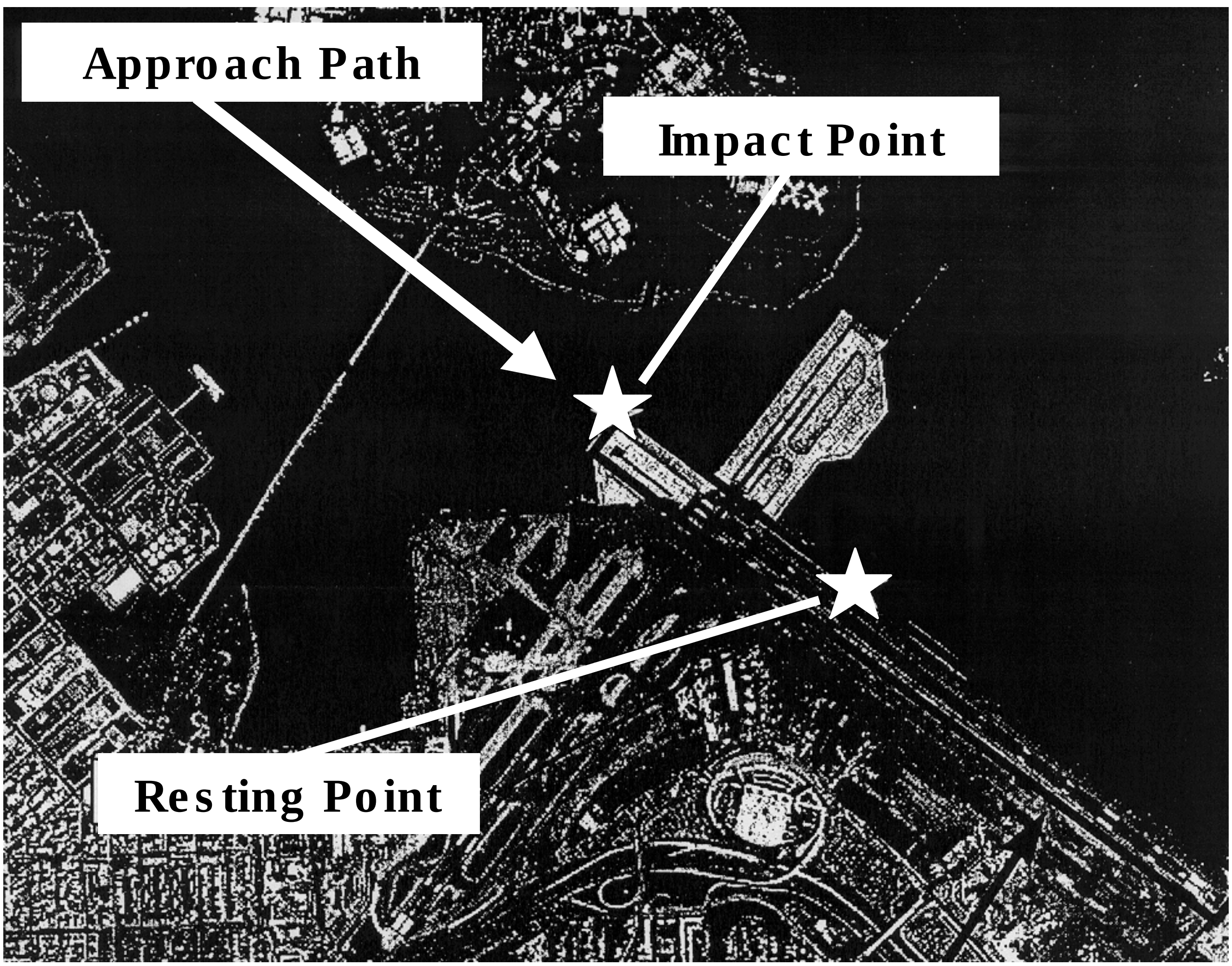

FIGURE 1. An aerial view of LaGuardia Airport: The darkest areas are water. The stars represent the points where Delta 554 first impacted Runway 13 and where it skidded to a stop 2,700 ft. down the runway and facing 180° from the direction of approach.

The 48-year-old captain, with about 9,000 total flight hours including 3,755+ flight hours in the MD-88, was the pilot-in-command. He had no previous aviation accidents or incidents and possessed a current FAA first-class medical certificate with the requirement to have glasses available for near vision. The first officer, a 38-year old with about 6,800 total flight hours including 2,200+ flight hours in the MD-88, had a current FAA first-class medical certificate with no visual restrictions. The captain had flown the approach into LaGuardia several times before, always under visual meteorological conditions. The pilot reportedly used his progressive addition lenses about 25% of the time and his monovision contact lenses about 75% of the time while flying. According to his eye doctor, the pilot was issued contact lenses in 1990 with his dominant right eye set for distance vision and the left eye set for near vision. The right contact lens corrected distant vision to 20/20 and the near vision to 20/60, while the left contact lens corrected distant vision to 20/80 and near vision to 20/20. The captain was wearing monovision contact lenses at the time of the accident. The prescribing eye doctor was unaware the patient was a pilot and that monovision contact lens use was prohibited by the FAA. Additionally, he could not remember discussing monovision limitations with this patient and had not performed a depth perception test. A post-accident evaluation conducted at Emory University revealed that the pilot had a substantial reduction in depth perception when using his monovision contact lenses.

According to the NTSB report, several factors may have contributed to the Delta 554 accident. The lights on Runway 13 were spaced 150 feet apart, while the lights on most runways are 200 feet apart. To pilots accustomed to 200-foot spacing, this difference could result in an overestimation of their altitude by 70 feet. Runway 13 had an infrequently used ILS approach that was made more difficult by the ILS localizer being offset to the right of the runway centerline by several degrees of arc. The ILS approach required the pilot to turn left slightly after transitioning to visual references. In an approach over water under reduced lighting conditions, there

FIGURE 2. This photo shows the wreckage of Delta 554 as it sat aside Runway 13 at LaGuardia Airport. Three passengers suffered minor injuries during the emergency evacuation that was ordered by the pilot after a report of the smell of jet fuel.

are fewer visual cues for judging altitude than would be found in detailed terrain. The absence of visible ground features, the presence of rain and fog and the irregular spacing of the runway lights may have combined to create an optical illusion that caused the pilot to believe he was higher and farther away from the runway. Additionally, since the aircraft was not equipped with an instantaneous vertical speed indicator (VSI), the lag time of the VSI limited the usefulness of the information it provided during the final critical seconds of the approach.

DISCUSSION

Depth perception is enhanced when viewed binocularly. The sense of depth mediated by binocular vision is referred to as stereopsis, which is the disparity between images from each eye that is used to judge angular difference and interpreted for depth perception. Stereopsis differs from monocular depth perception cues in that it is physiological rather than learned. Therefore, stereopsis provides a more convincing stimulus for judging depth than does monocular cues. From the stereoacuity measurement (arc min), the threshold of stereopsis (maximum distance at which stereopsis is useful) may be calculated. Some scientists have measured the threshold of stereopsis at over 300 feet, which is within the range of many flight tasks, including aerial refueling, formation flight, and low altitude maneuvers (9). Other vision specialists say that stereopsis is useless beyond 20-30 feet. However, depth perception is not exclusively dependent on stereopsis. Monocular depth perception cues include linear perspective, interposition (an overlaid object appears farther away), clarity, and motion parallax. Since these cues are learned, they are more susceptible to fictitious information from visual illusions.

In the Delta 554 accident, visual cues were obscured by the rain and fog, creating a visually deprived environment that could have induced visual illusions. For example, the dim (low contrast) lights on the runway could produce an illusion of being farther away and higher. The “black hole” illusion, which results when a pilot has little peripheral detail, can also generate an illusion of being too high. The pilot’s diminished distant vision and stereopsis may have exaggerated these illusions. Additionally, the offset or decentered approach to Runway 13 complicated the landing attempt, since it would have required a precise readjustment by the pilot close to the runway. The lack of monocular cues may have reduced the time the pilot had to react.

Contact lenses have limitations in the aviation environment. Corneal edema has been reported in well-fit contact lens wearers when exposed to altitude hypoxia. Low barometric pressure and low relative humidity are indigenous to the aviation environment. During decompression, nitrogen gas may form bubbles beneath a contact lens affecting vision. Low humidity, such as the 10-15% relative humidity of an aircraft, can dehydrate hydrophilic (soft) contact lenses, reduce lens movement, and increase conjunctival injection. Lens dehydration has been associated with visual performance (low-contrast acuity) loss (4,10). In a survey of 31,205 aircrew members of the Active, Reserve, and Air National Guard Air Force (pilots, navigators, and flight surgeons), 26% of those who wore contact lenses experienced displacement and 10% experienced a loss of contact lenses inflight (11). This may be due to lens dehydration, abrupt head and eye movements, and aggressive flight maneuvers. About 24% of the aircrew reported removing a contact lens inflight, primarily for dryness or a foreign body beneath the lens (11). It is important to note that about 98% of the military aircrew members who wore contact lenses felt that their use afforded them an operational advantage. A study conducted by the U.S. Army found that presbyopic helicopter pilots preferred bifocal contact lenses to bifocal spectacles in actual flight operations. Of particular note was that over half (10 of 17) of these aviators preferred the monovision or modified monovision (a distance vision lens on one eye and a bifocal contact lens on the other eye) contact lens design as their corrective modality of choice (12).

Normal anatomical and physiological changes with aging can affect the wearer’s visual performance when using contact lenses. These changes include: flaccid eyelids, reduced tears, diminished corneal sensitivity, senile miosis, and loss of accommodation and lens transparency. Contact lens use by women may also be adversely affected by changes in hormone levels from taking oral contraceptives or from menopause (13). Additionally, individuals with compromised near vision may have problems properly cleaning and caring for their contact lenses. A soiled contact lens can result in a water-repellant (hydrophobic) lens surface, changing the fit and physical properties (water content, oxygen transmissibility) of the lens.

Furthermore, as people grow older, they are more prone to use prescription medications that can alter tear production and quality, and disrupt contact lens wear. These medications include: anticholinergics, antihistamines, antihypertensives, dermatological medications, and antidepressants (14).

The Food & Drug Administration has recognized monovision as an acceptable use for contact lenses. The use of monovision has been a frequently prescribed modality to correct presbyopia for 30+ years with no reported ill effects. Additionally, no scientific data demonstrate a higher incidence of motor vehicle accidents with monovision contact lenses, compared with traditional ophthalmic lens correction for presbyopia. It is interesting to note that the pilot of Delta 554 had used monovision contact lenses successfully for about six years while flying with an exemplary record. During this period, the pilot also appears to have passed check flight tests performed by the FAA and Delta Air Lines while wearing monovision correction. Therefore, this may suggest that external factors, such as the marginal visual conditions, lack of monocular cues, irregular approach configuration, and the lag in the vertical speed indicator overwhelmed the pilot's visual capabilities, and could have affected even a pilot with normal uncorrected or optimally corrected vision. Further research is required to explore this possibility.

Eye care practitioners should always ask patients about their work and recreational activities when dispensing monovision contact lenses. Although they may not be legally responsible for knowing the vision standards and regulations for their patients' occupations or avocations, such information would be invaluable to the doctor when consulting with the patient on the limitations of monovision as a corrective modality while performing certain activities. Patients with challenging occupational and avocational distant vision demands may not be appropriate candidates for monovision lenses. If monovision contact lenses are prescribed, ancillary vision tests, such as depth perception, should be performed to quantify any reduction in visual performance. To ensure the safety of the operator and the general public, eye care practitioners may wish to suggest that another qualified individual accompany the patient after prescribing changes in strength or type of refractive correction to aid in the adjustment to any potentially adverse visual perception changes.

Eye care practitioners should consider the following before dispensing monovision contact lenses to any patient:

1. Monovision can reduce second degree fusion in 10-20% of patients. Clinically measured near stereoacuity (fine depth perception) can be expected to diminish 40-50 arc sec (15). Monovision may be more problematic when the anisometropia (one eye requiring a different lens correction than the other) reaches 1.25D (16). Although monovision contact lenses may not cause a visual illusion, it may compromise the quality of the overall visual scene and binocular function.
2. Stereopsis is more sensitive to monocular blur than to similar amounts of binocular blur. Additionally, residual astigmatic error, particularly in the dominant distance-corrected eye at oblique axis, causes significantly greater binocular visual acuity loss in monovision (15).
3. Monovision contact lenses produce a slight reduction in high contrast visual acuity, compared with traditional binocular distance and near correction (15).
4. Deficits of visual acuity and contrast sensitivity from monovision at threshold conditions may reduce target identification.
5. Monovision may result in both distance and near "ghosting," which is due to incomplete suppression of interocular blur (15). The ability to suppress the blur may improve with adaptation, but equivalent performance levels to normal binocular vision may never be achieved.
6. Monovision patients may experience hazy vision and occasional loss of balance during the adaptation period (15).
7. Monovision has been shown to decrease occupational task performance speed by 3 to 4%, compared with distance contact lenses combined with reading glasses (17).

In conclusion, under current FAA regulations, pilots are prohibited from using monovision contact lenses to correct refractive error and/or presbyopia. Although a pilot is well adapted to monovision, the reduction in visual performance from using such lenses may be exacerbated under marginal visual conditions and high workloads. The limitations of monovision contact lenses, including the voluntary relinquishing of binocular cues to depth perception, should be carefully discussed with the patient, especially if he/she operates an aircraft. In the case of the Delta 554 accident, the NTSB concluded that the inability of the pilot to overcome his misperception of the airplane's position due to degraded stereopsis and increased reliance on monocular cues, was a contributing factor. In a related issue, the use of refractive surgery or intraocular lenses after cataract surgery, with intentional unilateral undercorrection for best uncorrected far and near visual acuity, could result in similar visual performance decrements while flying. Further research is recommended, perhaps in a full-motion flight simulator and under a variety of environmental conditions, with pilots wearing monovision contact lenses. This research could provide additional understanding of the limitations of monovision correction in an operational aviation environment and how those limitations could influence flight performance under adverse conditions. Additionally, the research may be used to review the current policy regarding the use of monovision refractive correction.

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