ROYAL CANADIAN AIR FORCE

AVIATION ROYALE CANADIENNE

AIRPOWER IN FORMATION
AGILE • INTEGRATED • REACH • POWER

PUISSANCE AÉRIENNE EN FORMATION
AGILITÉ • INTÉGRATION • PORTÉE • PUISSANCE

Perspectives on Aeromedical Evacuation in the RCAF

Major Melissa Gear, MD, MPH, CCFP, ABPM(AM)

ASCS Flight Surgeon, Medical Director Strat AE

Medicine UNIVERSITY OF TORONTO | Occupational Medicine

1 Nov 2022

CANADIAN ARMED FORCES
FORCES ARMÉES CANADIENNES

National Defence Défense nationale

Canada

Disclosure

The views expressed in this presentation are mine and do not necessarily reflect the views, opinions or official policy of the Canadian Armed Forces.

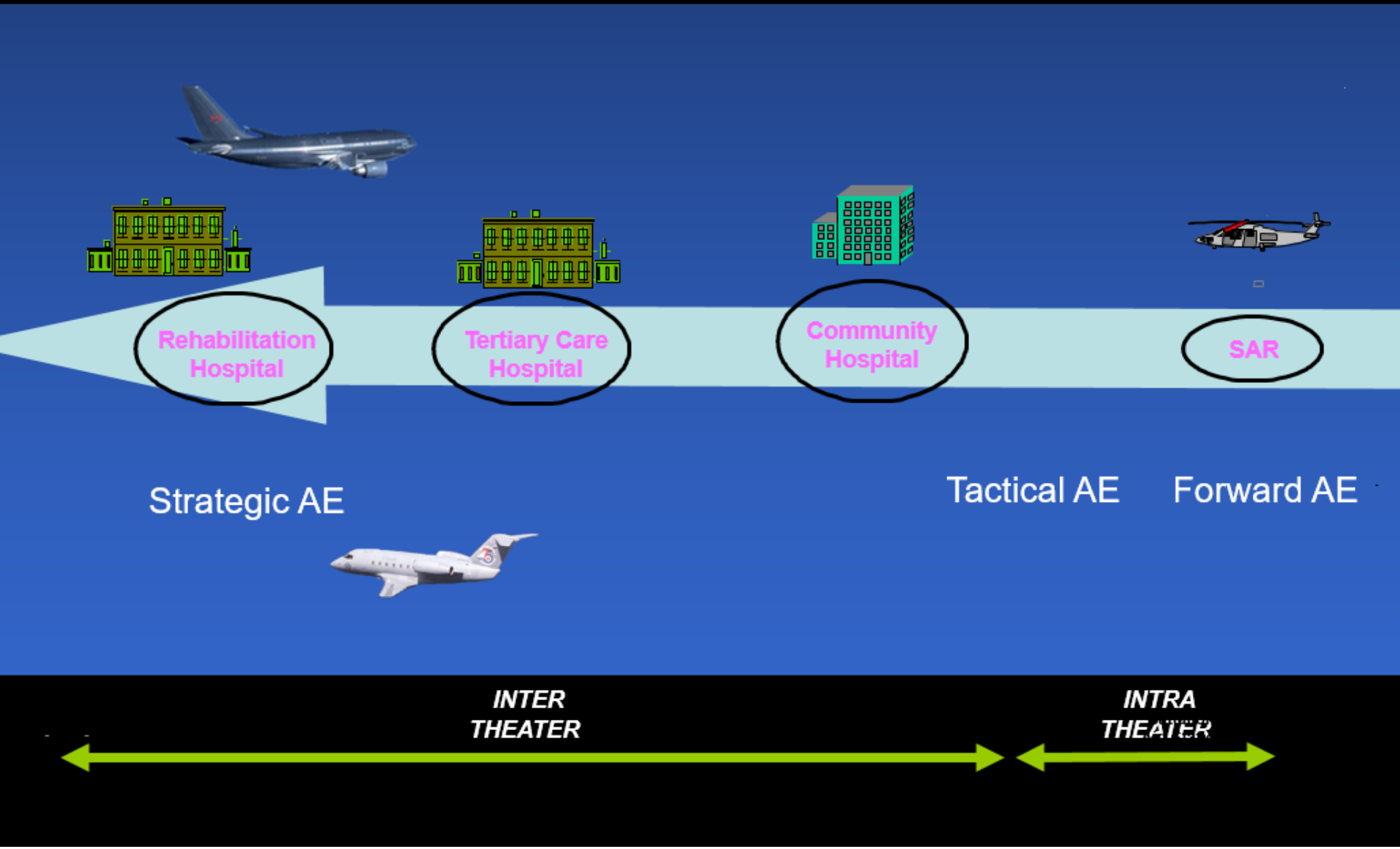
I have no conflicts of interest to declare.

Objectives

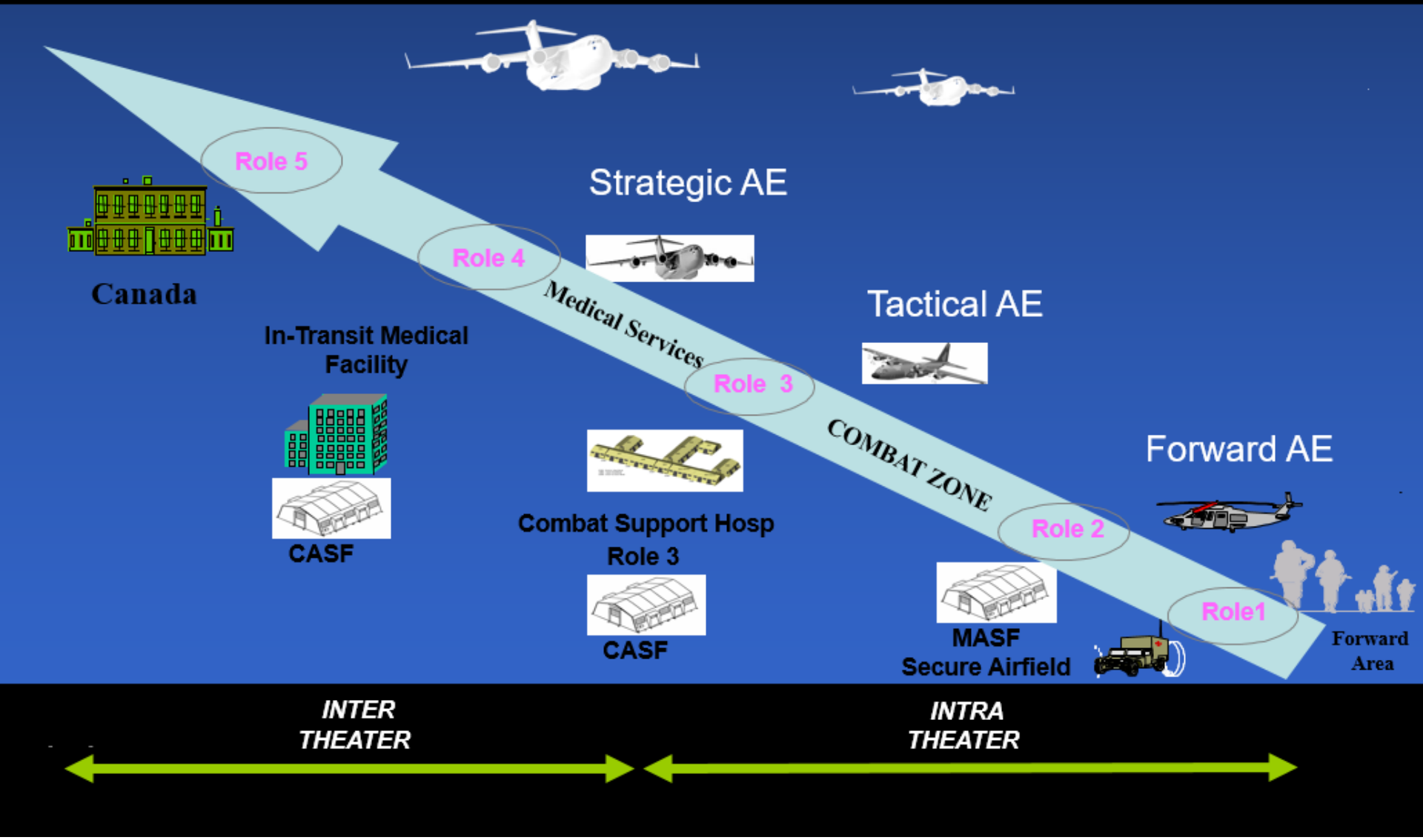
1. Spectrum of AE in the RCAF
2. In-flight medical considerations
3. Challenges with AE mission validation

PART A:
Spectrum of Aeromedical Evacuation in the RCAF

Operational Concept for Domestic

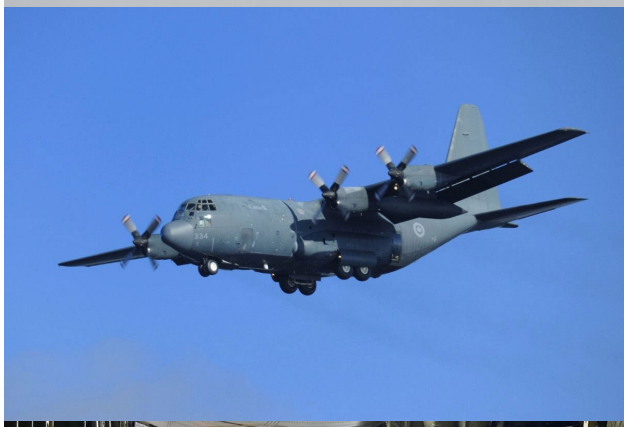


Operational Concept for Casualty Flow



SAR (Search and Rescue) Platforms

AIRPOWER IN FORMATION



Forward AE Platforms

Canadian Emergency Response Team (**CMERT**)

Strategic AE Platforms

CC144 Challenger

CC130J Hercules

CC150 Polaris

CC177 Globemaster III

PLATFORM	PATIENT CAPACITY
CC177 (Globemaster)	36 litters (tier) or 60 (floor)*
CC150 (Airbus)	2 critical care bed*
CC130J (Herc)	97 litters (tiers) or 18 (floor)*
CC144 (Challenger)	2 basic care beds or 1 critical care

Strategic AE missions

AIRPOWER IN FORMATION
AGILE • INTEGRATED • REACH • POWER

AE System – Aeromedical Evac Missions

Year	Strat	Domestic	Humanitarian	Tactical	Missions	(AE-CCAE)		Total Pts
2008	25	3	0		28	32	6	38
2009	24	5	0		29	42	4	46
2010	27	10	Op Hestia (28)		37	112	10	122
2011	11	7	0		18	21	1	22
2012	3	4	1		8	6	2	8
2013	0	4	1		5	8	1	9
2014	5	5	0	2	12	8	4	12
2015	4	5	0	0	9	7	3	10
2016	3	4	0	0	7	7	0	7
2017	8	0	1	0	9	9	0	9
2018	7	6	0	0	13	13	0	13
2019	11	3	Op Lentus (9)	0	14	13	2	15
2020	5	3	Op Globe (2)	0	8	9	1	10
2021	3	2	RFA MB & SK 7 & 2	0	14	7	9	11
	TOTAL AE MISSIONS 2008 -2021				176	293	46	341

PART B:
In-flight medical considerations

Primary Goals of AE

1. Provide (at minimum) same level of care as sending facility
2. Compensate for stresses of flight
3. Manage medical complications

AE Crew Composition (Goal 1)

Basic Strategic AE Crew

- Two AE Crew Members (AECM) (Flight Nurse and Med Tech)
- AECM assigned role of MCD (Medical Crew Director)
- Flight Surgeon

CCAE (Critical Care) Team

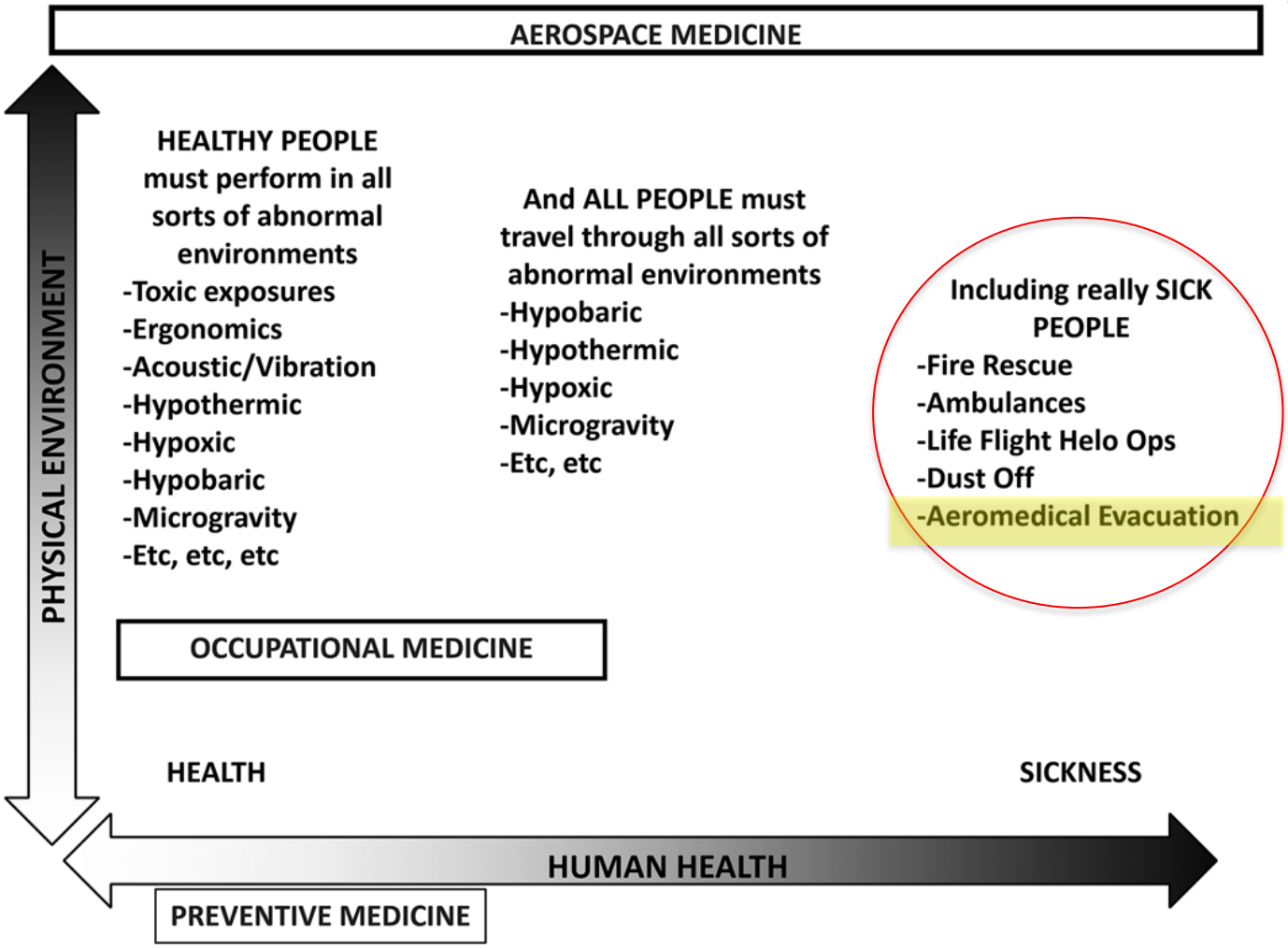
- Basic AE Team (Flight Nurse + Flight Med Tech)
- 1-2 Critical Care Nurses (1 AECM and 1 Cdn Fd Hosp)
- 1 Critical Care Medical Officer (Anes, Intensivist, etc.)

Mental Health AE Crew

- Basic AE Team (Flight Nurse + Flight Med Tech)
- 1 Mental Health Nursing Officer

Note: Routinely augmented by a Flight Surgeon

Compensate for Stressors of Flight (Goal 2)



Aerospace Medicine and Human Performance
ISSN: 2375-6314, Online ISSN: 2375-6322
DOI: https://doi.org/10.3357/AMHP.914PresPage
Volume 91, Issue 4, pages 311-31

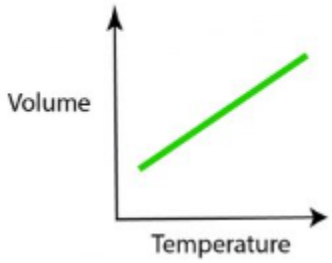
Stressors of Flight

1. Decreased Partial Pressure of Oxygen
2. Decreased Barometric Pressure
3. Increased Noise
4. Decreased Relative Humidity
5. Variation in Cabin Temperature
6. Vibration/ G-Forces/ Turbulence
7. Poor Lighting
8. Anxiety/Apprehension

#1 & 2 Gas Laws

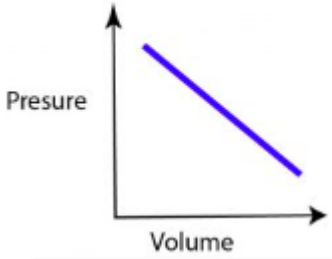
AIRPOWER IN FORMATION
AGILE • INTEGRATED • REACH • POWER

Charles' Law



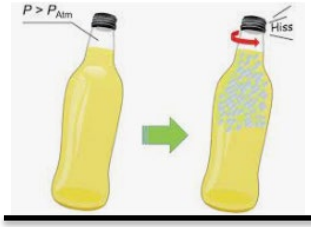
1 degree drop for each 100m gain in altitude
Patients and AE gases

Boyle's Law



Gas expands at altitude
Equipment and patient

Henry's Law

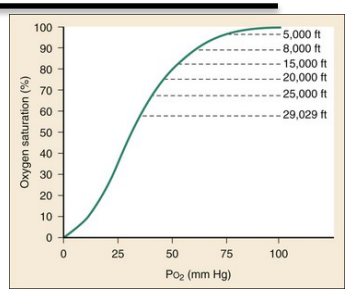


Explains DCI

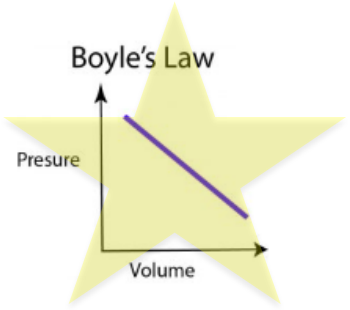
Dalton's Law

$P_T = P_1 + P_2 + P_3$

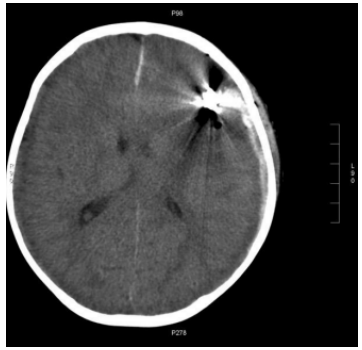
Explains why hypoxia occurs at altitude although $\%O_2$ remains constant



Air in the brain

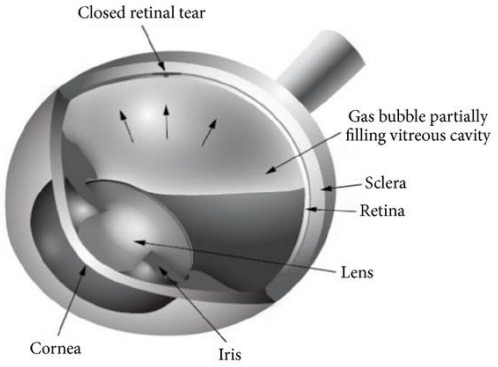


- Case study of 21 AE with pneumocephalus (mean 9.2ml air)
  - no adverse outcomes
- Transient increase ICP < 5 during take off & landing
  - Feet forward & head aft

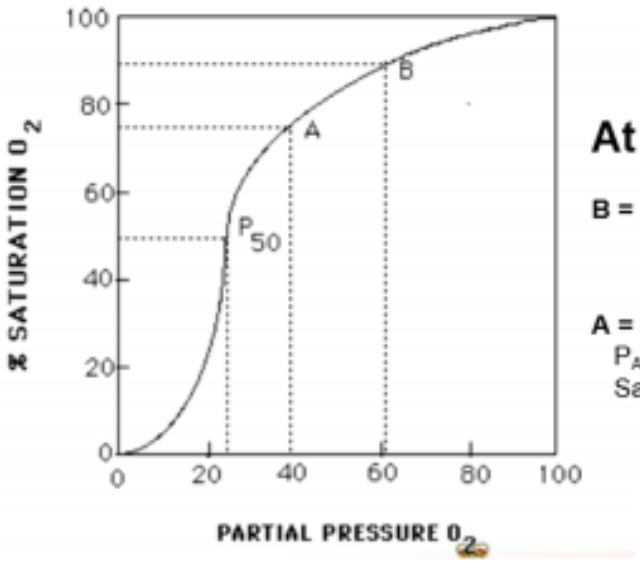


Air in the eye

- delay travel for approximately 2 wk after (SF6) and for 6 wk (C3F8)
- Penetrating eye trauma



In-flight O_2 requirements



At 8000 Ft

B = Healthy Lungs
P_AO_2 is 64
SaO_2 is 90%

A = severe COPD
P_AO_2 is 40
SaO_2 is 75%

Dalton's Law

$P_T = P_1 + P_2 + P_3$

TABLE 2: CONVERSION FOR IN-FLIGHT OXYGEN ADMINISTRATION

CABIN ALTITUDE	OXYGEN PERCENTAGE															
10,000	30	36	44	51	58	65	73	80	87	94	100					
9,000	29	35	42	49	56	63	70	77	84	91	98	100				
8,000	28	34	40	46	54	61	67	74	81	87	93	100				
7,000	27	32	39	45	52	58	65	71	78	84	91	97	100			
6,000	26	31	37	44	50	56	62	69	75	81	87	94	100			
5,000	25	30	36	42	48	54	60	66	72	78	84	90	96	100		
4,000	24	29	35	41	46	52	57	64	70	75	81	87	93	97	100	
3,000	23	28	33	39	45	50	56	61	67	73	78	84	89	95	100	
2,000	23	27	32	38	43	48	54	59	64	70	75	81	86	91	97	100
1,000	22	26	31	38	41	47	52	57	62	67	73	78	83	88	93	98
0	21	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95

Desired Sea Level Equivalent (SLE) Oxygen Percentage

Even though the delivered oxygen may be at 100%, the partial pressure of oxygen necessary to deliver 100% SLE cannot be obtained (ex: 100% O_2 @ 8,000 feet only provides 75% O_2 SLE).

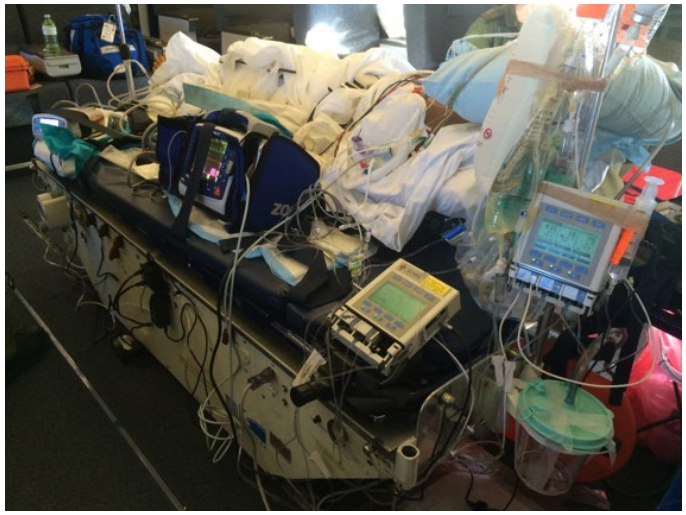
Desired % of oxygen SLE cannot be obtained at these altitudes.

Reference: USAF AFI-48-307 Vol 1 Table 8-3 (2017)

#3: Increased Noise

AIRPOWER IN FORMATION
AGILE • INTEGRATED • REACH • POWER

Visual and Auditory alarms



Crew/ Patient communication

Patient hearing protection

#4 Decreased relative humidity

- Relative Humidity during typical flight
  - < 5% after 2 hours
  - < 1% after 4 hours

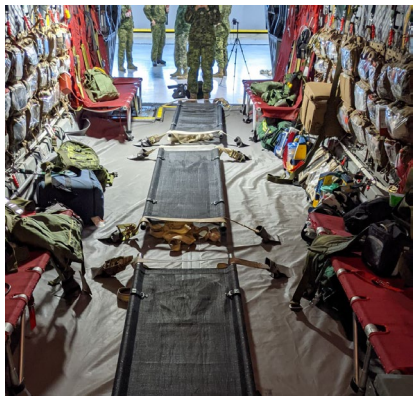
- Anticipate thickened respiratory secretions

#5 Variation in Cabin temperature

- Varies between aircraft and even within the same aircraft

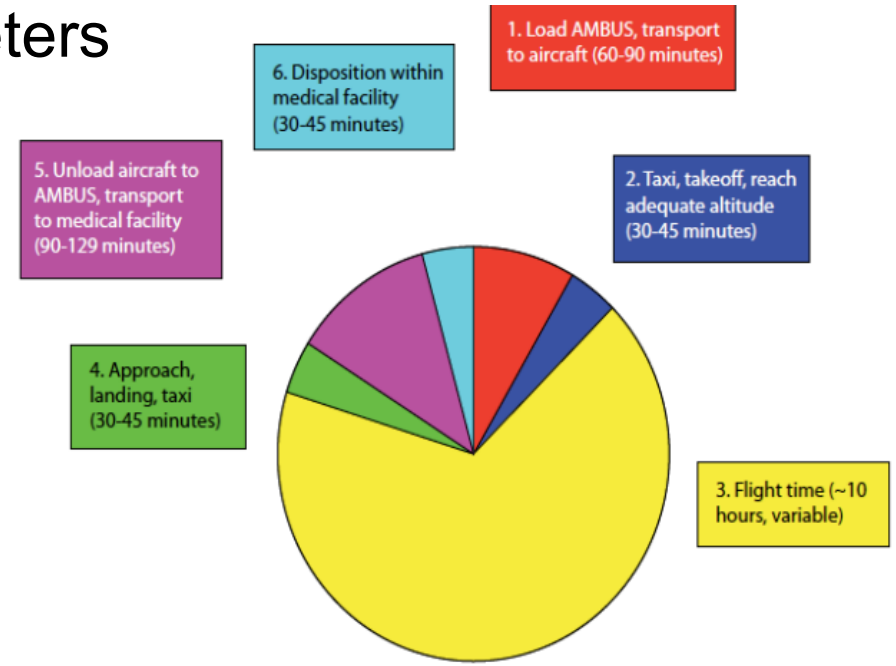
#6 Acceleration/ Deceleration/ Vibration

- Medical supplies and equip
  - dangerous projectiles – nothing loose
- Fractures
  - Instability - can't use pulley traction, sand bags
  - Very painful – ensure well padded
- Beds and litters aligned parallel to long-axis
- Take off and landing



Pain management

- Analgesia
  - PO/ IM/ IV
  - PCA pumps
  - continuous nerve block catheters
  - epidural catheters



* sedation and analgesia needs are likely to increase during transport

Motion sickness

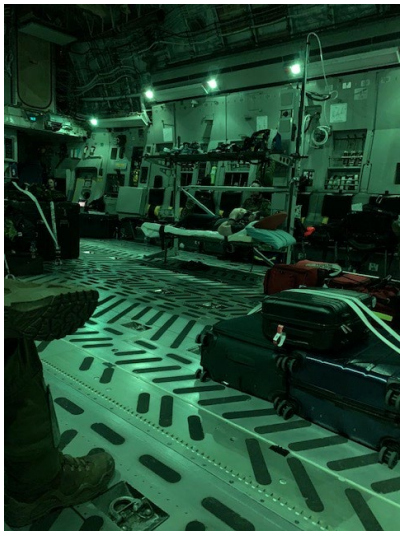
- air sickness
  - vomiting (aspiration)
  - ⇧ICP
  - dehydration
  - abdominal wound disruption

* Consider anti-emetics pre-flight in all patients, suction readily available

* 1st gen antihistamine preferred

7. Poor lighting

- Monitoring patient
- Interventions
- communication



8. Anxiety/ Apprehension

- unfamiliar environment
- communication
- returning home
- flight safety considerations

Airway considerations

- Airway and Endotracheal Tube
  - Critically injured & unstable patients should have a definitive airway prior to transport
    - Difficult to intubate in-flight
    - Difficult to assess in-flight (breath sounds, chest wall movement)
    - Noise, vibration, poor lighting
- ETT Cuff - Safest is air-filled & measure cuff pressures
  - Saline in cuff - low compressibility - ischemic a/w injury

  * BEWARE OF ETT MIGRATION DURING TRANSPORT

Chest Tubes

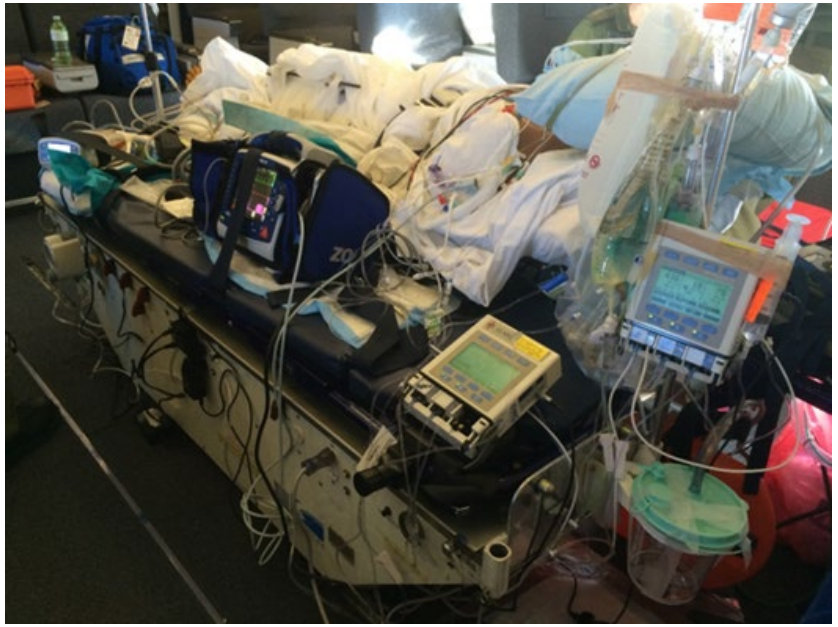
- CXR pre-fight
- R/O pneumotx in all pt with hx of thoracic trauma
- R/A all pts with chest tubes to check position & function
- Prophylactic chest-tubes not indicated
- Unfit to fly for 24hr post chest tube removal

* Heimlich valve not required in line, required if chest drain removed

Ventilators

- Does your ventilator compensate for altitude changes?
- Humidification of Gases – HME
- Time to ensure correct vent settings prior to transport from OMF

Tube/ equipment management



SMEED

Anemia

Tissue O_2 delivery dependent on:

1. Hgb level (mitigate: transfusion)
2. Hgb saturation (mitigate: suppl O2 or CAR)
3. FiO_2 (mitigate: suppl O2 or CAR)
4. Cardiac output
5. Plasma O_2 content

Table 9. Altitude Equivalent FiO_2 and Hemoglobin Levels

Altitude Equivalent FiO_2 and Hemoglobin Levels				
Acute Anemia				
Altitude (ft)	Ground Equivalent FiO_2 (%)	Ground Equivalent Hemoglobin (g/dl)	Saturation (100%)	Saturation (85%)
			Arterial Oxygen Content (vol%)	
12,000	13.3	5	6.7	5.7
11,000	13.8	6	8.0	6.8
9,500	14.7	7	9.4	8.0
8,400	15.4	8	10.7	9.1
7,200	16.1	9	12.1	10.3
6,000	16.8	10	13.4	11.4
4,800	17.6	11	14.7	12.5
3,500	18.5	12	16.1	13.7
2,400	19.2	13	17.4	14.8
1,200	20.1	14	18.8	15.9
0	21.0	15	20.1	17.1

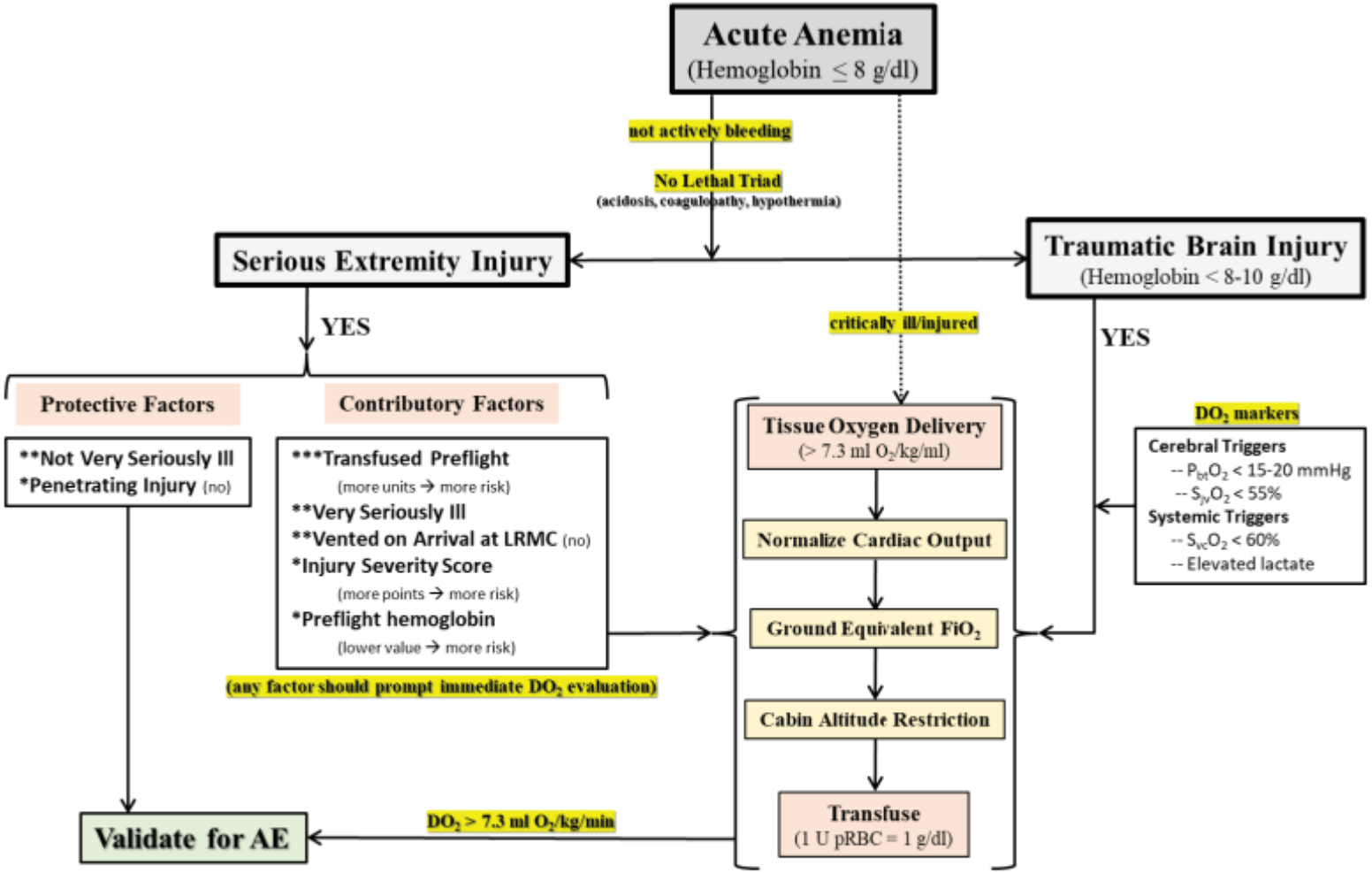
Note: This table was created from materials within multiple sources. **(McLaughlin, 2003; AAMETM, 2006; Butler, 2020d)**. FiO_2 (oxygen fraction of inspired air), ft (feet), % (percent), g (gram), dl (deciliter), vol% (volume percent).

Reference in notes

Anemia

- Normal cabin altitude (8000 ft)
  - Hgb 8 -10g/dl may be required to provide adequate tissue oxygenation
  - provide suppl O_2 if Hgb < 8.5 g/dl
  - with FiO_2 50% or more, Hgb 7-8 g/dl should be adequate (assuming normal CO & metabolic demand)
- Critical care pts have impaired or low normal CO and/or increased metabolic demands

  = Hgb > 8 g/dl required



Note: This algorithm takes the study's findings and conjoins them with information/results from a number of publications to produce a logical and coherent approach to the patient with acute anemia. **(Diringer, 2011; Lelubre, 2016; Butler, 2020b; Butler, 2020d; Chou, 2021)** ***Denotes being named a factor in three of the four predictive models. **Denotes being named a factor in two of the four predictive models. *Denotes being named a factor in one of the four predictive models. g (gram), dl (deciliter), LRMC (Landstuhl Regional Medical Center), DO_2 (tissue oxygen delivery), ml (milliliter), O_2 (oxygen), kg (kilogram), min (minute), FiO_2 (oxygen fraction of inspired air), U (unit), pRBC (packed red blood cells), $P_{bt}O_2$ (partial pressure of oxygen in brain tissue), $S_{jv}O_2$ (jugular vein oxygen saturation), $S_{vc}O_2$ (vena cava oxygen saturation).

Figure 7. TVFS Validation Algorithm for Patients with Acute Anemia

Reference in notes

VTE

- Flight increases risk due to:
  - Immobility
  - Dehydration
  - nature of injury

J Gen Intern Med. 2007 Jan; 22(1): 107–114.
Published online 2007 Jan 17. doi: 10.1007/s11606-006-0016-0
PMCID: PMC1824715
PMID: 17351849

Air Travel and Venous Thromboembolism: A Systematic Review

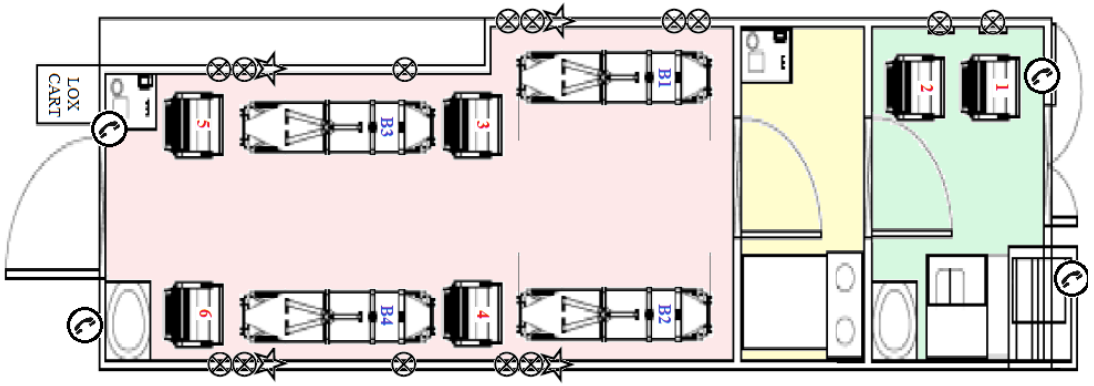
John T. Philbrick, MD,[1,2,3] Rebecca Shumate, MD,[1] Mir S. Siadaty, MD, MS,[2] and Daniel M. Becker, MD, MPH[1,2]

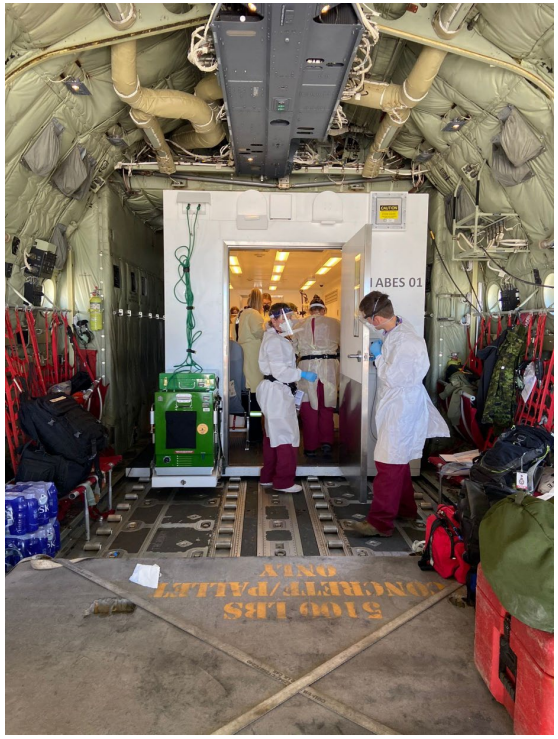
Author information · Copyright and License information Disclaimer

- Rare from flights <6hrs
  - incidence ~0.5% from >8hr flights
  - unlikely during flight, often within 72hrs

- Risk stratify for flights >6 hrs
  - **Low**: general advice
  - **Moderate:** graduated compression stockings (15-30 mmHg at the ankle)
  - **High**: LMWH

Infectious Disease: ABES

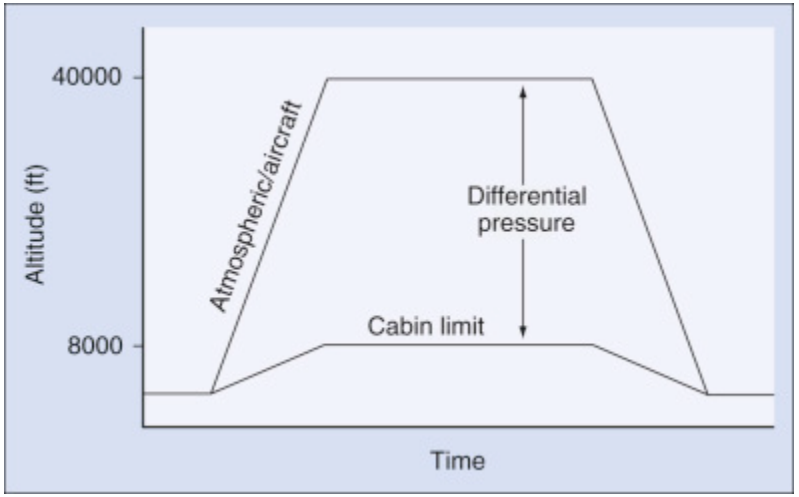




Cabin Altitude Restrictions

<u>Absolute Indications</u>

1. DCI
2. Intracranial Air (?)
3. Intraocular Air
4. Cardiac Injuries



* More appropriate for managing problems associated with trapped air/ evolved gas rather than hypoxia

Cabin Altitude Restrictions

AIRPOWER IN FORMATION
AGILE • INTEGRATED • REACH • POWER

Concerns

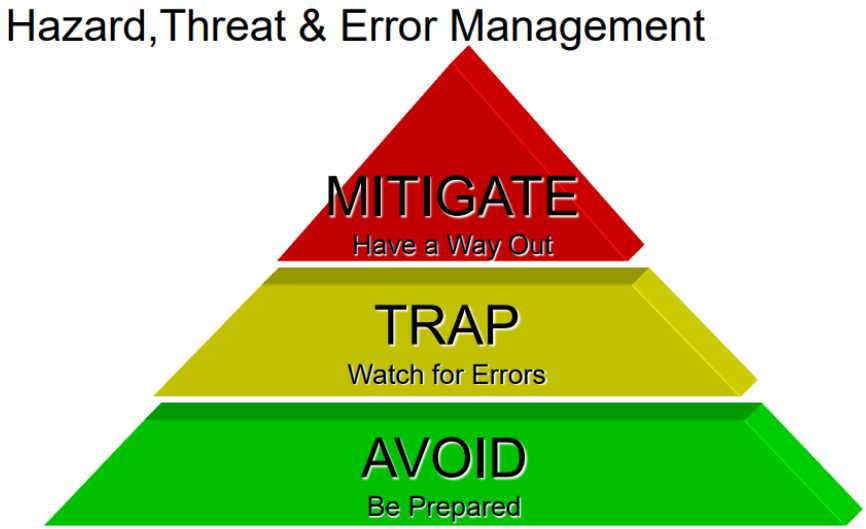
1. Decreased maximum flight level
2. Increased turbulence
3. Increased flight time
4. Increased fuel consumption (↓ range)

C17: CAR 2000ft – max ceiling 24,000ft
CAR 4000 – 8000 ft, no restriction

* Can request changes to flight profile to min vector forces

Manage Medical Complications (Goal 3)

- Planning is key
- Medication discussion
- Plan of care
- *Potential complications*
  - Most likely and most severe complications



In-flight Medical Emergencies

- Notify the MCD as soon as practical
- Recommend changes to mission profile
  - Aircraft diversion
  - Cabin altitude restriction
- Identify to the MCD any requirement for appropriate additional resources at destination such as:
  - Ground transport crew
  - Nurse and/or physician
  - Oxygen, medications and equipment

Diversion

Things to Consider

- Time to alternate vs. original destination
- Adequate medical resources
- Getting resources to the flight-line
- Pilot's concerns
  - Airfield runway, weather, security, fuel
- Consultation with MCD & AC Commander

Death Enroute

- Do not divert
- Do not declare legally dead until AC is on ground
  - Issues with treaties with other countries
- On board MD can halt resuscitation
  - Record apparent time of death (Local/Zulu)

Part C: Challenges with Mission Validation

Considerations

- Initial validation based on AE Request and Initial SITREP
- Consider *entire* journey *(*not just flight)
- Priority/ classification/ dependency
- Aircraft capability and availability
- Crew – type, preparation, location
- Patient and aeromedical crew logistics

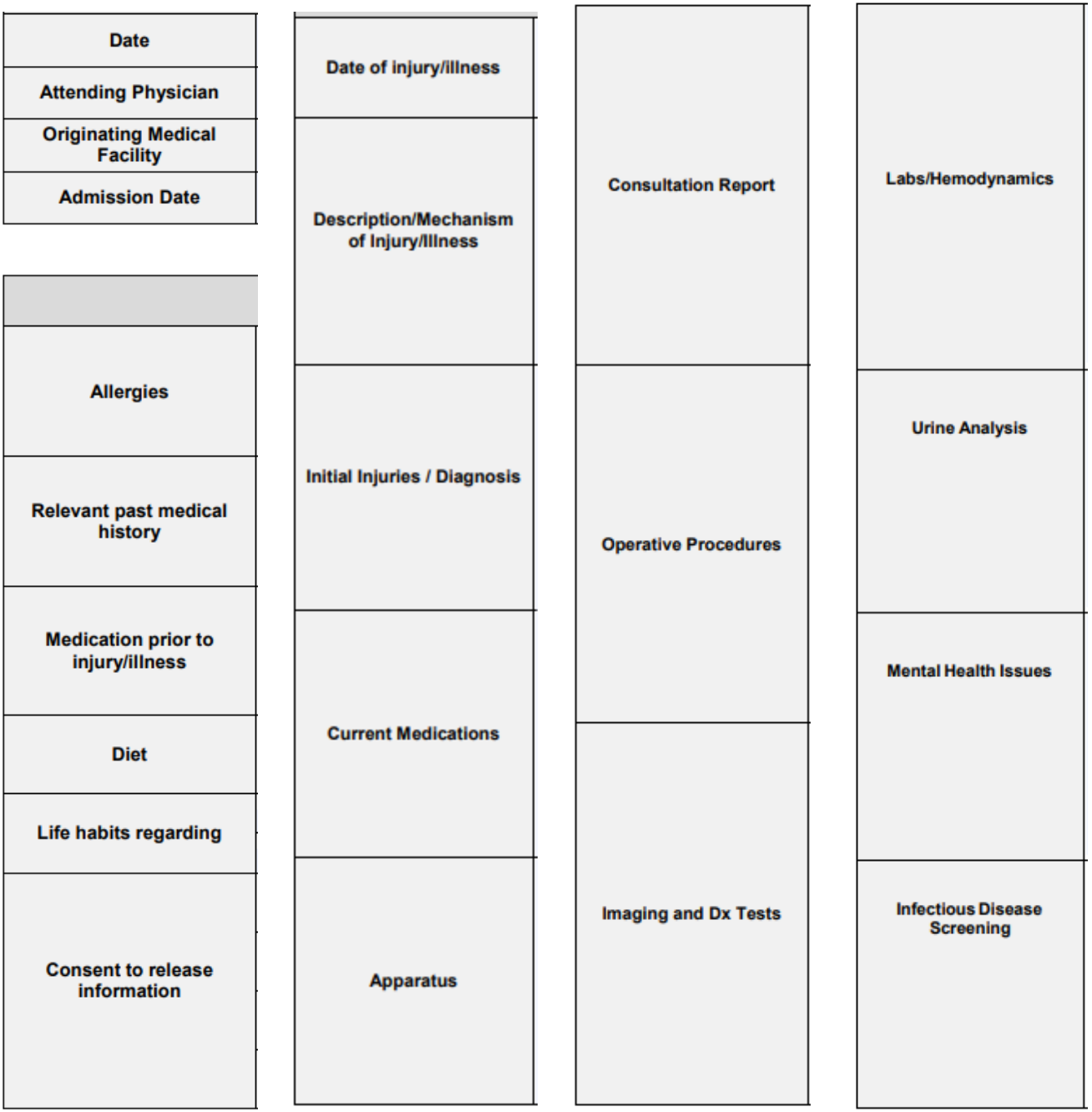
AE Request

STRATEGIC AEROMEDICAL EVACUATION (AE) REQUEST

SECTION A – PATIENT INFORMATION			
Name:		Patient ID: (if applicable)	
Rank:		SN:	
Gender:		DOB:	
Parent unit:		MOC/MOSID:	
Move Window (Date/Time patient can be moved) Earliest:	Latest:		
Originating Medical Facility (OMF)			
Name of OMF:		Ward	
		Phone	
Attending/Referring Physician:		Phone	
		Email	
Referring CAF Physician:		Phone	
		Email	
Administrative Point of Contact at OMF:		Phone	
		Email	
Destination Medical Facility (DMF)			
Name of DMF:		Ward	
		Phone	
Attending/Receiving Physician:		Phone	
		Email	
Receiving Base/Wing Surgeon:		Phone	
		Email	
Administrative Point of Contact at DMF:		Phone	
		Email	

SECTION B – MISSION INFORMATION		
Priority		Additional AE crew required: (AE crew consists of one Flight Nurse, one Flight Med Tech and one Flight Surgeon) Specify:
Classification		Special equipment required: Specify:
Dependency		Altitude restrictions: Specify: NOK accompanying: Name:

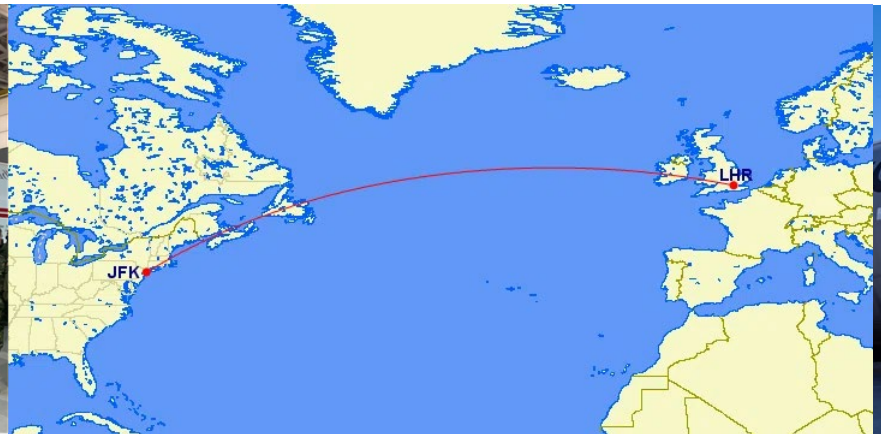
Initial Med SITREP



+ daily updates

Challenges

- Language barriers/ documentation/ comms
- Standard of care/ patient not always as advertised
- Medication differences
- ‘eyes’ on the ground locally
- Securing a receiving bed at destination
- Equipment - not brought or not airworthy – can’t use
- Transport logistics
- Time zones



Key Take Away Points:

1. Not as simple as “fit to fly”
2. Remember primary goals of AE
3. Planning is key

Questions?

Maj M.E. Gear
melissa.gear@forces.gc.ca