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How to handle cardiac arrest in spaceflight - a guideline for cardiopulmonary resuscitation in microgravity

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Conflict of interest

(1)

Why do we need a special guideline?

Resuscitation 95 (2015) 100–147

Contents lists available at ScienceDirect

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

ELSEVIER

EUROPEAN RESUSCITATION COUNCIL

European Resuscitation Council Guidelines for Resuscitation 2015
Section 3. Adult advanced life support

CrossMark

Jasmeet Soar[a,*], Jerry P. Nolan[b,c], Bernd W. Böttiger[d], Gavin D. Perkins[e,f], Carsten Lott[g], Pierre Carli[h], Tommaso Pellis[i], Claudio Sandroni[j], Markus B. Skrifvars[k], Gary B. Smith[l], Kjetil Sunde[m,n], Charles D. Deakin[o], on behalf of the Adult advanced life support section Collaborators[1]

Why do we need a special guideline?

(6)

Why do we need a special guideline?

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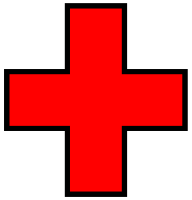
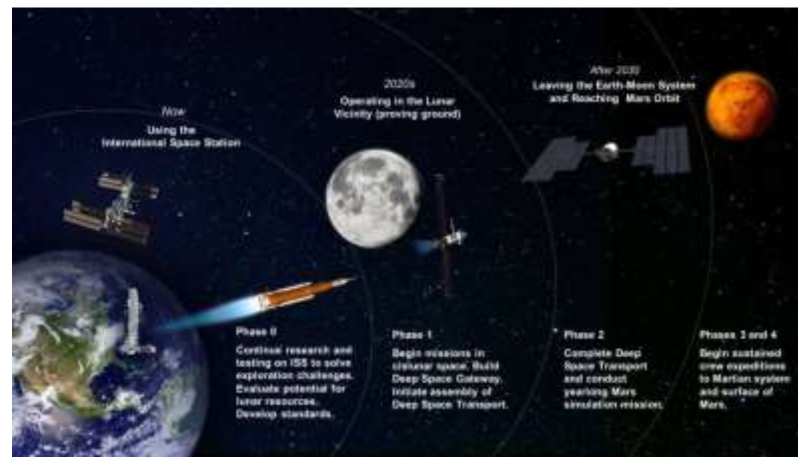
Why do we need a special guideline?



Microgravity

(2)



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What is the likelihood of a severe medical event?

- General population: 6% per person per year
- → crew of 6, with mission duration ~ 900 days
- → one severe medical event!

REVIEW

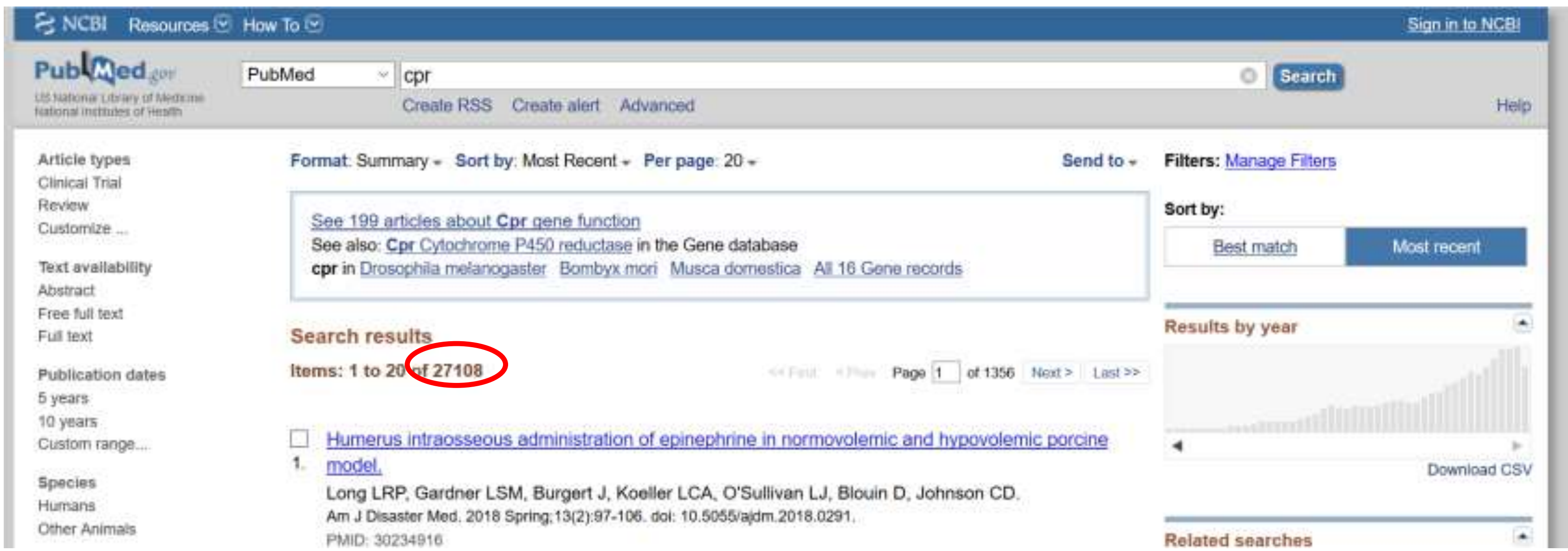
Anaesthesia in outer space: the ultimate ambulatory setting?

- Life threatening event: 1% per person per year
- → crew of 6 , 900 days
- → 15-20% chance

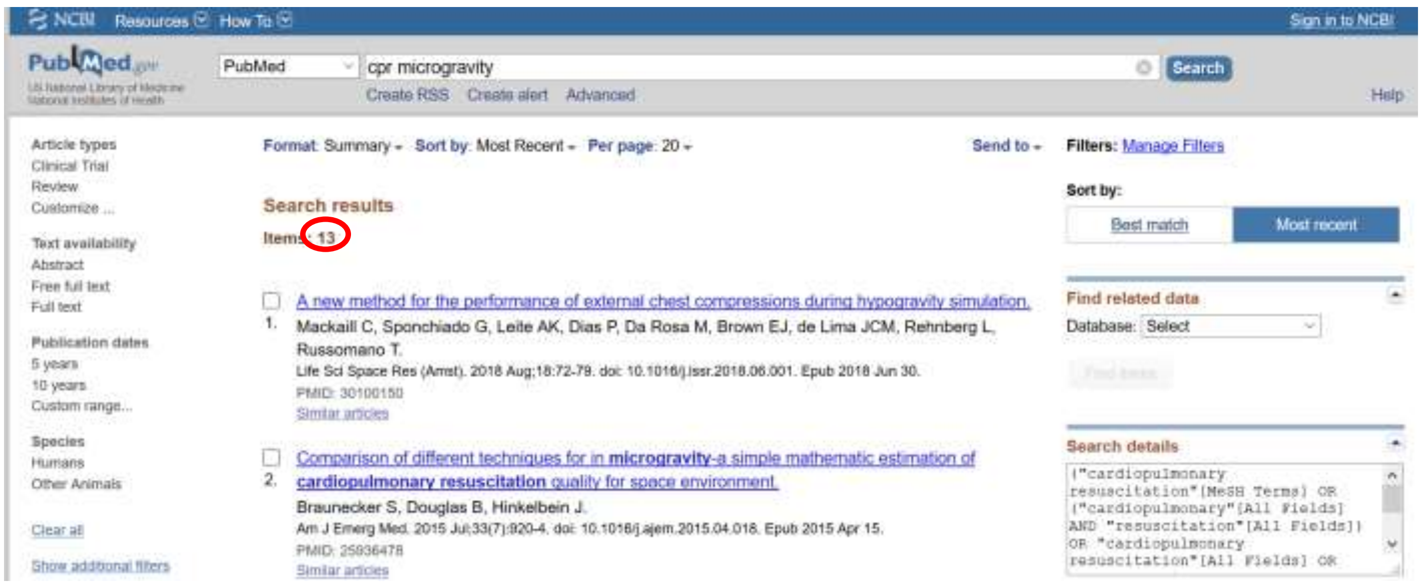
- BUT: Highly screened, (mostly) young and healthy population

- Space tourism: probably also older participants
- →pre-existing conditions

Every severe medical event could lead to a cardiac arrest
→ We need a plan



Every severe medical event could lead to a cardiac arrest
→ We need a plan



- Up to this day → no cardiac arrest in microgravity
  → No CPR, no experience under real conditions

- Only 3 instances ever required evacuation (1x urosepsis, 1x 14-beat run VT, 1 x severe headache after possible CO² buildup)

- Evacuation is at the moment only possible via Sojuz spacecraft
- →Necessity to wear pressurized suit

- For space exploration missions → no prompt evacuation will be possible

The guideline

- Formation of a taskforce
- Scientists with a wide range of backgrounds
- Aerospace medicine, emergency medicine, anaesthesia, surgery, cardiology, physics,…

Jochen Hinkelbein[1,2], Steffen Kerkhoff[1,3], Stefan Braunecker[4], Fabrizio Cirillo[5], Edoardo de Robertis[6], Eckard Glaser[2,7], Pete Hodkinson[8,9], Ivan Zefiro Iovino[10], Stefanie Jansen[11], Matthieu Komorowski[12,13], Christopher Neuhaus[2,14], Lucas Rehnberg[15], Gianmarco Romano[17], Thais Russomano[16,18], Oliver Spelten[19], Jan Schmitz[1,2], Oliver Ullrich[2,20], Rochelle Velho[21], Tobias Warnecke[22]

Affiliations:

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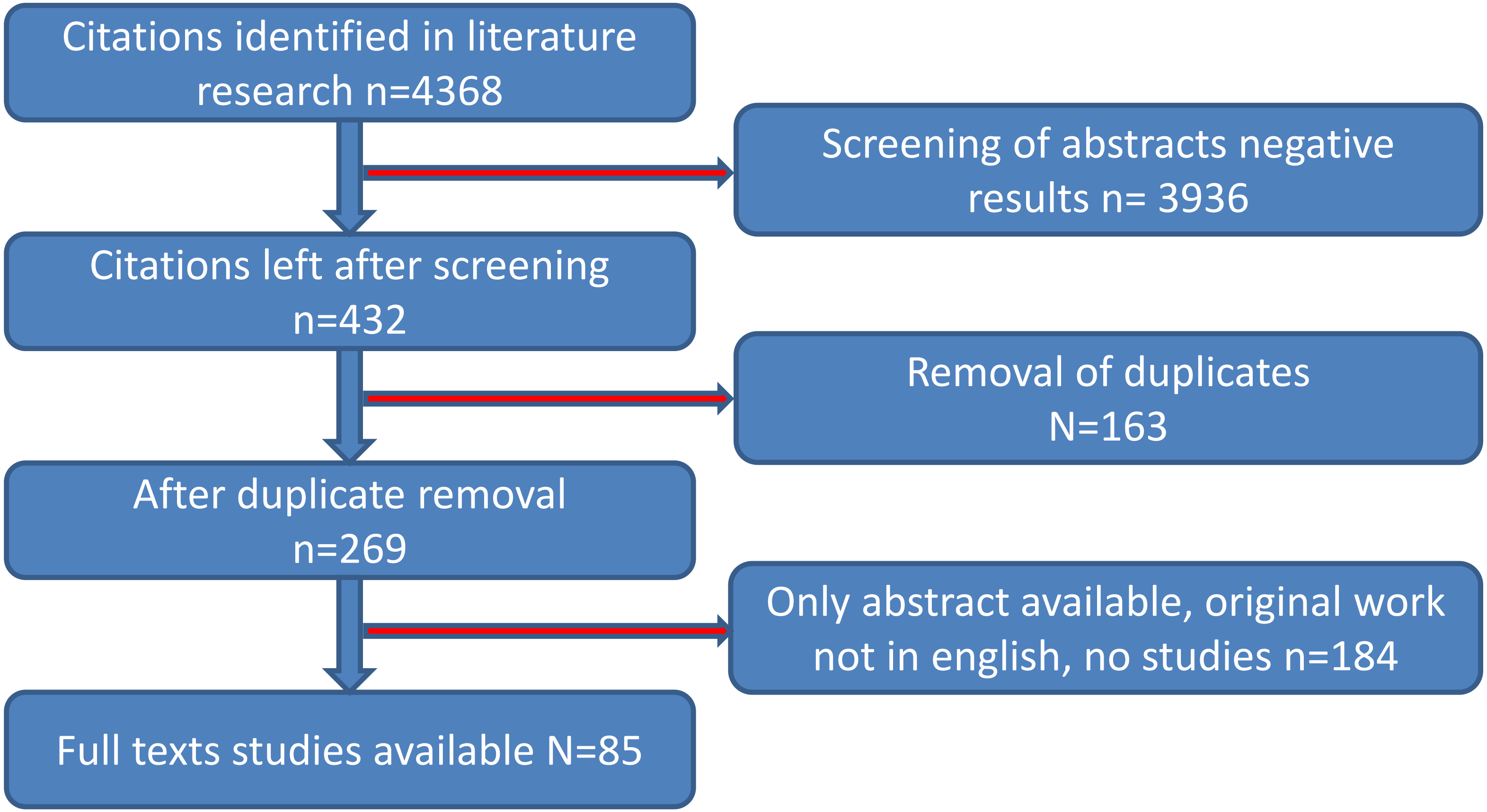
Methods

- Brainstorming
- Determination of relevant topics (15 main groups)

-Chest compressions
-Automated chest compression devices
-Airway management
-Ventilation
-Suction
-Defibrilation
-Vascular access
-Medication
-ROSC
-Death
-Telemedicine
-Reversible causes
-Technical limitations of spaceflight
-Training
-Ethics

- Development of 137 PICO-questions to guide the literature research
- „ *Should a patient in cardiac arrest in microgravity be fastened on the crew medical restraint system for CPR or should he be free floating regarding beginning of effective chest compressions?* “
- Search strategy for the MEDLINE® database (www.pubmed.gov)
- “((("restraint, physical"[MeSH Terms] OR restraint[All Fields]) OR "restraint, physical"[MeSH Terms]) OR fasten[All Fields]) AND (((((("weightlessness"[MeSH Terms] OR "weightlessness"[All Fields] OR "microgravity"[All Fields]) OR "weightlessness"[MeSH Terms]) OR ("weightlessness"[MeSH Terms] OR "weightlessness"[All Fields])) OR "weightlessness"[MeSH Terms]) OR "space flight"[MeSH Terms]) AND (((((("cardiopulmonary resuscitation"[MeSH Terms] OR ("cardiopulmonary"[All Fields] AND "resuscitation"[All Fields]) OR "cardiopulmonary resuscitation"[All Fields] OR "cpr"[All Fields]) OR "cardiopulmonary resuscitation"[MeSH Terms]) OR cardiopulmonary[All Fields]) OR "cardiopulmonary resuscitation"[MeSH Terms]) OR ("resuscitation"[MeSH Terms] OR "resuscitation"[All Fields])) OR "cardiopulmonary resuscitation"[MeSH Terms]))”
- **Aim: strictly evidence-based guideline (GRADE-methodology)**


Citations identified in literature research n=4368
Screening of abstracts negative results n= 3936
Citations left after screening n=432
Removal of duplicates N=163
After duplicate removal n=269
Only abstract available, original work not in english, no studies n=184
Full texts studies available N=85

- Remaining literature was then rated using the GRADE-method by two groupmembers

Section/B	study design Quality starting factor	Quality of evidence	The 5 downgraders	The 3 Upgraders
			Quality is lowered if	Quality is raised if
Factors 2-10 The 8 GRADE quality factors	Randomized trials →	↓ High	Limitations of design -1 Serious -2 Very serious	Large effect +1 Large +2 Very large
		Moderate ↑	Inconsistency -1 Serious -2 Very serious	Dose response +1 Evidence of a gradient
	Observational studies →	↑ Low	↓ Indirectness -1 Serious -2 Very serious	Antagonistic bias +1 All plausible confounding would reduce the effect or +1 Would suggest a spurious effect when results show no effect
		↑ Very low		
			Imprecision -1 Serious -2 Very serious	
			Publication bias -1 Likely -2 Very likely	
	Total Points →			

- Every taskforce member was assigned to two of the main topics
- → draft of recommendations for the assigned topic

- Then two-round Delphi-procedure for consensus finding

- Taskforce members could rate the proposed recommendations with agreement/disagreement and give additional comments

- Of the 27 proposed recommendations, 23 recommendations were consented, mainly with strong consensus

- Quality of evidence and consensus were then assessed and
- → strength of recommendation determined

	clarity of risk / benefit	quality of supporting evidence	implications
1A strong recommendation high-quality evidence	benefits clearly outweigh risk and burdens, or vice versa	Consistent evidence from well performed RCTs or overwhelming evidence of some other form. Further research is unlikely to change confidence in the estimate of benefit and risk.	Strong recommendation, can apply to most patients in most circumstances without reservation.
1B strong recommendation moderate-quality evidence	benefits clearly outweigh risk and burdens, or vice versa	Evidence from RCTs with important limitations or very strong evidence of some other form. Further research is likely to have an impact on the confidence in the estimate of benefit and risk and may change the estimate.	Strong recommendation, likely to apply to most patients.
1C strong recommendation low-quality evidence	benefits appear to outweigh risk and burdens, or vice versa	Evidence from observational studies, unsystematic clinical experience, or from RCTs with serious flaws. Any estimate of effect is uncertain.	Relatively strong recommendation; might change when higher quality evidence becomes available.
2A weak recommendation high-quality evidence	benefits closely balanced with risk and burdens	Consistent evidence from well performed RCTs or overwhelming evidence of some other form. Further research is unlikely to change confidence in the estimate of benefit and risk.	Weak recommendation, best action may differ depending on circumstances or patients or societal values.
2B weak recommendation moderate-quality evidence	benefits closely balanced with risks and burdens, some uncertainty in the estimates of benefits, risks and burdens	Evidence from RCTs with important limitations or very strong evidence of some other form. Further research is likely to have an impact on the confidence in the estimate of benefit and risk and may change the estimate.	Weak recommendation, alternative approaches likely to be better for some patients under some circumstances.
2C weak recommendation low-quality evidence	uncertainty in the estimates of benefits, risks and burdens; benefits may be closely balanced with risks and burdens	Evidence from observational studies, unsystematic clinical experience, or from RCTs with serious flaws. Any estimate of effect is uncertain.	Very weak recommendation; other alternatives may be equally reasonable.

Chest compressions

Astronaut Bursch performs CPR on a "human chest" dummy on the ISS.

American Journal of Emergency Medicine

Original Contribution

Comparison of different techniques for in microgravity—a simple mathematic estimation of cardiopulmonary resuscitation quality for space environment

Basic Life Support in Microgravity: Evaluation of a Novel Method During Parabolic Flight

Simon N. Evetts, Lisa M. Evetts, Thais Russomano, João C. Castro, and John Ernsting

Evetts SN, Evetts LM, Russomano T, Castro JC, Ernsting J. Basic life support in microgravity: evaluation of a novel method during parabolic flight. Aviat Space Environ Med 2005; 76:506–10.

methods of basic and advanced life support (ALS) in microgravity (2,8). Protocols have been examined that could be used for trauma management in conjunction

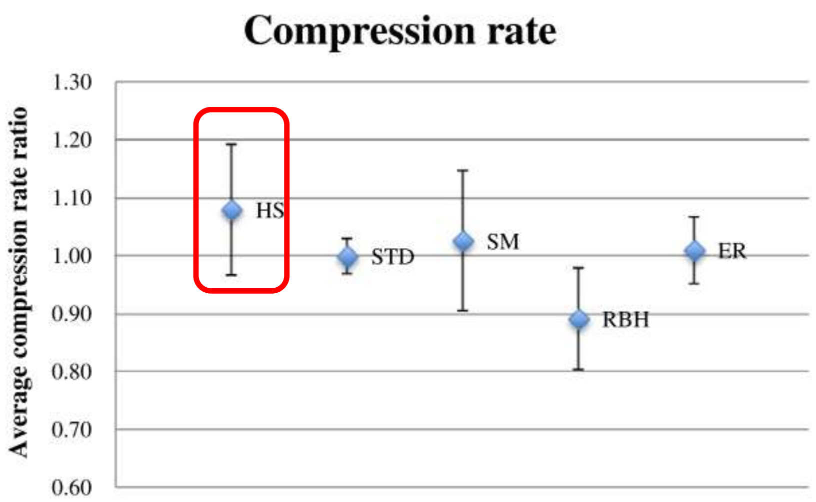


Fig. 3. Average CR in ratio to guideline.

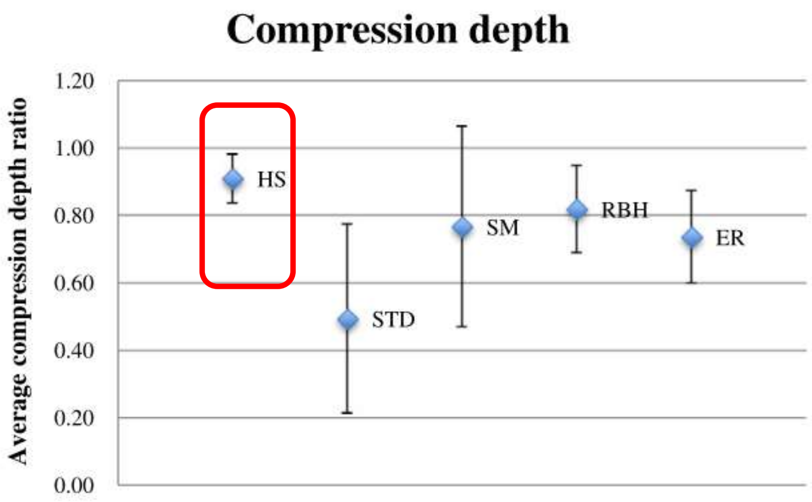


Fig. 2. Average CD in ratio to guideline.

No.	Recommendations	Quality of evidence (QoE)	Consensus	Strength of recommendation
#1	CPR in microgravity SHOULD be divided into a chain of survival consisting of Basic Life Support (BLS) and Advanced Life Support (ALS).	moderate	strong	1B strong recommendation moderate-quality evidence
#2	For BLS at the site of emergency the Evetts-Russomano method (ER) of performing chest compressions SHOULD be applied. If the rescuer cannot perform adequate chest compressions with the ER method, he should switch to the Reverse-Bear-Hug method (RBH).	moderate	strong	1B strong recommendation moderate-quality evidence
#3	As soon as the patient has been restrained on the Crew Medical Restraint System chest compressions SHOULD be applied using the Handstand-method (HS).	moderate	strong	1B strong recommendation

Airway management

Fig. 1. Experimental apparatus showing the frame holding the two mannequins and the two flyers.

Figure 1. Laryngoscope-guided tracheal intubation with the manikin floating free with the head between the knees.

(7)

Airway Management with E
Combitube® during Parabol

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Check for updates

acta Anaesthesiologica Scandinavica

REVIEW ARTICLE

Airway management in microgravity: A systematic review

Tobias Warnecke[1] | Felix Tochtermann[2] | Steffen Kerkhoff[3,4,5] | Matthieu Komorowski[5,6] | Christopher Neuhaus[4,7] | Jochen Hinkelbein[3,4,5]

ing Spaceflight
vices in Simulated Microgravity

Table 1. Airway Management Data

	ETT			COPA			LMA			ILM		
	Poolside	Free-floating	Restraints	Poolside	Free-floating	Restraints	Poolside	Free-floating	Restraints	Poolside	Free-floating	Restraints
Insertion attempts; n												
1	40	0	22	40	38	40	39	36	39	40	37	40
2	0	2	10	0	2	0	1	4	1	0	3	0
3	0	5	7	0	0	0	0	0	0	0	0	0
Fail	0	33	1	0	0	0	0	0	0	0	0	0
Placement; n												
Adequate	40	6	37	36	34	34	40	39	40	38	38	36
Inadequate	0	1*	2*	4	6	6	0	1	0	2	2	4
Airway management failure; n	0	34	3	4	6	6	0	1	0	2	2	4
Time to successful insertion; s	19 ± 3	33 ± 21	36 ± 7	19 ± 3	31 ± 7	33 ± 6	19 ± 2	33 ± 8	34 ± 6	19 ± 2	31 ± 7	34 ± 5

Number of insertion attempts, adequacy of placement, airway management failure and time to successful insertion in normogravity by the poolside (Poolside), simulated microgravity with the manikin floating free (Free-floating) and simulated microgravity with the manikin attached to the floor with restraints (Restraints) for the endotracheal tube (ETT), cuffed oropharyngeal airway (COPA), standard laryngeal mask airway (LMA) and intubating laryngeal mask airway (ILM). Data are mean ± SD or numbers (%).

* Esophageal intubation.

#10	The endotracheal intubation remains the gold standard for securing the airway if performed by a skilled provider and SHOULD be executed in that case.	moderate	strong	**1B** **strong recommendation** **moderate-quality evidence**
#11	When endotracheal intubation is attempted patient and rescuer should be restrained using the Crew Medical Restraint System.	moderate	strong	**1B** **strong recommendation** **moderate-quality evidence**
#12	If no rescuer with extensive training in endotracheal intubation is present a second generation supraglottic airway device SHOULD be used for airway management.	moderate	strong	**1B** **strong recommendation** **moderate-quality evidence**

Defibrillation

#15	A defibrillator SHOULD only be used on a patient that is restrained to an electrically isolated and safe surface.	low	strong	**1C strong recommendation low-quality evidence**
#16	An automated external defibrillator (AED), with long duration batteries and long shelf-life self-adhesive pads, SHOULD be stored with the emergency equipment.	low	strong	**1C strong recommendation low-quality evidence**
#17	The AED SHOULD have a user-friendly interface, a step-by-step instruction voice for correct pads positioning and electrical shock delivery and a timing device for correct chest compressions/ventilation rate.	low	strong	**1C strong recommendation low-quality evidence**
#18	All crewmembers SHOULD be trained in the use of the specific AED provided during the mission.	none	strong	**1C strong recommendation low-quality evidence**

Limitations

- Studies either performed in simulated microgravity or parabolic flight
- → weak representation of the real circumstances during spaceflight
- → parabolic flight offers only ~ 20 seconds of microgravity
- Limited set of studies have been performed
- Case numbers are very low
- → in some cases expert consensus was necessary

Future

- Guideline needs to be reevaluated frequently

- More high quality studies need to be performed

- Possible focus on
- → defibrillation
- → crew training
- → treatment of reversible causes
- → post resuscitation care

Thank you for your attention!

(8)

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List of figures

(1) https://nonprofitquarterly.org/wp-content/blogs.dir/56/files/2018/02/no-money-handshake.jpg
(2) https://www.zdf.de/kinder/logo/raumfahrer-erreichen-iss-100.html
(3) https://www.nasa.gov/johnson/exploration/deep-space
(4) https://en.wikipedia.org/wiki/Extravehicular_activity
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(8) https://starwarsblog.starwars.com/wp-content/uploads/2017/08/bacta-tank-luke-han-leia.jpg