ARTICLE IN PRESS

Air Medical Journal ■■ (2018) ■■–■■

Contents lists available at ScienceDirect

Air Medical Journal

journal homepage: http://www.airmedicaljournal.com/

Original Research

Helicopter Transportation Increases Intracranial Pressure: a Proof-of-Principle Study

Iscander M. Maissan, MD [1,*], Leonie A. Verbaan, BSc [1], Marco van den Berg [2], Robert Jan Houmes, MD, PhD [1], Robert Jan Stolker, MD, PhD [1], Dennis den Hartog, MD, PhD [3]

[1] *Erasmus University Medical Center Rotterdam, Department of Anesthesiology, Rotterdam, The Netherlands*
[2] *ANWB-Medical Air Assistance, Lelystad, The Netherlands*
[3] *Erasmus University Medical Center Rotterdam, Department of Trauma Surgery, Rotterdam, The Netherlands*

A B S T R A C T

Objective: After severe (primary) brain injury, Dutch physician-based helicopter emergency medical services start therapy to lower the intracranial pressure (ICP) on scene to stop or delay secondary brain injury. In some cases, helicopter transportation to the nearest level 1 trauma center is indicated. During transportation, the head-down position may counteract the ICP-lowering strategies because of venous blood pooling in the head. To examine this theory, we measured the optic nerve sheath diameter (ONSD) during helicopter transport in healthy volunteers.
Methods: The ONSD was measured by ultrasound in healthy volunteers during helicopter liftoff and acceleration in the supine position or with a raised headrest.
Results: In this proof-of-principle study, the ONSD increased during helicopter acceleration (–9° Trendelenburg, mean = 5.6 ± .3 mm) from baseline (0° supine position, mean = 5.0 ± .4 mm). After headrest elevation (20°-25°), the ONSD did not increase during helicopter acceleration (mean ONSD = 5.0 ± .5 mm).
Conclusion: ONSD and ICP seem to increase during helicopter transportation in –9° head-down (Trendelenburg) position. By raising the headrest of the gurney before liftoff, these effects can be prevented.

Brain injury is the leading cause of death in young adults after trauma.[1] The best prognosis is achieved when patients are directly transported to a level 1 trauma center to receive intracranial pressure (ICP)-lowering therapy as soon as possible.[2] In 2015, 1,092 severe traumatic brain injury (TBI) patients (Glasgow Coma Scale < 9) were treated in the field by 1 of the 4 so-called Lifeliners, physician-staffed helicopter emergency medical services (HEMS) in the Netherlands. If indicated, ICP-lowering strategies (Table 1) were started on scene to optimize tissue perfusion and minimize secondary brain injury.[3] All patients were transported directly to a level 1 trauma center. One hundred twenty-three (11%) of these patients were transported by helicopter and the others (89%) by car/ambulance.

Dutch Lifeliners are Airbus EC-135–type helicopters. Because of the design of the aircraft, patients are positioned in the supine position with their head in the flight direction. The brancard should only be used in the flat position during liftoff and landing because of the downward velocity criteria of the European Aviation Safety Agency.[4]

The pilot chooses a proper landing and takeoff procedure depending on the characteristics of the landing location (HEMS location). The landing site should be 25 m^2 (2 × overall length) and free of any obstacles. The slope should be les then 10°. Depending on the wind, obstacles may block the landing or takeoff track. The preferred approach is the HEMS confined profile in which the landing spot is constantly in sight during landing and takeoff (Fig. 1A). During takeoff, the pilot can land the helicopter back on the previous landing spot in case of an emergency, such as engine failure. If a landing site is surrounded by high obstacles, a vertical profile (Fig. 1B) may be suitable. If anything happens during landing or takeoff, the pilot can land vertically on the spot.

The patient is in the Trendelenburg position when accelerating (–9°) and flying (–5°) because of helicopter flight profiles. The

* Address for correspondence: *Iscander M. Maissan, MD, Erasmus University Medical Center Rotterdam, Department of Anesthesiology, 's Gravendijkwal 230, Rotterdam 3015 CE, The Netherlands.*
E-mail address: I.Maissan@erasmusmc.nl (I.M. Maissan)

1067-991X/$36.00

https://doi.org/10.1016/j.amj.2018.02.010

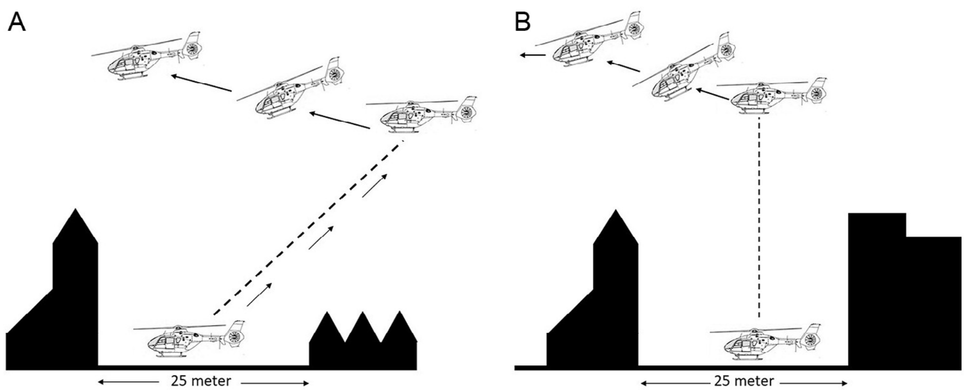

Figure 1. Visual representations of takeoff. A, HEMS confined takeoff. B, Vertical takeoff.

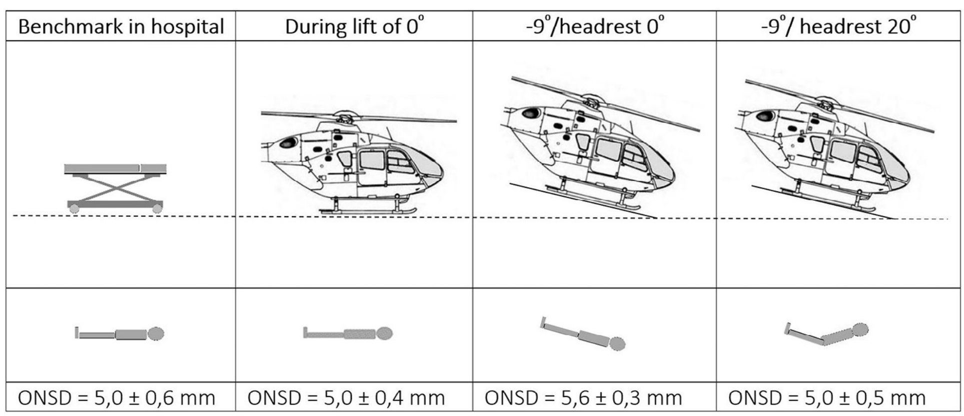

Figure 2. The 4 measurements performed.

Table 1
Strategies Used by Lifeliners in the Netherlands to Reduce Intracranial Pressure

Aim	Approach
Reduce oxygen consumption by the brain	Deep sedation
Careful intubation (high change in first-pass success)	Airway expert (exposure > 50 per year)
Counteract vasodilatation in the skull	Controlled "normoventilation" ($ETCO_2$ = 30-35 mm Hg)
Reduce brain edema	Hyperosmolar therapy
Maintain mean arterial pressure (80-100 mm Hg)	Fluids and vasopressors

$ETCO_2$ = end-tidal carbon dioxide.

Trendelenburg position may increase ICP because of stasis of venous blood in the head.[5,6] This may counteract the ICP-lowering strategies started before transportation. We hypothesized that head-up positioning by altering the headrest of the gurney may prevent increases in ICP because of the nose-down flight profile of the helicopter.[7] To examine this theory, we performed ultrasonic measurements of the optic nerve sheath diameter (ONSD) in healthy volunteers during helicopter transportation. Previously, our group and others showed that changes in ICP can be measured noninvasively by measuring the ONSD.[8,9]

Methods

This proof-of-principle study was conducted in accordance with the Declaration of Helsinki and complies with the principles of Good Clinical Practice. The protocol was approved by the Medical Ethics Committee of Erasmus Medical Center Rotterdam, Rotterdam, Netherlands (MEC-2016-409).

Healthy adult (≥ 18 years) volunteers with no self-reported medical history of ocular or brain disease were recruited at the medical faculty, and baseline measurements of the ONSD were taken in the recovery room of our surgical department to evaluate the volunteers' echogenicity (benchmark baseline measurements). The next day, the volunteers were placed in an EC-135–type helicopter in the supine position. The ONSD of the right eye was measured during liftoff and acceleration as depicted in Figure 2. A third measurement was taken with the headrest elevated 20° to 25° based on brancard characteristics during acceleration. The ONSD was visualized in the axial plane (Fig. 3A) and measured 3 mm behind the retina (Fig. 3B) as described previously.[5,6,8-12]

Basic vital parameters (ie, blood pressure, pulse, and saturation) were monitored during these measurements. All measurements were taken at the same flight altitude (500 ft) except for the benchmark baseline measurements in the hospital.

Results

We included 3 males and 2 females in the study, and their basic parameters were considered normal. An increase in the ONSD during acceleration (–9°) and a decrease to baseline after gurney correction was observed in all volunteers (Table 2). The overall mean baseline ONSD during our screening measurements in the hospital was 5.0 ± .6 mm. The overall mean baseline ONSD was 5.0 ± .4 mm in the helicopter while hovering (0°) and 5.6 ± .5 mm during helicopter incline (–9°). The overall mean ONSD after gurney cor-