Loss of Consciousness During Single Sling Helicopter Hoist Rescue Resulting in a Fatal Fall

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INTRODUCTION: Although harness suspension trauma has been documented since the 1960s, especially in the mountaineering setting, there is little robust medical research into the area. Helicopter hoist rescue shares similar risks and is reserved for those cases that cannot be accessed safely by other routes, where extrication may be hazardous or will take an unreasonable amount of time. The single sling or chest harness used for hoist rescue is a single harness around the upper torso and is easier and quicker to apply than a stretcher. However, the risks of a chest harness need to be balanced against the patient's condition, the environment, aircraft performance, and the urgency of the rescue.

CASE REPORT: We report an adult male falling 80 ft to his death while being hoisted into a rescue helicopter for a likely fractured ankle. A single rescue sling harness technique was used, but the patient became unconscious, slipped out of the harness, and fell. He had significant comorbidities, including cardiomyopathy, obstructive sleep apnea, morbid obesity, and diabetes.

DISCUSSION: A decrease in cardiac output secondary to thoracic compression was the presumed cause for his loss of consciousness and the potential physiological mechanisms and modifying factors are discussed. Further research into harness suspension trauma is required. Stretcher, double point harnesses, or rescue baskets are likely safer methods of hoisting, especially in a medically compromised patient.

KEYWORDS: helicopter rescue, hoisting, chest harness, sling harness, orthostatic shock, venous pooling, double sling harness.

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Use of a helicopter hoist is an extrication method used on both land and sea. It is reserved for those cases that cannot be accessed safely by other routes, where extrication may be hazardous, or will take an unreasonable amount of time. These may include cliff edges, water rescues, and rugged terrain.

The common types of rescue equipment used are a rescue sling, a rescue sling with a hypothermia strap (a second strap running under the patient's knees), or a stretcher or rescue basket, as depicted in **Fig. 1**. Hoist rescue requires high levels of operator training and currency, and has inherent risk to both the aircrew and the patient. While the sling is easier and more quickly applied than a stretcher, patient condition, the environment, aircraft safety, and urgency of the rescue all must be considered when choosing the rescue technique.

The physiological effects of suspension in a harness can be severe enough to be life threatening and may be exacerbated by comorbidities that impair a patient's ability to compensate. Although the literature is limited and mostly examines rope rescue scenarios rather than helicopter hoisting, it is directly comparable in terms of harnesses and the physiology of impairment caused by harness suspension is the same. Suspension trauma is a phenomenon recognized and investigated as early as the 1960s. Initial studies examined climbing-related falls and harness suspension. A patient in the vertical position develops pooling of blood in the legs and abdomen second to motionless muscles not acting to aide venous return, with a resulting reduction of circulating blood volume and a relative hypovolemia, cerebral hypoperfusion, and then cerebral hypoxia. The response to this is to collapse and bring the body to the horizontal plane and, therefore, improve venous return and restore consciousness. A suspended patient results in no ability for the body to achieve the horizontal plane, improve venous return, and restore cerebral perfusion. The harness suspending them can also act like a tourniquet, further decreasing venous return.[4]

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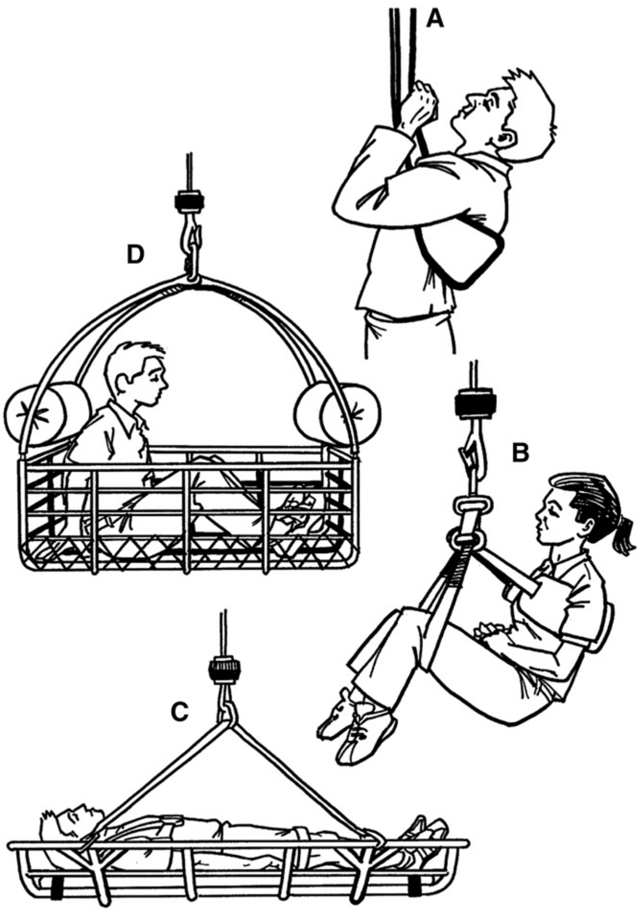

Fig. 1. Methods of helicopter hoist rescue. A) single sling; B) double or "hypothermia" sling; C) stretcher; D) Coast Guard Rescue Basket.

Factors that can affect the risk of suspension trauma include inability to move the legs, coexisting injuries, hypothermia, hypoglycemia, hypoxia or hypercapnia, the vasovagal response to pain (often from compression from the harness), shock, including blood loss or dehydration, and cardiovascular or respiratory disease.[4] Some of the major warning signs of suspension trauma are similar to a presyncopal syndrome and consist of faintness, breathlessness, sweating, pallor, flushing, tachycardia, and hypertension followed by hypotension.[9]

The physiological effects of rescue with a single sling harness in particular have also been recognized for over 40 yr. Studies have shown that there is a significantly reduced tolerance for the single sling even in healthy individuals compared to a double sling harness, rescue basket, or stretcher. A previous study[7] has shown that a chest harness compared to a full body harness caused more rapid onset of upper extremity symptoms of numbness and tingling. The symptoms were only tolerated for 0.62 to 13.13 min in young fit healthy subjects. Another study[3] looked at respiratory function following a case of a severe asthmatic having a respiratory arrest during hoisting in a single sling and arriving in the helicopter cabin unconscious, although fortuitously the patient did not fall. In a small study[3] of 12 subjects, they demonstrated that the single sling was probably superior to supine positioning in a stretcher in a patient with respiratory compromise, but that in all techniques tested there was a significantly reduced vital capacity (VC) and forced expired volume in 1 s (FEV_1) during hoisting.

A larger follow-up study in 2011[6] supported the findings of the previous small study, but also included analysis of the Coast Guard rescue basket. It demonstrated a restrictive effect of the single sling compared to the double sling, with the least effect on respiratory function in the Coast Guard rescue basket. It also showed an increase in heart rate, respiratory rate, and a decrease in oxygen saturation to a statistically significant level between control and the single sling.

One of the best studies[5] in this area was prompted by the death of a 25-yr-old soldier who had been left suspended in a single sling for just 6 min. It demonstrated the orthostatic effects of 50° head up tilt, tolerated to an average of 27 min with presyncopal symptoms as the end point. It further compared 50° head up tilt to 50° head up tilt with legs elevated in a double sling harness and found that only 11% (one person) developed presyncopal symptoms in this position at 1 h. This indicates the importance of securing a position that supports venous return during suspension. Other studies have suggested that patient comorbidities may exacerbate the physiological effects of suspension. For example, higher body weight has been shown to accelerate changes in heart rate, blood pressure, and minute ventilation seen during suspension.[10] Another study[8] showed a significant change in cardiopulmonary parameters following suspension in a chest harness for 3 min compared to a sit harness (leg and waist straps). In healthy 25-35 yr old soldiers it demonstrated a 34.3% drop in VC and 30.6% drop in FEV_1 and an increase in end tidal carbon dioxide ($P_{ET}CO_2$) by 11.5%. There was no change in oxygen saturation, although 3 min may not be a long enough time to see a change in saturation. They also noted a 36% drop in cardiac output secondary to an increase in intrathoracic pressure and, therefore, a reduction in right and left ventricular preload plus an associated bradycardia secondary to the Bezold Jarisch reflex. Given these physiological changes, it is reasonable to suspect that patients with pre-existing impairments of cardiac or respiratory function will tolerate suspension less well, with patients potentially becoming symptomatic in less time than it takes to complete the hoist. We report a case of a fatal fall occurring during a helicopter hoist rescue after the patient lost consciousness and explore the interaction between the chosen rescue technique (single sling), the predictable physiological effects of that technique, and the interaction with the patient's comorbidities, which likely contributed to the event.

CASE REPORT

A 65-yr-old man slipped and fell down a thickly wooded slope in Victoria, Australia, while on a hunting trip, sustaining a closed ankle injury, presumed to be an ankle fracture. The terrain was rugged and he was not able to hike the 1 km to a road, so emergency services were activated.

The patient weighed 138 kg, was 175 cm tall, with a calculated BMI of 45.1, placing him in the middle of the morbid obesity range. He had Type 2 diabetes mellitus, hypertension, and hyperlipidemia, but had good glycemic, hypertensive, and lipid control. He had been diagnosed 5 yr prior to the event with atrial fibrillation with heart failure, for which he was treated with bisoprolol, furosemide glyceryl trinitrate patch, spironolactone, and he was taking warfarin.

Transesophageal echocardiograms showed moderate to severe left ventricular impairment which improved post-cardioversion with restoration of sinus rhythm. Atrial fibrillation recurred, however, and was persistent. It was also noted he had a moderately dilated right ventricle, moderate mitral regurgitation, a dilated left atrium, and tricuspid regurgitation with elevated pulmonary artery pressures of 45 mmHg. His ECG showed a right bundle branch block. On serial reviews he had no significant decline in cardiac function.

He had a 60 pack-year smoking history. He was diagnosed with moderate to severe sleep apnea a year prior to the reported incident and was provided with a positive airway pressure machine, but was noncompliant.

A helicopter emergency medical service (HEMS) carrying a state ambulance service paramedic was dispatched to the incident scene. After the paramedic had assessed the patient on the ground it was decided to hoist extricate the patient via a single sling harness. A stretcher winch was deemed unsuitable due to the risk of snagging in overhanging trees. The sling harness was placed under his arms, the chest strap fastened, and he was given instructions regarding the winching process, including the need to keep his arms down. He was noted to be alert and cooperative and able to follow instruction, and he had been given morphine 10 mg intravenously by the initial paramedics on scene.

A 'two person' hoist was conducted with the flight paramedic supporting the patient with his legs wrapped around the patient's body in a 'bear hug' position. During the winch it was observed that the patient was struggling to keep his arms down. After 65 s they reached the skids of the helicopter, at which time the patient began to struggle and appeared agitated. Despite attempts by the paramedic, the patient was able to lift his arms and began to slip from the harness. The patient was observed to lose consciousness prior to slipping completely from the sling. Despite attempts by the winch operator and flight paramedic to pull him into the aircraft he fell approximately 80 ft to the ground and could not subsequently be revived.

Forensic examination reported the cause of death as multiple injuries sustained in a fall from height. They were unable to determine the cause of the unresponsive episode during the winch and whether it constituted a separate life-threatening event preceding the fall. It was speculated that it may have been a cardiac rhythm disturbance, vasovagal syncope, or related to the morphine administered prior to the rescue attempt. It was also noted therapeutic levels of paracetamol, codeine, and morphine ($0.1 \text{ mg} \cdot \text{L}^{-1}$) were identified in his blood, consistent with analgesia given pre-hoisting.

The investigation determined that the harness did not malfunction. The choice of the single sling harness with chest strap was in accordance with the Victorian air ambulance protocol, the aircraft operators' training and procedures, and applicable aviation regulations. The harness was deemed serviceable, had been used appropriately, and was not used outside its design parameters. The patient weight also was not outside the capabilities of the harness according to the manufacturer.

The Australian Transport Safety Bureau investigation of the incident[1] identified that the use of the rescue sling without using the hypothermia strap was not suitable for this patient given his size and comorbidities and, following his loss of consciousness, contributed to the patient falling from the harness. Additionally, limited guidance on choice of appropriate winch rescue equipment relative to patient comorbidities was provided to rescue crewmembers by the helicopter operator or ambulance service. Following this accident, the operator and Air Ambulance Victoria introduced a seat-type harness for patient recovery via hoist and issued guidance to their crews on the order of priority of use for rescue equipment during overland hoist operations. The Australian Civil Aviation Safety Authority also issued an Airworthiness Bulletin clarifying the use and application of rescue/retrieval slings. In addition, various helicopter emergency medical service providers have improved information sharing to communicate operational knowledge and lessons learnt.

DISCUSSION

This is the first report of a fall in 30 yr that we are aware of with use of a single sling harness where the person was conscious at the time the hoist commenced and the rescue was not from the water. The last reported incident[2] was in the United States in 1975 when a rescue crewman was winched down in a single sling device and a backpack. The combined pressure from both devices led to nerve compression and loss of sensation in his arms. The result was lifting of his arms, sliding through the sling, and falling 50 m, although he subsequently survived.

Most helicopter hoists take less than 1 min and the limited evidence to date suggests this is tolerated in healthy individuals with no effect upon the rescue. However, the reported patient had significant comorbidities, which would predictably magnify the effect of harness suspension. In such a high-risk individual, the hoist would likely have been tolerated had the second sling under the knees also been used. This would have both reduced the degree of thoracic compression by bearing some of the weight in addition to reducing the effect of venous pooling. This patient's body habitus was also not favorable for maintaining his arms in a down position, a requirement for a single sling hoist technique. The loss of consciousness and fall were probably the result of the effect of a single sling technique causing thoracic compression, vascular collapse, and loss of consciousness.

This case highlights the potential significance of physiological changes induced by a single sling rescue technique, particularly in individuals with comorbidities which impair cardiac and respiratory function. Rescuers should take into account patient comorbidities in their choice of rescue modality and balance these risks against other risks that may be inherent in a particular rescue such as time pressure due to dangers to the patient or aircraft, or inability to apply an alternative device such as when the patient is in the water. It is recommended that the single sling technique be reserved for rescues from the water, highly time critical situations, or where no other modality can be safely used. Previous research suggests that the Coast Guard Rescue Basket[6] or a seat-type harness will be better tolerated by patients with cardiorespiratory compromise and that these techniques should be preferentially used in these patients where possible.

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