Citation for published version (APA):
Saving lives in spaceflight - a guideline for cardiopulmonary resuscitation in microgravity

Steffen Kerkhoff1,2,3, Stefan Brauneccker1, Fabrizio Cirillo5, Edoardo De Robertis1, Eckard Glaser1, Peter Hodkinson4,5, Ivan Zefiro Iovino2, Stefanie Jansen4, Matthieu Komorowski12,14, Christopher Neuhauer1,13, Lucas Rehberg13,14, Gianmarco Romano6, Thais Russomano11,13, Jan Schmitt12,13, Oliver Splieten1, Ulrich Stolz6,15, Rochelle Velho16, Tobias Warnecke1, Christoph Adler17, Jochen Hinkelbein1,2

Background
As mankind strives to explore space beyond the moon by planning space exploration missions to Mars and as space tourism becomes closer to operational viability, medical planning for those missions must consider the possibility of life threatening medical emergencies. For Earth, well-established and proven guidelines concerning cardiopulmonary resuscitation (CPR) are published. Nevertheless, such a guideline does not exist for the special environment of microgravity, despite mankind is exploring space since 1961. Nonetheless, several studies have been conducted to investigate the feasibility and best technique of CPR in microgravity. The aim of this guideline is to critically appraise all the literature of CPR in weightlessness and create the most up to date evidence-based guidance for its application under the special circumstances of spaceflight.

Methods
A task force was created by the German Society of Aerospace Medicine (DGLRM) to develop a guideline for CPR in weightlessness, based on the member’s clinical and scientific background. Then standardized questions using the PICO-model were created, to guide the systematic literature review, which was mainly performed using “PubMed”. The retrieved 4,356 abstracts were then screened using the browser-based tool “abstractor” in double-reviewer technique, and the selected papers were subsequently reviewed utilizing the GRADE-method. The guideline was then divided into 15 sections and the recommendations for each section were finalized by 2 experts. All proposed recommendations were then presented to the whole task force and subject to a structured consensus finding process using the RAND-DELPHI method.

Results
Similar to Earth-based guidelines, a differentiated approach to CPR with a division into basic life support (BLS) and advanced life support (ALS) is necessary for the special environment of microgravity. In immediate BLS, the chest compression method of choice is the Ewetts-Russomano method (ER), whereas in an ALS scenario, with the patient being restrained on the Crew Medical Restraint System, the handstand method (HS) should be applied. Airway management should only be performed if at least two rescuers are present and the patient has been restrained. A supraglottic airway device should be used for airway management where crew members untrained in endotracheal intubation (ETI) are involved.

Conclusion
CPR in microgravity is feasible and should be applied according to the Earth-based guidelines of the AHA/ERC in relation to fundamental statements, like urgent recognition and action, focus on high-quality chest compressions, compression depth and compression-ventilation ratio. However, the special circumstances presented by microgravity and spaceflight must be considered concerning central points such as rescuer position and methods for the performance of chest compressions, airway management and defibrillation.

Table 1 Examples of the preliminary recommendations concerning airway management during CPR in microgravity

No. No. Recommendations Quality of evidence (GRADE) Consensus Strength of recommendation
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 B recommendation moderate-quality evidence
11 When endotracheal intubation is attempted patient and rescuer should be restrained using the Crew Medical Restraint System. Moderate strong B 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 B recommendation moderate-quality evidence

1 Department of Anesthesiology and Intensive Care Medicine, University Hospital of Cologne, 50937 Cologne, Germany.
2 German Society of Aviation and Space Medicine (DGLRM), Munich, Germany.
3 Space Medicine Group, European Society of Aerospace Medicine (ESAM), Cologne.
4 Department of Critical Care, King’s College London, London, United Kingdom.
5 Department of Neurosciences, Reproductive and Obstetricotomological Sciences, University of Naples “Federico II”, Via S. Pansini, 5, 80131 Naples, Italy.
6 German, Germany.
7 Division of Anesthesiology, University of Cambridge, Box 33, Addenbrooke’s Hospital, Hills Road, Cambridge, CB2 2QG, United Kingdom.
8 Royal College of Anaesthetists, 35-43 Tavistock Place, London WC1H 9JR, UK.
9 Department of Anesthesiology, Head-neck Surgery, University of Cologne, 50937 Cologne, Germany.
10 Department of Surgery and Cancer, Faculty of Medicine, Imperial College London, Exhibition road, London, SW7 2AZ, UK.
11 Division of Anaesthesiology, University of Zurich, 8091 Zurich, Switzerland.
12 Department of Anaesthesiology, Heidelberg University Hospital - Heidelberg, Germany.
13 Centre for Human and Applied Physiological Sciences, King’s College London, London, United Kingdom.
14 University Hospital Southampton NHS Foundation Trust, Wessex Neurological Centre, Neuro Intensive Care Unit, Southampton, UK.
15 University Hospital Southampton NHS Foundation Trust, Wessex Neurological Centre, Neuro Intensive Care Unit, Southampton, UK.
16 Academic Department of Anaesthesiology, Critical Care, Pain and Resuscitation, Heart of England NHS Foundation Trust, Birmingham, UK.
17 Department of Anesthesiology, and Intensive Care Medicine, Evangelisches Krankenhaus, Düsseldorf, Germany.
18 Department of Internal Medicine II, Heart Centre of the University of Cologne, Germany.