CABIN DEPRESSION AND SLOW ONSET HYPOXIA

CRM, SIMULATOR AND SCENARIO BASED PHYSIOLOGY

LESSONS LEARNED FROM 2500 PILOTS TRAINED IN SLOW ONSET HYPOXIA

SOUTHERN AEROMEDICAL INSTITUTE
DR. PAUL BUZA
MEDICAL DIRECTOR

AVIATION PHYSIOLOGY
NEUROLOGY
DIVING MEDICINE
CLINICAL HYPERBARIC MEDICINE
OUR PRIMARY OBJECTIVE TODAY
"IF IN DOUBT
GET THE MASK OUT"
WHERE IS THE HIGHEST RISK FOR FATALITY?

EXPLOSIVE VS. SLOW ONSET CABIN DEPRESSURIZATION
LEARJET 35/N47BA

• 0919: Depart Orlando International Airport

• 0927: Flight reports climbing through 23,000 ft

• 0927: Clearance and last full transmission from aircraft at 23,000 feet

• 0933: Controller attempts contact at 36,500 feet

• Wheels off the ground to time of incapacitation is 14 minutes.
AUSTRALIA SEPT 4, 2000
BEECH SUPER KINGAIR 200
8 OCCUPANTS

- Approximately 20 minutes after take off open microphone transmissions included one unintelligible syllable, sounds of a person breathing, background propeller and engine noise.
- Charter flight taking off with solo pilot and 7 gold miners from Perth.
- Soon after departure pilot was cleared to FL 250.
- Aircraft struck ground near Burketown in Queensland.
HELIOS FLIGHT 552
SIX CREW – 115 PASSENGERS

- 06:07 Aircraft takes off from Larnaca airport.
- 06:11 Normal communication (10K)
- 06:12 Altitude alarm (16K)
- 06:14 Masks deploy (18K)
- 06:20 No further communication

Wheels off the ground to incapacitation was 13 minutes.
CESSNA 421
NTSB IDENTIFICATION: ERA12LA290
APRIL 19, 2012

- 0643: Departs Slidell Louisiana
- 0715: Reports at 27,000 feet
- 0735: Began to deviate with no response to ATC
- Military flyby sees pilot slumped forward unconscious. Windows iced over.
- Cause of incapacitation undetermined
SOCATA TBM 700N  
RENFREW, ONTARIO  
OCTOBER 8, 2012

- 1200: Depart Carp Ontario
- 1204: 7000 feet
- 1207: 11,500 feet
- 1208: 14,000 feet
- 1212:58 Pilot read back cleared to 24K last transmission
- 1216: Spiral dive from 27,000 feet at 25K/min
- At 8K leveled off for 6 seconds then dove again? Did he wake up briefly on descent?
- Wheels off the ground to time of spiral dive 16 minutes.
- TBM 900
- Cirrus SR22T

2014?
THE COMMON DENOMINATOR

**Question:**

What did these events have in common?

**Answer:**

- Occurred as a function of takeoff
- Most likely a failure of pressurization on ascent
- Slow cabin ascent rate of approximately 1500/ft. per minute.
- Slow onset hypoxia has a higher probability for fatality!
SLOW ONSET HYPOXIA
## Time of Useful Consciousness (TUC)

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<th>Altitude</th>
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# 8000 Feet

**“The Great Compromise”**

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# 14,000 Feet is Not Benign!

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### APPROACHING THE PHYSIOLOGICAL CLIFF

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### 30,000 FEET

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LESSONS LEARNED

From Having Flown 2500 Pilots in the Slow Onset Model
HYPOXIA IS A FUNCTION OF TAKE-OFF

- The highest probability of fatality associated with cabin depressurization is during the ascent.
18,000 FEET
THE POOR MAN’S ALTIMETER

- 90% of all pilots will experience their first initial symptom of hypoxia at 18K during the cabin ascent
- Visual spatial illusions we always trust our instruments
- Hypoxia we can always trust our bodies!

- Dizziness
- Numbness and tingling
- Warm flushing over chest
- Visual changes – Tunnel and loss of color vision
- Cyanosis
- Changes in breathing
OLDER PILOTS WILL RECOGNIZE HYPOXIA SOONER THAN YOUNGER PILOTS

- Function of age itself
- More experienced
- Based on current research scheduled to be published
EACH PERSON IS UNIQUE

“THE HYPOXIA FINGERPRINT”

- Each person has a different hypoxia experience

- However, that experience remains consistent over long periods of time.
<table>
<thead>
<tr>
<th>Oxygen Saturation (%)</th>
<th>Status</th>
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<tbody>
<tr>
<td>92-99%</td>
<td>Normal</td>
</tr>
<tr>
<td>80-91%</td>
<td>Mild to Moderately Low</td>
</tr>
<tr>
<td>70-79%</td>
<td>Severe</td>
</tr>
<tr>
<td>50-69%</td>
<td>Critical</td>
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</table>
**A NEW TUC TABLE BASED ON ASCENT RATES**

<table>
<thead>
<tr>
<th>Ascent Rate (From cabin altitude of 5K)</th>
<th>Time of Useful Consciousness</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 fpm</td>
<td></td>
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<tr>
<td>1,000 fpm</td>
<td></td>
</tr>
<tr>
<td>1,500 fpm</td>
<td>9.2 min. Based on 100 consecutive pilots O2 sat average 63%!!!</td>
</tr>
<tr>
<td>2,000 fpm</td>
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</tbody>
</table>
TIME TO RECOVERY IS SHORT
Average Time to Recovery is 60.19 seconds

Time To Recovery

Subject Number

O₂ 99%

O₂ 63%

Full Recovery

Time to >98% SO₂, in Seconds

Average Time to Recovery is 60.19 seconds
HYPOXIA IS DIFFERENT AT NIGHT
YOUR VISUAL EXPERIENCE WILL BE DIFFERENT
WE NEED TO PRACTICE OUR MASKS
THE TASK ORIENTED SOLO PILOT IS THE HIGHEST RISK

- Had just completed an Australian Air Force High Altitude Chamber program 6 months prior to the accident.
SEQUENCE OF HYPOXIA

10,000-18,000 ft
- Abdominal bloating and frequent ear popping
- Cabin cooling

18,000 ft - 24,000 ft
- First symptoms – dizziness, tunnel vision,
- Numbness – tingling of the hands and feet
- Continued significant abdominal bloating
- Early fixation
- Occurs quickly within minutes

24,000 ft - 30,000 ft
- Rapid deterioration
- Severe cognitive slowing
- Fixation
- Loss of situational awareness
- Cyanosis
- Garbled speech
- Myoclonus (shaking)
- Loss of consciousness

MSL-10,000 ft
- Frequent Ear Popping
- Altimeter climbing faster than usual
CRM INTEGRATION
CREWS SHOULD BE ABLE TO IDENTIFY QUICKLY
**THE SPECTRUM OF HYPOXIA**

- Explosive 10-15s
- Rapid 1-5min
- Slow Onset 10-15 minutes
- Very Slow onset 1-2 hours
- Long Haul Flights – Cabin Altitude exposures of 5-15feet?

**Physiological fatigue?**
A CHAMBER THAT IS REPRESENTATIVE OF THE AIRCRAFT
INDIVIDUALIZED TRAINING IS MORE EFFECTIVE THAN LARGE GROUP SESSIONS
SCENARIO BASED ATC COMMUNICATION
SCENARIO BASED PHYSIOLOGICAL TRAINING

Chamber
Flight Sims
ATC Communication

SAMI
<table>
<thead>
<tr>
<th>SCENARIOS</th>
<th>AIRCRAFT</th>
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<tbody>
<tr>
<td>Aspen</td>
<td>Teetosboro</td>
</tr>
<tr>
<td>San Francisco</td>
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<tr>
<td>Meridian</td>
<td>Daytime</td>
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<tr>
<td>Malibu</td>
<td>Night Time</td>
</tr>
<tr>
<td></td>
<td>Weather</td>
</tr>
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<td></td>
<td>Solo or Crew</td>
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SCENARIO BASED PHYSIOLOGICAL TRAINING

"THE TWILIGHT PROTOCOL"

- Chamber Lighting set for Night Flight allowing night adaptation
- Sim set at dusk to preserve mountain views
- Sim take-off - Aspen/Innsbruck Runway
- Teach Mask Valsalva Technique

August 11, 2013
ONCE YOU HAVE DONNED YOUR MASK YOUR JOB IS NOT DONE.

• You need to equalize your ears on the descent.

• The most likely time to have a debilitating ear squeeze is on the final approach.
TRAPPED GASES- BOYLE’S LAW

EAR PAIN MOST LIKELY TO OCCUR IN THE FINAL PHASE OF FLIGHT

• Don’t fly if you have a head cold. It may be easy to ascend but you could have severe ear pain in the final phases of descent.

• Valsalve frequently as needed on descent. Once is often not enough.

• You will almost always feel ear “pressure” before ear pain so that is the time to equalize your ears!

Boyle’s Law: The volume of a gas is directly proportional to the pressure holding temperature as a constant.

18K
2.3psi

Remember that pressure at 18,000 ft is half that at sea level, so volume doubles in size.

Balloon at
Sea Level Pressure
14.7psi

Ascent
During ascent, gas volumes expand on both sides of the ear drum, and leave the inner ear easily.

Descent
During descent, pressure increases on both sides of the ear drum, but is sometimes difficult to enter the small Eustachian tube.

Blockage
Ear pain occurs when the ear drum is stretched and pushed. As long as the pressure is equal on both sides of the ear drum, we refer to this as “being equalized”.

Sudden Ear Pain
Valsalva technique tries to force open the small Eustachian tube, thereby allowing equalization.

If sudden ear pain occurs which won’t resolve with swallowing or valsalva then:

“Look away and up” from pain and valsalva quickly and swallow.
OUR PRIMARY OBJECTIVE TODAY
WOULD YOU BE ABLE TO DON?
THANK YOU!!
“PROTECT THY BRAIN”
BREAK TIME
EFFECTS OF MILD HYPOXIA ON PILOT PERFORMANCES AT GENERAL AVIATION ALTITUDES

- Nesthus FAA 1997
- Studied mild hypoxia at 12,500 feet compared to normoxic group.
- Found more procedural errors in the mild hypoxic group especially during descent and landing phases.
- Found more stress in the hypoxia group using the TLX workload scale.
- Allow more time to physiologically recover by slowing down the descent.
WHAT IS THE AVERAGE O2 SAT IN ROUTINE FLIGHT?
TRAPPED GASES
Less common than ear pain is the phenomenon of a “sinus squeeze” felt mostly around the eyes.

If pain occurs, it will most likely be around the eyes or forehead.
A MESSAGE FROM THE CHEF
“BE CAREFUL WITH WHAT YOU EAT”

• Free Air Release Technique
TAKE HOME POINTS!

- All fatalities related to slow onset
- Hypoxia is a phenomenon of take-off
- Slow onset hypoxia (10 -15 minutes) is most dangerous
- Slow hypoxia is not as obvious as you would like to think-fixation is pronounced!
- Each person is unique compared to others so CRM is crucial!
NEXT GENERATION HAE TRAINING REQUIREMENTS

- Simulator based
- Scenario based
- Physiologic
- Individualized
- CRM based
- Customized Scenarios
ACCOMPLISHED IN ONE HOUR SIMULATOR SESSION

• Requires 1 additional hour of simulator time to the existing requirements

• Significantly improves quality in training

• Video useful for recurrent training
SIGNS AND SYMPTOMS OF HYPOXIA

- Dizziness
- Numbness and tingling
- Warm flushing over chest
- Visual changes – Tunnel and loss of color vision
- Cyanosis - blue lips and fingernails
SPACE SUIT TRAINING
THE AGING PILOT AND EXHAUSTION

• The Other Equation

\[ E = F^2 \]

Where: 
- \( E \) is exhaustion
- \( F \) is fatigue
THE AGING PILOT AND EXHAUSTION

The Other Equation

From \( E = (F)^2 \)

We can now derive:

\[
E = (SD + CS + A)^2
\]

Where: E is exhaustion

F is fatigue

SD is Sleep Deprivation

CS is Chronic Stress

A is Age
SLEEP IS A PHYSICAL NEED!
NO DIFFERENT THAN FOOD OR WATER
SLEEP AND FATIGUE

- Stage 1
- Stage 2
- Stage 3
- Stage 4 (Deepest Stage)
- REM Rapid Eye Movement

Awake
Calm
Wakefulness
Stage 1
Theta Waves
Stage 2
Sleep Spindles
& K Complexes
Stage 3 & 4
Delta Waves
REM Sleep
THE CYCLES OF SLEEP
EACH CYCLE IS 90 MIN
YOU NEED 5 CYCLES EACH NIGHT
WHY?

Do you feel like a million bucks?
HOW CAN I RUIN A GOOD NIGHT SLEEP?
LET ME COUNT THE WAYS
WHAT CAN WE DO TO STAY AWAKE?

• Good sleep!
• Caffeine when needed
• Good O2 sats->95%
• Cool cabin
• Proper planning
EXERCISE
THE MAGIC PILL

• 30-minute sessions at least 3 times per week
• Known to reduce high blood pressure
• Reduces the risk for diabetes
• Reduces high levels of cholesterol
• Excellent stress reliever!
• Better quality sleep
• Strengthens Immune System
SIMULATOR BASED HYPOXIA TRAINING
“THE PHYSIOLOGIC HIGH ALTITUDE ENDORSEMENT”

HAE
Mandatory
No Physiology

Altitude Chamber Training
Not Mandatory but strongly recommended

SAMI
CRM & Scenario based physiological high altitude endorsement