THE SEATED ARM-LOCK METHOD: A NEW CONCEPT OF BASIC LIFE SUPPORT IN SIMULATED HYPOGRAVITY OF THE MOON AND MARS

Yacine Benyoucef(1), Tim Keady(2), Nikita Marwaha(3)

(1) Université de Montpellier 2, Faculté des Sciences, 371 Avenue du Doyen Gaston Giraud, 34295 Montpellier (France)
Email: yacine.benyousef@gmail.com

(2) University College Cork, College Road, Cork (Ireland)
Email: timkeady@gmail.com

(3) University of Birmingham, Edgbaston Birmingham, West Midlands B15 2TT (United Kingdom)
Email: nm.marwaha@gmail.com

Cardiopulmonary resuscitation (CPR) is an emergency procedure to return life to a person in cardiac arrest. This is indicated in those who are unresponsive with no breathing or only gasps. Studies have shown that the priority should be given to good external chest compressions, and to avoid the case where artificial ventilation may compromise survival [1]. Consistently with human space flight programs aboard the International Space Station (ISS), the Evetts-Russomano method seems to be appropriate to rescue a victim of cardiac arrest in microgravity [2, 3, 4, 5] but, in hypogravity, as far as we know, no method is yet appropriate to rescue astronauts [6]. According to our trial, using the classical basic life support (BLS) technique does not provide good results, especially during extended periods of resuscitation. The Seated Arm-Lock (SeAL) method seems to offer improved outcomes in simulated hypogravity.

SEVERAL DECADES AFTER the United States (U.S.) Project Apollo, responsible for the landing of the first humans on the Moon in 1969 [7], aiming to land a man on the Earth's satellite and to return him safely [8], many nations are mastering new space technologies and long-duration human space flights. Collaborative space agencies and partners just defined a global exploration roadmap to destinations where humans may someday live and work [9]. Deep space missions are the main stepwise goal to enhance Earth safety, to extend human presence and to search for life. For that, the ISS should provide a sustainable operating platform to near-Earth asteroid exploration and extended duration crew missions in the Lunar vicinity and surface, before missions to Mars. Since we were sending humans into extreme environments, medical crews continuously develop countermeasures to ensure safety and rescue. Today, it is of utmost importance and our duty as spacefaring humans to develop specific basic life support techniques to rescue astronauts on a low-gravity surface before an extended human mission is embarked upon.

Cardiac function and mass are diminished by long-term spaceflights. This effect is generated by a fluid shift from the lower to the upper body, resulting in upper body blood volume expansion [10]. This stimulates central volume carotid, aortic and cardiac receptors inducing a transient increase in diuresis and natriuresis. The size of the heart decreases, with modified cardiac filling, stroke volume and cardiac output [11]. Data from magnetic resonance imaging measurements show a 14% reduction in left ventricular mass pointing out a cardiac remodeling compromising myocardial function [11]. Arteries also change, responding to smaller volume by constricting to keep the blood flowing since they no longer see the sheer forces that stimulate arterial walls. Endothelial lining remodels wall with a lipid/protein and inflammation environment, inducing a local or systemic damage [11]. This data show that spaceflights can be physiologically deleterious. A long-duration journey out of Earth could then bring aboutchronic myocardial remodeling leading to heart failure and cardiac arrest. Therefore, providing efficient CPR in a low-gravity environment out of Earth should be the priority of any planned mission to the Moon or Mars. The proposed technique does not require equipment and considers the contraints expected during external exploration, taking into account that incidences may or may not occur within planetary habitats.

Performing the classic method of basic life support in simulated hypogravity is unstable and each compression pushes you away from the victim, resulting in a decreased rate and compression depth. The position requires more arm flexion and good arm strength, and...
quickly becomes tiring; it may also be hard for deconditioned or weaker crew to perform. For this reason we have developed a new cardiopulmonary resuscitation method in order to improve BLS during future missions on the surface of the Moon and Mars. The Seated Arm-Lock method was devised as a means to combat the main problem in performing cardiopulmonary resuscitation in hypogravity. Namely, the increased difficulty in achieving adequate depth of compression without the rescuer becoming exhausted or being pushed away from the victim. The solution involves the rescuer straddling the victim with the victims arms being locked in behind the rescuers knees. The rescuers knees should be in the shoulder area of the victim and his toes by the victims hips, pointed backwards. The position prevents the rescuer being pushed away from the victim by using the arms as strong and comfortable pivot points. No residual tone is required in the victims arms.

MATERIALS AND METHOD

Protocol
Subjects were required to practice CPR using the Seated Arm-Lock technique prior to the beginning of the experiment under conditions of +1Gz and in simulated hypogravity on the Moon and Mars. The SeAL for basic life support was compared to the classical method of BLS. The frequency and depth of chest compression was recorded continuously throughout a 3 min protocol (30 compressions and 6 seconds break as per the 30:2 ratio from the American Heart Association guidelines) [5, 12]. The perceived exertion of the subject was taken using the Borg Scale. The heart rate was recorded after each trial.

Equipment
The European Space Agency (ESA) provided us with a full-body CPR mannequin (Resusci Anne SkillReporter, Laerdal Medical Ltd., Orpington, UK) able to measure external chest compression (ECC) depth and rate (± SD). Real-time feed-back of each compression was provided by a small light-emitting diode (LED). Coloured lights of the LED indicated depth of ECCs (red, 0-39mm; yellow, 40-49mm; green, 50-60mm). An electronic metronome established an effective ECC rate of 100 compressions.min⁻¹ [4, 5].

To simulate hypogravity, we used a modified cable-cross over fitness machine also provided by the ESA. The volunteer wore a harness connected to the counterweights via a pulley system and a steel cable. The amount of counterweight to use for the volunteer was calculated by working out his relative mass in the simulated conditions using two equations [13]:

\[
RM = (0.6BM \times SGF) / 1Gz \quad \text{Eq.1}
\]

\[
CW = 0.6BM - RM \quad \text{Eq.2}
\]

where Eq.1 enables to calculate the relative mass of the subject (RM = relative mass in kg, BM = body mass on Earth in kg, SGF = simulated gravitational force in m.s⁻², 1Gz = 9.81m.s⁻²) and Eq.2 gives the counterweight (CW in kg) to use to simulate hypogravity.

Data analysis
The results are shown as a preliminary trial with n=1 participant. No statistics are available.

RESULTS

Considering the gravitational force on the Moon (+0.162Gz) and on Mars (+0.387Gz), and a subject weight of 82kg, we applied a counterweight of 42kg to simulate hypogravity on the Moon and 31kg for the hypogravity field on Mars.

On Earth, with no counterweights, we found equivalent mean compression depth between the classical BLS and the SeAL (42±2mm). On Mars, the SeAL should provide an improved mean compression depth (45±6mm) rather than on the Moon (42±4mm). Moreover, we were able to provide 100 ECC.min⁻¹, which it was impossible in the regular case. The most important thing to notice is that the SeAL technique offers a high level of stability, much greater than the regular method allows in simulated hypogravity.

Figure 1 External chest compression depth in different simulation of hypogravity compared to the Earth. In grey, the regular method of basic life support, in black, the SeAL.

The heart rate increased similarly between the two methods after performance on Earth (81±2bpm), on the Moon (150±2bpm) and on Mars (110±5bpm), so that the SeAL is not more physically demanding; only the environmental constraints enhance the difficulty to perform efficient resuscitation work. This idea is confirmed by using a Borg Scale to evaluate the
perceived exertion after each trial, consisting of a numerical range from 6 to 20 and verbal cues corresponding to each number (very light, 6; light, 11; hard, 15; exhaustion, 20). Results are similar between the two methods on Earth (10), on the Moon (17) and on Mars (13).

The ER has an adequate ECC depth (42 mm), yet the rate is low (80 per minute). The classical basic life support and the Seated Arm-Lock method are equivalent in rate and depth of compressions, and our results meets the American Heart Association (AHA) guidelines [12] concerning CPR on Earth. The SeAL position however shows more stability and comfort. Locking the arm of the victim with your legs prevents you from being pushed away from him/her during chest compressions. The rescuer is not quite seated on the abdomen, but he has his knees close to the axillae of the victims shoulders, with his own shoulders directly above the cardiac area, offering more precision for compression, and the ability to use arm flexion to enhance the strength of the compression if necessary. However it is hoped that the locking of the victims arms behind the rescuers knees will decrease the need for arm flexion by providing a stable point of attachment between victim and rescuer, allowing the rescuer to mainly use his shoulders and torso to provide the power of compression. If the victim has upper-limb trauma, using this technique will depend on the extent of injury but in most cases, the priority would be to provide chest compressions before attending to problems in the limbs. Moreover, the SeAL is easy to carry out and fill the 2-3 minutes gap between the cardiac arrest and the rescue.

DISCUSSION

Currently, the Evetts-Russomano (ER) method seems to be the best technique to increase chances of resuscitation in microgravity [5, 13] compared to other methods [2] like the Bear Hug, which provides a good rate of compression (90 per minute), but the depth is below guidelines (36 mm) or the Hand Stand which involves a vertical-inverted position, provides adequate external chest compressions depth (40 mm) and rate (98 per minute), however the position is unstable, and it may take time for the rescuer to find a good balance.

The classical basic life support and the Seated Arm-Lock method are equivalent in rate and depth of compressions, and our results meets the American Heart Association (AHA) guidelines [12] concerning CPR on Earth. The SeAL position however shows more stability and comfort. Locking the arm of the victim with your legs prevents you from being pushed away from him/her during chest compressions. The rescuer is not quite seated on the abdomen, but he has his knees close to the axillae of the victims shoulders, with his own shoulders directly above the cardiac area, offering more precision for compression, and the ability to use arm flexion to enhance the strength of the compression if necessary. However it is hoped that the locking of the victims arms behind the rescuers knees will decrease the need for arm flexion by providing a stable point of attachment between victim and rescuer, allowing the rescuer to mainly use his shoulders and torso to provide the power of compression. If the victim has upper-limb trauma, using this technique will depend on the extent of injury but in most cases, the priority would be to provide chest compressions before attending to problems in the limbs. Moreover, the SeAL is easy to carry out and fill the 2-3 minutes gap between the cardiac arrest and the rescue.

CONCLUSION

The Seated Arm-Lock method could be used both on the Moon and on Mars, and seems to be a better option than the regular method. It addresses the issues associated with the classical method such as exertion and stability, and allows for an easy transition for people who already know the classical method. Furthermore, there is no loss of accuracy of hand positioning. However, this work is
preliminary and needs a complete trial, specially designed for the SeAL with trained volunteers. In summary, this method of cardiopulmonary resuscitation is a way of securing yourself to the victim that does not require the use of additional equipment. It is comfortable for both parties and makes adequate compression depth more achievable than the classical method in simulated hypogravity.

ACKNOWLEDGEMENTS

We would like to thank the European Space Agency for inviting us at the European Astronaut Centre to partake in the Space Medicine Workshop of 2011. We would also like to thank Dr Simon Evetts for running the workshop, and for providing us with the opportunity to develop our ideas. We also want to thank WYLE GmbH for granting us with a prize for the Seated Arm-Lock method. We further acknowledge our institutions, the University of Montpellier 2 and its Faculty of Science (France); the University of College Cork (Ireland) and the University of Birmingham (England), for supporting us in our respective educational programmes.

CONFLICT OF INTERESTS

There is no conflict of interests regarding this work.

REFERENCES