A 29-YEAR-OLD MAN WITH DIZZINESS AND HEADACHE AFTER SKYDIVING

Author: Doedo Schipper, RN, BSN, P.ed, Longmont, CO
Section Editor: Laura M. Criddle, PhD, RN, CEN, CCNS, FAEN

A 29-year-old man wearing a skydiving jumpsuit was transported by private vehicle to our emergency department from the drop zone of a local airport. He was able to walk to the front desk, where he complained of dizziness, headache, and nausea. The man was neurologically intact and had a Glasgow Coma Scale score of 15. Vital signs were as follows: blood pressure, 151/76 mm Hg; respiratory rate, 20 breaths/min; and heart rate, 68 beats/min. The patient was normothermic, and room air oxygen saturation was 98%. The most striking thing about this patient was his unusual appearance. The man's face was tinged blue with a prominent line of demarcation just below the nose. Above the line, his face had a distinctly bluish discoloration (Figure 1).

Our emergency department is located close to one of the country's largest skydiving operations, and we see the occasional extremity injury associated with this sport. However, this patient's mechanism of injury was very unusual.[1] He explained that he had made a jump but his main parachute malfunctioned on opening. This particular chute was a small high-performance model designed for rapid descents and high maneuverability. The left side of the man's parachute failed to deploy correctly, which caused him to spin violently. He explained that he came close to passing out but managed to release the main parachute handle. He then pulled a second handle to deploy the emergency chute. The reserve parachute opened successfully, and the patient made an uneventful landing. On the ground, his friends noted that he was dizzy, his face was blue, and his eyes were bulging outward.

The unusual application of force to tissues associated with this patient's presentation merits further discussion. After opening on only one side, the malfunctioning parachute began to spin at a high rate of speed. This swung the skydiver to the outside of the turn, subjecting him to increasingly positive gravitational (G) forces. G loading has been well researched and described in various space and aeronautical publications,[2,3] but it is rarely a concern in civilian health care settings. Three different directions of force are involved: the x-, y-, and z-axes. The direction of the z-axis runs from head to toe. When subjected to positive forces along the z-axis, blood is pulled from the head to the lower extremities. In negative G situations, blood is directed toward the head.

Appreciating this patient's mechanism of injury requires a basic understanding of the principles of flight. Our patient was using a high-performance parachute designed for speed and maneuverability. These specialty chutes are only flown by very experienced skydivers, such as our patient, who had made more than 3,000 jumps. This type of parachute functions much like a small, inflatable airplane wing. Under normal conditions, the skydiver is suspended 9 feet below the canopy. During our patient's chute deployment, a malfunction distorted the normally smooth wing shape, making it asymmetrical. Dyssymmetry generated a greater amount of lift on one side of the wing, causing the parachute and suspended skydiver to spin. Later communication with the parachute manufacturer (May 2010) showed that instrumented test flights with similar chutes have documented forces as high as positive 3.5 Gs under normal function conditions.

Sustained G force injuries are distinctly different from the familiar acceleration-deceleration injuries produced by motor vehicle collisions, falls, and so on. Such injuries are unusual in the civilian population because there are very few situations in which civilians can encounter significant, sustained G loads. Mild G loads, which rarely result in injury, can be experienced by roller coaster riders.[4] Aerobatic pilots are among the only persons with access to equipment (stunt planes) that can produce and withstand significant Gs. Aerobatic aircraft may be certified for forces as great as positive and negative 10 Gs.[5] During aerobatic competitions, certain maneuvers create significant G loads. Positive G forces drive the pilot into the plane's seat, whereas negative Gs lift the pilot away from the seat to strain against safety restraints. Most people have viewed

Doedo Schipper, Longmont United Hospital, Longmont, CO.
For correspondence, write: Doedo Schipper, RN, BSN, P.ed; E-mail: doedo.schipper@gmail.com.

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FIGURE 1

Pronounced bluish facial discoloration in patient subjected to extreme G forces after parachute malfunction. This figure is available in color and as a full-page document online at www.jenonline.org.

video or film footage of the huge centrifuges used for military pilot and astronaut training. These pilots are spun under controlled circumstances where they learn to remain conscious under loads as great as positive 9 Gs.

Research has been largely focused on the consequences of positive G loads. Study participants report feeling very uncomfortable when subjected to negative G forces. The effects of sustained negative G loads include bradycardia, dysrhythmias, and blood stagnation in the brain. A force of negative 1 G creates unpleasant head and facial congestion. Negative 2 to 3 Gs produces severe congestion, throbbing headache, swollen eyelids, facial and ocular hemorrhage, and blurring, graying, or reddening of the visual fields. A negative 5 G force for as little as 5 seconds is considered the upper limit of human tolerance.[6]

Our patient presented with an interesting and unusual combination of both positive and negative G effects. Suspended in his harness, he had no way of resisting rapid rotation. He clearly recalled seeing his partially deployed parachute, which would only have been within his line of sight if his neck were hyperextended. This suggests that

FIGURE 2

Bilateral subconjunctival hemorrhages in patient subjected to extreme G forces after parachute malfunction. This figure is available in color and as a full-page document online at www.jenonline.org.

while the man's torso and extremities were subject to a *positive* G load, his head was under a *negative* G load of at least 3.5 Gs. Such extreme force drove blood into the patient's head—augmenting arterial flow while restricting venous outflow—resulting in severe venous congestion and transient cerebral hypo-oxygenation. This mechanism of injury explains the skydiver's near syncope, facial edema, multiple soft-tissue hemorrhages, soft palate and periocular petechiae, blurred vision, blue facial discoloration, and bilateral subconjunctival hemorrhages (Figure 2).

In the emergency department, the patient was given 4 mg of intravenous ondansetron (Zofran), 25 mg of meclizine (Antivert, Bonine), and 1,000 mg of oral acetaminophen for nausea, dizziness, and headache. He refused narcotic analgesics. Concerned that the patient might have intracranial bleeding or dissection of his carotid or vertebral arteries, several imaging studies were ordered. The patient underwent computed tomography (CT) and CT angiography of the neck, as well as magnetic resonance imaging (MRI) of the brain and brainstem. During the MRI procedure, he experienced another episode of nausea that resolved with 4 mg of ondansetron. Numerous scalp hemorrhages were noted on MRI, increasing toward the cranial vertex. However, no intracranial hemorrhage was seen. Throughout his ED stay, the patient remained neurologically intact with stable vital signs. He was sent home after a 5-hour observation period, with ondansetron and meclizine prescriptions and a referral to a neurologist for any ongoing symptom management. Five days after the incident, the skydiver reported being symptom free, except for his slowly resolving subconjunctival hemorrhages.

The presentation of a patient with sustained negative G force injuries is extremely rare, and a search of the medical literature failed to identify any published reports of such injuries associated with skydiving. No doubt the condition has occurred before, but accidents during the parachute deployment phase are frequently associated with fatal outcomes.[7] Had our patient's period of negative G loading persisted even slightly longer, he would have lost consciousness and been unable to take the 2 steps required to survive this emergency: (1) release the faulty parachute and (2) open the reserve chute. Emergency nurses need to be aware of the powerful effects of sustained positive and negative G loading and consider patients subject to these forces candidates for trauma team activation even though they do not meet standard activation criteria.

For further information on the effects of G force, see the US Army publication "Aeromedical Training for Flight Personnel," available at http://www.everyspec.com/ARMY/FM+-+Field+Manual/FM_3-04x301_13931/.

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Laura M. Criddle, PhD, RN, CEN, CCNS, FAEN
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