In-flight Cardiopulmonary Resuscitation during Commercial Air Transport: Consensus statement and Supplementary Guideline from the German Society of Aerospace Medicine (DGLRM)

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Abstract

**Background:** Approximately 3 billion people worldwide will travel by commercial air transport in 2016. A calculation based on the number of passengers transported shows that between 1 out of 14,000 to 1 out of 50,000 passengers will experience acute medical problems during a flight. Cardiac arrest accounts for 0.3% of all in-flight medical emergencies, yet it is responsible for 86% of in-flight events resulting in death. So far, no guideline for in-flight cardiac arrest (IFCA) does exist providing specific treatment recommendations.

**Methods:** A task force was created to develop a guideline for the treatment of in-flight cardiac arrest based on clinical and investigational expertise in this area. By using a systematic literature search including GRADE, RAND, and DELPHI methods, specific recommendations for the treatment of IFCA have been created.

**Results and conclusions:** Several main recommendations have been developed: emergency equipment location as well as content should be mentioned in the pre-flight safety announcement; ECG should be available for patients with cardiac arrest, it is very important to request help by an on-board announcement after identification of a patient with cardiac arrest; two-person CPR is considered optimum and should be performed if possible; the crew should be trained regularly in basic life support – ideally with a focus on CPR in aircraft; a diversion should immediately be performed if the patient has a return of spontaneous circulation.

**Key-words:**
CPR; cardio-pulmonary resuscitation; cardiac arrest; airplane; in-flight medical emergencies; BLS; AED
Background

In 2016, approximately 3 billion people worldwide will travel by commercial air transport \(^1\) including more than 1 billion tourists \(^2\). Although air travel is safe in general, passenger demographics and pre-existing medical conditions as well as the number of passengers aboard larger aircraft (e.g. Airbus A380) and flights over very long distances \(^3\) raise the probability of in-flight emergencies per flight. Therefore, medical issues during air travel of passengers have attracted increasing interest in recent years \(^2, 4\). Depending on the destination, 22 to 64% of travellers report some illness \(^2\).

Although in-flight medical emergencies frequently occur in commercial airline operations, detailed data on incidence, causes, and consequences still remain limited \(^5-7\). This area of emergency medicine is rarely investigated scientifically, or even published so far \(^4, 8, 9\). A calculation based on the number of passengers transported shows that between 1 out of 14,000 to 1 out of 50,000 passengers will experience acute medical problems during a flight \(^5-7\). However, most emergencies are mild, self-limited and can be treated effectively and definitively on board with little or no equipment and without interruption of the flight \(^10\). Severe disorders occur infrequently and fatalities are very rare \(^11\). However, diversions and unplanned landings are quite expensive and require sophisticated management of the remaining passengers.

Sudden cardiac arrest remains a leading cause of death throughout the world \(^12\). In a recent study, Nable et al. \(^13\) found that cardiac arrest accounts for only 0.3% of all in-flight medical emergencies, yet it is responsible for 86% of in-flight events resulting in death \(^11\). Unfortunately, cardiac events during commercial aviation are not that infrequent \(^8\), and result in a high percentage of in-flight mortality \(^14, 15\). Cardiac arrest on board has an incidence of 1 per 5-10 million passenger flights with about 1,000 persons deaths annually aboard International Airlines Transport Association (IATA) carriers \(^16, 17\).

Current cardiopulmonary resuscitation (CPR) guidelines by the American Heart Association (AHA) \(^18\) and the European Resuscitation Council (ERC) \(^17, 19\) only provide general recommendations for cardiac arrests in transportation vehicles and in-flight
medical emergencies aboard airplanes. However, these guidelines are for general purpose and do not consider the specificities of the aviation-/airplane-related setting. Furthermore, aviation-specific management of cardiac arrest during flight is not sufficiently addressed in the published literature.

Despite a few previous studies on this topic and some recommendations in the current ERC or AHA guidelines for CPR no sound or extensive recommendations are available yet how to handle patients with an in-flight cardiac arrest (IFCA).

The objective of this consensus statement and supplemental guideline is to analyse published literature and to derive evidence-based and expert-opinion recommendations addressing specifically in-flight cardiopulmonary resuscitation after sudden cardiac arrest in (commercial) airplanes.

**Methods**

**Literature evaluation strategy**

A task force was created to develop a guideline on the treatment of in-flight cardiac arrest based on clinical and investigational expertise in this area. A set of questions and keywords was prepared by the taskforce to guide the literature search. These were first drafted and then validated by the chairmen of the taskforce and literature reviewers.

The chairmen of the taskforce also established the inclusion criteria for the studies according to the search terms listed in table 1. This process was started in January 2015 and completed in September 2015. The final literature search was conducted between September 2015 and December 2015. A broad filter for cardiac arrest in airplanes was applied in conjunction with a study type filter and a specific subgroup filter based on the questions and keywords. MEDLINE, EMBASE and Cochrane Library were searched from January to December 2015 for normalized and free-text terms such as “cardiac arrest” etc. (search strategy: table 1). A total of 2,387 records were identified. Articles identified went through a two round selection process described below.
First, title and abstract screening removed duplicates and papers selected according to the inclusion criteria defined previously. This process was conducted by a systematic screening and, when in doubt, checked by a second reviewer. Systematic reviews, randomized controlled trials, cohort studies, case control studies, and cross sectional surveys were included. Existing guidelines were identified and considered separately. Narrative reviews, editorials, case series or case reports were excluded. Only publications in English were included.

Full-text versions of the remaining articles were obtained and divided amongst the authors for further screening using the aforementioned criteria. The articles were checked individually for risk of bias, applicability and significance. In the final set of articles, evidence gathered was critically appraised using the GRADE methodology. As GRADE was used to assess the quality of the evidence, the following features were assessed for each outcome. GRADE was based on study design limitations (selection, performance, detection, attrition and reporting bias), effect consistency and size, directness, precision, publication bias, dose response effect and presence of antagonistic bias. The GRADE system has not standardized this decision-making process of the expert panel. In an effort to standardize this evidence processing, the methodology committee of this working group selected the Rand Appropriateness Method (RAM).

For consensus, when strong evidence was lacking, a three round Delphi method was used. Voting was performed by e-voting for the first, second, and third rounds. The experts formulated draft recommendations before each conference to serve as a foundation for subsequent discussion and evaluation. The expert panel was updated through short presentations about the literature search results and subsequent interpretation for drafting of the proposed recommendations. After a single round of face-to-face debating, anonymous voting rounds were conducted, followed subsequently by internet-based voting rounds. This process provided a structured and validated method for expert panel activities. In addition, it standardized statistical methodology for determining the degree of agreement to serve as a foundation for deciding about the recommendation grade (weak, intermediate, and strong consensus). A strong consensus was defined as an
agreement of >90%, an intermediate consensus with 70-90% agreement, a weak consensus with 50-70% agreement, and no consensus as <50%.

After preparation of the final manuscript with all recommendations included, it was sent to the board of the society (DGLRM) for approval. This guideline is based on a consensus of an expert group corresponding to level S2e of the classification levels of the Association of the Scientific Medical Societies in Germany (AWMF, Arbeitsgemeinschaft der Wissenschaftlichen Medizinischen Fachgesellschaften e. V., see www.awmf.org) with the identification number #182-001.

Guidelines for IFCA

Background

According to the International Civil Aviation Organization (ICAO) and other sources of information, in the year 2016 approximately 3.2 billion people worldwide travel by air. Although this mode of transportation is quite safe from a technical point of view, passengers with all their pre-existing individual health issues (e.g., age, pre-existing diseases, obesity, or the onset of new acute issues) are increasingly at risk of becoming a patient during flight.

In-flight cardiac arrest (IFCA) is a rare phenomenon (0.3% of in-flight medical emergencies) during commercial air travel, but represents a relevant cause of in-flight medical emergencies and is a major contributor to in-flight deaths. It has an incidence of 1 per 5-10 million passenger flights and each year, about 1,000 persons die aboard International Airlines Transport Association (IATA) carriers.

Irrespective of the cause of cardiac arrest, early recognition and calling for help, treatment including appropriate management of the deteriorating patient, early defibrillation, high-quality cardiopulmonary resuscitation (CPR) with minimal interruption of chest compressions and treatment of reversible causes, are the most important interventions. Especially in the remote environment of an aircraft, these guidelines require adaption, modification, and supplementation to ensure the best possible outcome for patients. Current CPR guidelines by the American Heart Association (AHA) and the European Resuscitation Council (ERC) are for general purpose and do not consider the particular aviation-/airplane-related setting.
The present consensus statement and guideline from the German Society for Aerospace Medicine (DGLRM) addresses aviation-specific management of in-flight cardiac arrest patients. Recommendations are displayed condensed as a summary in table 2.

**General recommendations**

**Emergency equipment location as well as major content has to be mentioned in the pre-flight safety announcement** (strong consensus, Level of Evidence low, Grade of Recommendation A).

**Information on the location of emergency medical equipment as well as brief information on how to act in case of a cardiac arrest must be printed on the seat pocket Safety Instructions card** (strong consensus, Level of Evidence high, Grade of Recommendation A).

Several considerations are important to improve the access to both equipment and patients available to reduce no-flow-time and improve outcome of patients suffering from an IFCA.

Infrastructure and fast access to emergency equipment can reduce the time lag to adequate therapeutic attempts and decrease no-flow-time significantly. Since all passengers and crew members on-board are potential bystanders, all should know exactly where emergency equipment and crew are located. Besides some general information in the pocket safety cards, the location of emergency equipment should be mentioned in the pre-flight safety announcement.

**It is of crucial importance that (professional) help is requested by an on-board announcement after identification of a patient with cardiac arrest** (strong consensus, Level of Evidence low, Grade of Recommendation A).

In the event of a passenger medical incident, there can be delays of more than 20 minutes to several hours before expert assistance is available and the availability of
medically trained persons on-board cannot be entirely relied upon. Many crew members as well as health care providers may require additional support or help to decide on complex cases or in exceptional circumstances.

**Teleconsultation should be available during the flight (intermediate consensus, Level of Evidence low, Grade of Recommendation B).**

Teleconsultation consists of a well-trained specialist on ground that could be called in case of any problems via satellite phone, video or radio communication. This service should be available 24/7 and is usually offered by airlines or affiliated companies. Especially for severe cases in remote locations teleconsultation has advantages. Besides giving advice, telephone-CPR could also be performed. Recent studies showed that this service is beneficial throughout the world and can save lives. Medical consultation or teleconsultation should likely be obtained once a perfusing rhythm has been established or in cases of prolonged resuscitation.

**It is important that a standardized documentation form is available (strong consensus, Level of Evidence low, Grade of Recommendation A).**

Data recently published on in-flight medical events are based mainly on figures gathered by individual airline companies and had been collected retrospectively. These results are often limited and might be biased due to the relatively small number of transportations per airline. Furthermore, most of the published data are based on retrospective analyses and no valid data on the worldwide incidence are available. Data from prospective studies remains to be published.

Studies on emergency medical equipment show a clear inconsistency in the medical equipment. However, these data may only be interpreted thoroughly if the incidence and nature of in-flight medical emergencies are taken into account. Therefore, a valid database on world-wide in-flight medical emergency is essential but does not exist yet, unfortunately. Another challenging problem besides the lack of standardized documentation during or after an international in-flight medical emergency, is the absence of denominator data, e.g. to calculate incidences or rates. Analysing absolute numbers only, severely limits data interpretation.
Without having sound numerator data and valid denominators progress in this field is very limited. Therefore, there is a clear necessity to achieve more accurate scientific results in this field by gathering conclusive data and to document findings in a standardized form. The DGLRM provides a standardized documentation form.

**CPR- and other emergency medical data can be registered in a standardized international data base (weak consensus, Level of Evidence low, Grade of Recommendation B)**

Besides data documentation in a standardized form, data collection in an (international) data base is of utmost importance to produce high numbers and to facilitate benchmarking, data analyses and international comparisons as well. For the time being no data-base or registry exist. All flight services should be committed to report their proper data sets to this international registry.

**Emergency equipment**

For commercial airline transport, legal requirements define required emergency medical equipment on-board aircraft. A minimum standard for medical emergency material is defined by national or international regulations. Therefore, all commercial aircraft have to be equipped with a first aid kit (FAK) that all cabin crew members are trained to use. The FAK is suited to cover most minor illnesses, e.g., nausea, headache, or dyspepsia.

In addition, aircraft equipped with more than 30 seats, must be equipped with a (special) medical kit which can be used by competent personnel (e.g., health care providers, physicians; i.e., doctor’s kit, DK). In these kits, besides equipment and medication, generally recommended the contents may be chosen by special requirements of the companies or by suggestions from their medical advisors. Intravenous medication as well as material required for intravenous access is often provided in a doctor’s kit. Unfortunately, the contents of these additional kits vary significantly throughout Europe.
Since data on in-flight emergencies is rarely published, it is not possible to adequately assess the usefulness of the material provided. However, both supplementary material/devices as well as drugs may be necessary for proper patient management.

It is of utmost importance that all medical equipment must be certified for storage as well as fully operational at the ambient conditions experienced on-board aircraft at the highest altitude the aircraft is certified to operate at or at the actual cabin pressure resulting during flight.

**An ECG should be available for patients with cardiac arrest (strong consensus, Level of Evidence moderate, Grade of Recommendation A).**

Measurement of blood pressure by non-invasive devices (NIBP) as well as continuous electrocardiography (ECG) is considered a minimal requirement for emergency patients. Although there is a lack of randomized controlled trial (RCT) literature to underscore this statement, it is supported by the working group and several other non-RCT publications. As an alternative to an ECG, an automatic external defibrillator (AED) with monitoring function on-board the aircraft is considered adequate, especially for patients suffering from an IFCA.

**A defibrillator (e.g. AED) is considered essential and should be available during the flight (strong consensus, Level of Evidence moderate, Grade of Recommendation B).**

Early defibrillation including the early use of AEDs by both emergency responders and trained health care providers improved outcome of resuscitated patients. Many airlines have recognized that survival of cardiac arrest depends on early access to CPR and defibrillation and therefore have placed AEDs on board long-haul aircraft. Furthermore, the Federal Aviation Administration (FAA) mandated as part of its 2001 safety guidelines that by 2004 all commercial airlines carry AEDs and train personnel in their use.

According to the ERC guidelines for CPR, an AED and a first aid kit should be requested immediately from cabin crew. Since time to defibrillation is one of the
most important factors for survival after cardiac arrest, basic life support should, therefore, be performed as soon as possible. Furthermore, the Federal Aviation Administration require all airlines flying into the United States to carry Automated External Defibrillators. According to EASA regulations the carriage of an AED is subject to the risk assessment of the pertinent airline. The needs of the pertinent operations should be taken into account.

A shockable rhythm is present in 25-31% of patients and the in-flight use of an AED can result in an increased overall survival rate (33-50% survival to hospital discharge). However, recently published data shows that an AED was used rarely (in only 0.4% of patients having an in-flight medical problem). Per se, AED use is possible during flight but crew and pilots should be informed.

The use of the AED aboard commercial aircraft is effective, with an excellent rate of survival to discharge from the hospital after conversion of ventricular fibrillation. There are not likely to be complications when the device is used as a monitor in the absence of ventricular fibrillation.

**An intravenous access is considered essential and should be available during the flight (strong consensus, Level of Evidence low, Grade of Recommendation B).**

An intravenous access is standard for drug application and adrenaline injection during CPR and is usually provided in the doctor’s kit. However, according to EASA regulations, intravenous access should be carried within the Emergency Medical Kit.

**Providing intraosseous access may be necessary and the device must be available (consensus, Level of Evidence low, Grade of Recommendation A).**

In cases when an i.v.-line cannot be placed timely or within a few attempts, the intraosseous (i.o.) route is an appropriate alternative. For intraosseous access specific needles are required. Whereas semi-automatic drilling needles are standard in most EMS systems, the devices are heavy and the use of lithium ion batteries being extremely problematic in an airplane. Automatic needles have the risk of failure.
and injury. Therefore, a “cook needle” is the best alternative in this very special setting for intraosseous access.

For CPR, epinephrine (adrenaline), amiodarone, lignocaine (lidocain), glucose, and midazolam must be available (strong consensus, Level of Evidence moderate, Grade of Recommendation A).

For CPR, and resulting arrhythmas it is of utmost importance to have required drugs in an intravenous formulation available for injection. As in current CPR guidelines recommended, the following drugs should be available on-board (e.g., in the doctor’s kit): epinephrine (adrenaline) [at least 5x 1mg], amiodarone [at least 3x 150 mg], glucose [at least 10 g], and midazolam [at least 2x 5 mg]. Alternatively to amiodarone, lignocaine (lidocain) [at least 100 mg] can be used.

Mechanical CPR devices may facilitate CPR in special situations, but are considered inappropriate during flight (strong consensus, Level of Evidence low, Grade of Recommendation C).

Mechanical devices for CPR are standard in many EMS systems and can be used in special circumstances, e.g., long transportation during CPR. However, the weight of these devices is high and their use on-board an aircraft may be extremely rare. Therefore, it is considered not useful to have such devices on-board commercial aircrafts.

Pulse oximetry is considered standard (“basic monitoring”) and should be available for treatment (strong consensus, Level of Evidence B, Grade of Recommendation B). Non-invasive blood pressure measurement devices are considered standard (“basic monitoring”) and must be available for treatment (strong consensus, Level of Evidence moderate, Grade of Recommendation A).
In addition to NIBP and ECG, pulse oximetry is also considered as a minimal standard for emergency patients. Pulse oximetry (SpO₂) monitoring and oxygen supplementation are used to detect and correct hypoxemia in emergency patients. Since improvements were made in pulse oximetry technology by Takuo Aoyagi, it has become a standard monitoring technique in emergency medical treatment of severely ill or injured patients. Pulse oximetry can enhance patient safety due to its ability to detect hypoxia earlier than other methods. There are mainly three sensor sites used (finger, toe, ear) all with a comparable accuracy.

However, regarding pulse oximetry, it should be recognized that some influencing factors may lead to false measurements. Influencing factors such as changes in the measurement kinetics or perfusion can lead to an aberration of the pulse wave signal and therefore inaccurate readings.

**The use of capnometry/capnography is marginally important during an in-flight cardiac arrest.** At the minimum a (simple) qualitative capnometer should be available (weak consensus, Level of Evidence low, Grade of Recommendation B).

Monitoring of end-tidal carbon dioxide (etCO₂) levels is standard care for cardiac arrest patients after endotracheal intubation and in spontaneous breathing patients. The use of capnometry/capnography can reduce the risk of undetected oesophageal intubation and reflect the quality of the CPR. Since the incidence of endotracheal intubation during flight is low, a quantitative measurement is often not necessary. However, at least qualitative measurements should be available since they are easy, cheap, and light-weight.

**Using a glucometer for glucose measurements is important during/after CPR and the device must be available** (weak consensus, Level of Evidence moderate, Grade of Recommendation A).

During and after CPR, serum glucose levels may vary substantially. To prevent severe hypoglycemia and hyperglycemia, blood glucose levels should be measured during and after CPR.
CPR strategies

Bystander CPR enhances the survival rate significantly and should be performed as soon as possible \(^{18, 19}\). If a cardiac arrest is recognized, professional help should also be sought immediately. Crew is sometimes reluctant to use on-board announcements requesting a healthcare provider for an emergency, since this may disturb passengers and produce unwanted attention. However, in the event of a cardiac arrest, all help should be gathered as soon as possible. The easiest and most effective way is an on-board announcement.

Two-person CPR is considered optimum (strong consensus, Level of Evidence moderate, Grade of Recommendation A).

Ideally, CPR (both BLS and ALS) is performed by at least two people according to the current CPR guidelines \(^{18, 19}\). Every 2 minutes a rotation between bystanders/crew should be performed to prevent exhaustion and reduced effectiveness \(^{18, 19, 43}\).

Overhead-CPR and telephone-CPR may be performed during resuscitation (weak consensus, Level of Evidence low, Grade of Recommendation C).

Chest compression during transportation seems to be feasible and efficient \(^{44}\). However, infrastructure and environmental factors can substantially interfere with the execution of CPR procedure \(^{45}\). For example, in the confined space of an aircraft, access to the patient may be reduced or nearly impossible. There are situations when cardiac arrest may occur in a confined space, making it difficult to kneel by the side of the patient \(^{46}\) (fig. 1). In the confines of an aircraft aisle, it may be difficult to perform standard CPR with one or two rescuers kneeling at the side of the patient \(^{46}\). There is a paucity of data on this topic, e.g. in helicopters during flight, and quality of chest compressions is inferior to other emergency scenarios if applied during flight \(^{44, 45}\). Havel et al. \(^{44}\) demonstrated that closed chest compression can generally be applied during transport but there may be at least some differences in effectiveness.
Optimally, the rescuer should be positioned in front of one of the aisle seats in the kneeling position for performance of chest compressions, and a second rescuer in front of the opposite aisle seat performing ventilation or applying the AED to the patient. The limitations would be the small space for either rescuer to perform their tasks 16.

In situations where it is not possible to perform standard CPR according to the CPR guidelines 19, over-the-head-CPR (OTH-CPR) may be considered as a suitable alternative 47 (fig. 2). The ERC guidelines recommend considering an over-the-head technique for CPR if access precludes conventional CPR 17. Guidelines for basic life support (BLS) describe this technique for manual chest compression 46.

Over-the-head chest compression was combined in one previous study with bag-valve-mask ventilation. This resulted in CPR that conformed closely to ERC guidelines 46. However, for OTH the average compression depth was significantly less than for the standard position ($P=0.0149$) and there were more compressions of incorrect depth ($P=0.0400$) 46. Handley et al. 46 also showed that for one-man CPR (which is presumably less frequently used than two-man CPR in the aeroplane cardiac arrest setting), standard CPR is superior to an over-the-head (OTH) technique. However, this study was limited by small numbers and the fact that it did not actually simulate real-life conditions, as it was carried out on mannequins in simulated flight cabins and not in moving airplanes. In congruency, Perkins et al. 47 also demonstrated that OTH-CPR is possible but associated with lower quality of CPR. Laying the collapsed person on the seats (if the arm-rests can be folded back promptly) and initiating CPR is the fastest option and allows initiation of essential life-saving procedures with the least interruption to precious time after cardiac arrest 16.

The optimum place for CPR is the galley, but may depend on the aircraft model (strong consensus, Level of Evidence C, Grade of Recommendation B). Also, CPR in the aisle of the aircraft is considered possible (intermediate consensus, Level of Evidence moderate, Grade of Recommendation C).

Environment
The confined environment of the aircraft cabin may also interfere with the on-board management of patients suffering a cardiac arrest, as treatment may be hampered by poor access, restricted space, interference from noise, and vibration that makes it difficult to assess pulse and breathing for CPR. Additionally, the quality of CPR may be low. In the challenging setting of an aircraft cabin in flight, the potential interventions are limited owing to confined and restricted space for patient care and less-than-appropriate positioning of the patient, limited personnel with the appropriate skill set, and limited supplies. It is most important to gain access to the patient, even if the patient has to be transferred several meters, e.g., to the galley. Also, the current guidelines for CPR recommend transferring the patient after cardiac arrest to a suitable location, e.g., galley or exit area.

The provision of CPR on-board airplanes is limited by the closed, confined spaces that rescuers are forced to operate in. The lack of space may make it difficult for rescuers to kneel comfortably by the side of the patient to perform standard CPR.

**CPR should ideally be performed/supervised by a health care provider (strong consensus, Level of Evidence C, Grade of Recommendation B) — if present. However, aircraft crew, trained in BLS-AED or CPR, or a layperson with corresponding training should also be recruited to perform chest compressions (strong consensus, Level of Evidence low, Grade of Recommendation B).**

During flight, the most appropriate and probably the only possible approach to the management of cardiac arrest is a basic approach. Thus, recognition of cardiac arrest, compression-only CPR and defibrillation with the use of an AED represent the interventions that the volunteer physician should consider applying.

**For airway management during in-flight CPR, the use of a supraglottic airway (e.g., laryngeal mask or laryngeal tube) may be superior to face mask ventilation or endotracheal intubation (ETI) (strong consensus, Level of Evidence low, Grade of Recommendation B).**
Airway management

While endotracheal intubation is considered the „optimal method“ of providing and maintaining a clear secure airway, it must be taken into account that the success rate for in-flight endotracheal intubation (ETI) is significantly lower as compared to elective intubation in hospitals (by a factor of 8.7) or emergency intubations at scene (by a factor of 2.3).

Today, supraglottic airway devices (SGA) have partly eliminated the need for early routine endotracheal intubation in many medical fields. Over the last years several manufacturers presented improved and new types of SGA. Newer generation devices have multiple advantages such as gastric access and a higher leak pressure. Insertion of a supraglottic airway devices is usually easier (no laryngoscope needed), faster (no muscle relaxation needed), and safer (no risk of oesophageal intubation) when compared with tracheal intubation. Furthermore, ETI requires substantially more training.

Cabin crew must be trained initially and once per year in CPR (strong consensus, Level of Evidence B, Grade of Recommendation A) and should be re-trained in CPR every six months (strong consensus, Level of Evidence moderate, Grade of Recommendation B).

Crew qualification

In the event of a passenger medical incident, delays ranging from 20 minutes to several hours before expert assistance is available and the potential lack of medically-trained persons on board must be taken into consideration. Therefore, sufficient and regular training of the aircraft crew in CPR and emergency medical treatment is of utmost importance. Cabin crew have an essential role in aviation safety and require appropriate recurrent training.

Recent literature indicated that a training interval in cabin crew of 12 months is too long and practical skills degrade over this period. The optimal frequency and type of recurrent training which maintains skills and knowledge at an appropriate level needs still to be determined for this occupational group.
The crew should be trained regularly in basic life support – ideally with a focus on CPR in aircraft (strong consensus, Level of Evidence low, Grade of Recommendation A).

A gradual decline in CPR and AED skills following training has been demonstrated in laypersons and medically trained persons and has been associated with the types of instructional techniques of employees, variations in programme delivery and the time interval between training and re-assessment.

In a recent study, most cabin crew members failed to deliver CPR correctly, showing wide variations in hand positioning, compression depth and rate, which is all critical for survival following cardiac arrest. Recent literature has confirmed that a short (15 minute) BLS refresher course was sufficient to maintain the skills. Especially for lay rescuers and non-medical rescuers, having a flow chart available can improve quality of CPR.

A standardized course in advanced life support (ALS) or immediate life support (ILS) is also helpful, but due to the complexity not necessary. A first-aid course is not considered sufficient for management of IFCA.

A diversion should immediately be undertaken if the patient has a return of spontaneous circulation (ROSC) (strong consensus, Level of Evidence low, Grade of Recommendation B).

Diversion

One strategy for the management of cardiac arrest patients in flight is the immediate diversion to the closest airport. However, evidence suggests that at the current time diversion for patients presenting with non-shockable rhythms may be futile and aircraft diversion includes additional risks: emergent landings, potential need to dump fuel, landing with overweight aircraft, altered flight patterns, landing in poor weather, high costs, and landing in unfamiliar conditions.

Prior to 1990, it was standard airline practice to divert aeroplanes to the nearest major airport if there was a cardiac arrested subject on board. The ERC guidelines recommend to request an immediate flight diversion to the nearest appropriate airport, but do not give any details when to request (if cardiac arrest is detected or
if return of spontaneous circulation (ROSC) is achieved). However, according to these guidelines, death on board can only be confirmed legally by a physician. If a dead person is found, or CPR has been terminated (see ethics of resuscitation and end-of-life decisions), flight diversion is not recommended.

In a recent study, an emergency diversion was performed in 22/1,312 cases (i.e., 1.7%). This percentage is low and in the range of previous research (1.1-13.0%). If the patient has been successfully resuscitated, diversion and emergency landing are probably the most appropriate recommendations to be made to the captain of the aircraft.

If a return of spontaneous circulation is not achieved within 20 to 30 minutes in the absence of a reversible cause, it is appropriate to consider cessation of resuscitation efforts.

**CPR should be continued during emergency diversion (strong consensus, Level of Evidence low, Grade of Recommendation A).**

The decision for diversion is typically made after ROSC of the patient. However, scenarios are possible where an emergency diversion is performed before ROSC. For example, when leaving land and expecting a flight over open water during an ongoing CPR, a diversion may be performed before ROSC. In that case – considering on-board safety issues – CPR should not be interrupted during landing at the diversion airport. However, this approach should be discussed with the cabin crew and the pilots.

**Post-resuscitation care**

**Fixation devices are considered marginally important and can help to fixate the patient after ROSC (weak consensus, Level of Evidence low, Grade of Recommendation C).**

After ROSC, patients can move or might be agitated. Therefore, sufficient fixation or immobilization devices may be helpful, especially to assure flight safety. There are no data or studies available on this topic.
Due to reduced ambient pressure in the aircraft cabin, oxygen should be used even after ROSC to compensate for a reduced oxygen partial pressure in the blood (strong consensus, Level of Evidence low, Grade of Recommendation B).

Oxygen toxicity and a worse outcome of resuscitated patients with hyperoxia have been described in the medical literature. However, environmental factors in the aircraft cabin are not comparable to the setting on ground. During flight on cruising altitude, cabin pressure is approximately 850 hPa resulting in an oxygen saturation in healthy adults of approximately 90-92%. Since current guidelines on CPR (on the ground) recommend not to use oxygen but target a range of 94-98% of oxygen saturation, supplementary oxygen by face masks in spontaneously breathing patients could be beneficial. By applying 2-3 litres oxygen per minute, oxygen saturation can be adjusted to the target range when using oxygen masks.

It is important to induce targeted temperature management as soon as possible after ROSC (weak consensus, Level of Evidence low, Grade of Recommendation B).

A few case reports confirmed the feasibility of Targeted Temperature Management (TTM) using cold i.v.-fluids and chemical cooling packs during air transport. Also, current ERC guidelines recommend temperature control (at least avoiding a body core temperature higher than 36°C) as early as possible but not using cold saline. In summary, avoiding post-ROSC fever may have the largest benefit.

To reduce patient temperature after ROSC, several methods are usually available in a commercial airplane. Due to convection and the large amount of air passing the aircraft cabin, removing clothing and not covering patients with a sheet may decrease body core temperature significantly. Whereas cold (infusion) fluids are usually not available and must be cooled before application, their use has been associated with worse outcome. However, crushed ice is available in large amounts in most airliners and can be used, e.g., for cooling the head, neck, armpits,
or the groin. It should be taken into account that using ice for cooling patients can have obvious drawbacks (e.g., obstacle for further treatment, delay in procedures, or frostbites) 73.

Acknowledgements
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- C.N. is Treasurer of the German Society for Aviation and Space Medicine (DGLRM).
- E.D.R. received honorarium form MSD.
- E.G. is CEO of the German Academy for Aviation- and Travel Medicine (DAFR).
- H.G. received travel reimbursement for presentations from Ambu and VBM, Germany.
- J.H. is Vice President of the German Society for Aviation and Space Medicine (DGLRM) and Treasurer of the European Society of Aerospace Medicine (ESAM); no other conflicts of interest do apply for J.H.
- J.S. is employed at Lufthansa.
References


Figure Legends

**Fig. 1:** CPR in confined space from the side in an aircraft. Whereas the patient lies in the aisle, the rescuer is placed sideward in the leg area.

**Fig. 2:** Over the head (OTH) CPR in the aisle of an aircraft.
### Table 1: Search strategy: Queries and topics for the systematic, evidence-based assessment of questions.

<table>
<thead>
<tr>
<th>Topic</th>
<th>Search string</th>
<th>Analyzed for guideline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Should the location and content of the emergency equipment be announced?</td>
<td>(location[All Fields] OR &quot;emergencies&quot;[MeSH Terms] OR &quot;emergencies&quot;[All Fields] OR &quot;emergency&quot;[All Fields]) AND (&quot;instrumentation&quot;[Subheading] OR &quot;instrumentation&quot;[All Fields] OR &quot;equipment&quot;[All Fields] OR &quot;equipment and supplies&quot;[MeSH Terms] OR &quot;equipment&quot;[All Fields] AND &quot;supplies&quot;[All Fields]) OR (&quot;equipment and supplies&quot;[All Fields])) AND (airliner[All Fields] AND (&quot;aircraft&quot;[MeSH Terms] OR &quot;aircraft&quot;[All Fields] AND &quot;airplane&quot;[All Fields])))</td>
<td>2</td>
</tr>
<tr>
<td>Should help be requested by announcement?</td>
<td>(help[All Fields] OR announcement[All Fields]) AND (airline[All Fields] OR (&quot;aircraft&quot;[MeSH Terms] OR &quot;aircraft&quot;[All Fields] OR &quot;aircraft&quot;[All Fields] OR &quot;airplane&quot;[All Fields])))</td>
<td>288</td>
</tr>
<tr>
<td>Should teleconsultation be used?</td>
<td>(&quot;CPR&quot; OR &quot;resuscitation&quot; OR &quot;basic life support&quot; OR &quot;cardiac arrest&quot;) AND (&quot;tele consultation&quot; OR &quot;operator&quot; OR &quot;dispatcher&quot; OR &quot;instructions&quot;) AND (&quot;outcome&quot;)</td>
<td>170</td>
</tr>
<tr>
<td>Is a defibrillator necessary?</td>
<td>(&quot;cardiopulmonary resuscitation&quot;[MeSH Terms] OR (&quot;cardiopulmonary&quot;[All Fields] AND &quot;resuscitation&quot;[All Fields]) OR &quot;cardiopulmonary resuscitation&quot;[All Fields] OR &quot;cpr&quot;[All Fields]) AND (&quot;defibrillators&quot;[MeSH Terms] OR &quot;defibrillators&quot;[All Fields] OR &quot;defibrillator&quot;[All Fields]) AND (inflight[All Fields] OR (&quot;emergencies&quot;[MeSH Terms] OR &quot;emergencies&quot;[All Fields] OR &quot;emergency&quot;[All Fields])) AND (airliner[All Fields] OR (&quot;aircraft&quot;[MeSH Terms] OR &quot;aircraft&quot;[All Fields] OR &quot;aircraft&quot;[All Fields] OR &quot;airplane&quot;[All Fields])))</td>
<td>17</td>
</tr>
<tr>
<td>Question</td>
<td>Search String</td>
<td>Result</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>--------</td>
</tr>
<tr>
<td>Should intravenous access be available during the flight?</td>
<td>((&quot;cardiopulmonary resuscitation&quot;[MeSH Terms] OR &quot;cardiopulmonary&quot;[All Fields] OR &quot;resuscitation&quot;[All Fields]) AND intravenous[All Fields]) OR access[All Fields] AND (inflight[All Fields] OR &quot;emergency&quot;[All Fields]) AND (airline[All Fields] OR &quot;aircraft&quot;[MeSH Terms] OR &quot;aircraft&quot;[All Fields]) OR &quot;airplane&quot;[All Fields])</td>
<td>108</td>
</tr>
<tr>
<td>Should intraosseous access be available during the flight?</td>
<td>(&quot;cardiopulmonary resuscitation&quot;[MeSH Terms] OR &quot;cardiopulmonary&quot;[All Fields] AND &quot;resuscitation&quot;[All Fields]) OR &quot;cardiopulmonary resuscitation&quot;[All Fields] OR &quot;cpr&quot;[All Fields]) OR intraosseous[All Fields] OR access[All Fields] AND (inflight[All Fields] OR &quot;emergencies&quot;[MeSH Terms] OR &quot;emergency&quot;[All Fields]) AND (airline[All Fields] OR &quot;aircraft&quot;[MeSH Terms] OR &quot;aircraft&quot;[All Fields]) OR &quot;airplane&quot;[All Fields])</td>
<td>102</td>
</tr>
<tr>
<td>Which drugs are essential?</td>
<td>((&quot;cardiopulmonary resuscitation&quot;[MeSH Terms] OR &quot;cardiopulmonary&quot;[All Fields] AND &quot;resuscitation&quot;[All Fields]) OR &quot;cardiopulmonary resuscitation&quot;[All Fields] OR &quot;cpr&quot;[All Fields]) OR (&quot;pharmaceutical preparations&quot;[MeSH Terms] OR &quot;pharmaceutical&quot;[All Fields] AND &quot;preparations&quot;[All Fields]) OR &quot;drugs&quot;[All Fields]) AND (inflight[All Fields] OR &quot;emergency&quot;[All Fields]) AND (airline[All Fields] OR &quot;aircraft&quot;[MeSH Terms] OR &quot;aircraft&quot;[All Fields]) OR &quot;airplane&quot;[All Fields])</td>
<td>151</td>
</tr>
<tr>
<td>Are mechanical devices required for IFCA?</td>
<td>((&quot;cardiopulmonary resuscitation&quot;[MeSH Terms] OR &quot;cardiopulmonary&quot;[All Fields] AND &quot;resuscitation&quot;[All Fields]) OR &quot;cardiopulmonary resuscitation&quot;[All Fields] OR &quot;cpr&quot;[All Fields]) OR (&quot;mechanical&quot;[All Fields] OR (&quot;instrumentation&quot;[Subheading] OR &quot;instrumentation&quot;[All Fields]) OR &quot;devices&quot;[All Fields]) OR &quot;equipment and supplies&quot;[MeSH Terms] OR &quot;equipment&quot;[All Fields] AND &quot;supplies&quot;[All Fields]) AND (inflight[All Fields] OR &quot;emergency&quot;[All Fields]) AND (airline[All Fields] OR &quot;aircraft&quot;[MeSH Terms] OR &quot;aircraft&quot;[All Fields]) OR &quot;airplane&quot;[All Fields])</td>
<td>121</td>
</tr>
<tr>
<td>What material is obligatory?</td>
<td>((&quot;cardiopulmonary resuscitation&quot;[MeSH Terms] OR &quot;cardiopulmonary&quot;[All Fields] AND &quot;resuscitation&quot;[All Fields]) OR &quot;cardiopulmonary resuscitation&quot;[All Fields] OR &quot;cpr&quot;[All Fields]) OR (&quot;instrumentation&quot;[Subheading] OR &quot;instrumentation&quot;[All Fields] OR &quot;equipment&quot;[All Fields] OR &quot;equipment and supplies&quot;[MeSH Terms] OR &quot;equipment&quot;[All Fields] AND &quot;supplies&quot;[All Fields]) OR &quot;equipment and supplies&quot;[All Fields]) OR &quot;obligatory&quot;[All Fields] OR material[All Fields] AND (inflight[All Fields] OR &quot;emergency&quot;[All Fields] OR &quot;emergency&quot;[All Fields] OR &quot;emergency&quot;[All Fields]) AND (airline[All Fields] OR &quot;aircraft&quot;[MeSH Terms] OR &quot;aircraft&quot;[All Fields]) OR &quot;airplane&quot;[All Fields])</td>
<td>561</td>
</tr>
<tr>
<td>Is the doctors’ kit or emergency medical kit sufficient?</td>
<td>(medical[All Fields] AND kit[All Fields]) AND (inflight[All Fields] OR &quot;emergencies&quot;[MeSH Terms] OR &quot;emergency&quot;[All Fields]) AND (airline[All Fields] OR &quot;aircraft&quot;[MeSH Terms] OR &quot;aircraft&quot;[All Fields]) OR &quot;airplane&quot;[All Fields])</td>
<td>24</td>
</tr>
<tr>
<td>Question</td>
<td>Query</td>
<td></td>
</tr>
<tr>
<td>----------</td>
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<td></td>
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<tr>
<td>How should CPR be performed in the airplane?</td>
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</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>Query</th>
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</thead>
<tbody>
<tr>
<td>What is the influence of restricted space for CPR?</td>
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<tr>
<th>Question</th>
<th>Query</th>
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<tr>
<td>Where should the CPR take place?</td>
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<table>
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<tr>
<th>Question</th>
<th>Query</th>
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</thead>
<tbody>
<tr>
<td>What airway devices should be used?</td>
<td></td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>Query</th>
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</thead>
<tbody>
<tr>
<td>Who should perform CPR?</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>Query</th>
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<tbody>
<tr>
<td>How often should crew be trained?</td>
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</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>Query</th>
</tr>
</thead>
<tbody>
<tr>
<td>Should a diversion or emergency landing be performed?</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>Query</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are fixation devices necessary?</td>
<td></td>
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</tbody>
</table>

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What oxygen application strategy is required after IFCA?

What should temperature management started?

What should be done after ROSC?

Should CPR be continued during emergency diversion?

Summary

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Table 2: Recommendations in this guideline. Levels of evidence were derived from table 3; consensus: strong consensus (>90% agreement), intermediate consensus (70-90% agreement), weak consensus (50-70% agreement), no consensus (<50% agreement).

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Level of evidence</th>
<th>Consensus</th>
<th>Grade of Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency equipment location as well as major content has to be mentioned in the pre-flight safety announcement</td>
<td>Low</td>
<td>strong consensus</td>
<td>A</td>
</tr>
<tr>
<td>Information on the location of emergency medical equipment as well as brief information on how to act in case of a cardiac arrest must be printed on the seat pocket Safety Instructions card</td>
<td>High</td>
<td>strong consensus</td>
<td>A</td>
</tr>
<tr>
<td>It is of crucial importance that (professional) help is requested by an on-board announcement after identification of a patient with cardiac arrest</td>
<td>Low</td>
<td>strong consensus</td>
<td>A</td>
</tr>
<tr>
<td>Teleconsultation should be available during the flight</td>
<td>Low</td>
<td>intermediate consensus</td>
<td>B</td>
</tr>
<tr>
<td>It is important that a standardised documentation form is available</td>
<td>Low</td>
<td>strong consensus</td>
<td>A</td>
</tr>
<tr>
<td>CPR- and other emergency medical data can be registered in a standardized international data base</td>
<td>Low</td>
<td>weak consensus</td>
<td>B</td>
</tr>
<tr>
<td>An ECG should be available for patients with cardiac arrest</td>
<td>Moderate</td>
<td>strong consensus</td>
<td>A</td>
</tr>
<tr>
<td>A defibrillator (e.g., AED) is considered essential and should be available during the flight</td>
<td>Moderate</td>
<td>strong consensus</td>
<td>B</td>
</tr>
<tr>
<td>An intravenous access is considered essential and should be available during the flight</td>
<td>Low</td>
<td>intermediate consensus</td>
<td>B</td>
</tr>
<tr>
<td>Providing intraosseous access may be necessary and the device must be available</td>
<td>Low</td>
<td>consensus</td>
<td>A</td>
</tr>
<tr>
<td>For CPR, epinephrine (adrenaline), amiodarone, lignocaine (lidocain), glucose, and midazolam must be available</td>
<td>Moderate</td>
<td>strong consensus</td>
<td>A</td>
</tr>
<tr>
<td>Mechanical CPR devices may facilitate CPR in special situations, but are</td>
<td>Low</td>
<td>strong consensus</td>
<td>C</td>
</tr>
<tr>
<td>Considered Inappropriate during Flight</td>
<td>Consensus</td>
<td></td>
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<td>--------------------------------------</td>
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<td></td>
<td></td>
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<tr>
<td>Pulse oximetry is considered standard (&quot;basic monitoring&quot;) and should be available for treatment</td>
<td>Moderate  strong consensus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-invasive blood pressure measurement devices are considered standard (&quot;basic monitoring&quot;) and must be available for treatment</td>
<td>Moderate  strong consensus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The use of capnometry/capnography is marginally important during an in-flight cardiac arrest. At the minimum a (simple) qualitative capnometer should be available</td>
<td>Low  weak consensus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Using a glucometer for glucose measurements is important during/after CPR and the device must be available</td>
<td>Moderate  weak consensus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two-person CPR is considered optimum</td>
<td>Moderate  strong consensus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overhead-CPR and telephone-CPR may be performed during resuscitation</td>
<td>Low  weak consensus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The optimum place for CPR is the galley, but may depend on the aircraft model (strong consensus, Level of Evidence C, Grade of Recommendation B). Also, CPR in the aisle of the aircraft is considered possible</td>
<td>Moderate  intermediate consensus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPR should ideally be performed/supervised by a health care provider— if present. However, aircraft crew, trained in BLS-AED or CPR, or a layperson with corresponding training should also be recruited to perform chest compressions</td>
<td>Low  strong consensus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>For airway management during in-flight CPR, the use of a supraglottic airway (e.g., laryngeal mask or laryngeal tube) may be superior to face mask ventilation or endotracheal intubation (ETI)</td>
<td>Low  strong consensus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cabin crew must be trained initially and once per year in CPR and should be re-trained in CPR every six months</td>
<td>Moderate  strong consensus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The crew should be trained regularly in basic life support— ideally with a focus on CPR in aircraft</td>
<td>Low  strong consensus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A diversion should immediately be undertaken if the patient has a return of spontaneous circulation (ROSC)</td>
<td>Low  strong consensus</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CPR should be continued during emergency diversion | Low | strong consensus | A
---|---|---|---
Fixation devices are considered marginally important and can help to fixate the patient after ROSC | Low | weak consensus | C
Due to reduced atmospheric pressure in the aircraft cabin, oxygen should be used even after ROSC to compensate for a reduced oxygen partial pressure in the blood | Low | strong consensus | B
It is important to induce targeted temperature management as soon as possible after ROSC | Low | weak consensus | B
**Table 3:** Levels of quality of evidence.

<table>
<thead>
<tr>
<th>Level*</th>
<th>Points</th>
<th>Quality</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>≥ 4</td>
<td>High</td>
<td>Further research is very unlikely to change our confidence in the estimate of effect or accuracy.</td>
</tr>
<tr>
<td>B</td>
<td>= 3</td>
<td>Moderate</td>
<td>Further research is likely to have an important impact on our confidence in the estimate of effect or accuracy and may change the estimate.</td>
</tr>
<tr>
<td>C</td>
<td>≤ 2</td>
<td>Low*</td>
<td>Further research is very likely to have an important impact on our confidence in the estimate of effect or accuracy and is likely to change the estimate OR any estimate of effect or accuracy is very uncertain (very low)</td>
</tr>
</tbody>
</table>

* Level C = can be divided into low (points =2) and very low (points=1 or less)
† Points are calculated based on the 9 GRADE quality factors (Table 1 section B)
**Figures**

**Fig. 1:** CPR in confined space from the side in an aircraft. Whereas the patient lies in the aisle, the rescuer is placed sideward in the leg area.
Fig. 2: Over the head (OTH) CPR in the aisle of an aircraft.

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