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Advanced Life Support

Optimizing airway management and ventilation during resuscitation and the role of prehospital physicians

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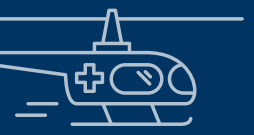
Prehospital Advanced Life Support

PhD Thesis J.L. van Schuppen



Chapter 1

General introduction and thesis outline

GENERAL INTRODUCTION

In critical patients, it is essential to manage the airway, breathing and circulation to ensure adequate tissue oxygenation and prevent hypoxia and death. Emergency care providers therefore focus on these aspects first when treating critical patients. When cardiac arrest occurs, cardiopulmonary resuscitation is started by providing chest compressions and ventilations, aiming to maintain tissue oxygenation. Although these practices are basic clinical routine for every emergency care provider, there are many hidden counteractions and challenges. Chest compressions will not transport oxygen to the tissues when a patient has an arrest due to hypoxia because of a blocked airway, chest compressions can make airway management difficult and ventilations can interfere with chest compressions. In addition, it is difficult to gain and maintain competence in these infrequent procedures and the prehospital setting can be extremely complex to work in.

The general aim of this thesis is to determine how to improve airway management and ventilation during prehospital advanced life support and to assess the added value of specialized physicians in the prehospital setting. This dissertation is subdivided in three objectives:

1. examine the use of the Glidescope® videolaryngoscope on tracheal intubation success and performance, compared to direct laryngoscopy, when ambulance nurses need to perform advanced airway management. In case of an obstructed airway, we compare the use of two emergency front-of-neck airway devices, namely the Ventrain® and the QuickTrach® for achieving oxygenation.
2. To explore the optimal compression pause duration for mechanical chest compression devices to give two ventilations. Current mechanical chest compression devices provide a compression pause of three seconds to give two insufflations, but we question if this is the optimal pause duration.
3. To determine the additional competencies of a mobile medical team with a specialized physician compared to ambulance nurses, and how often additional treatment is given by these physicians during the management of actual prehospital critical patients.

THESIS OUTLINE

In Chapter 2, a more extensive introduction can be found with an overview of current insights in the subjects of this thesis. Existing literature is summarized in a narrative style, with emphasis on the possibilities to improve airway management and ventilation in the prehospital setting. Practical advice is included on how to provide these critical interventions in the prehospital setting and challenges for research in the setting of prehospital resuscitation are outlined.

Part 1 of this thesis focuses on airway management during advanced life support by emergency care providers.

In Chapter 3 we systematically reviewed trials comparing the use of the Glidescope® videolaryngoscope with direct laryngoscopy on tracheal intubation success rate and procedure time when used by providers with limited experience in tracheal intubation. We also included the influence on chest compression interruptions during cardiopulmonary resuscitation.

In Chapter 4 we present data from an incomplete randomized controlled trial with a simulated prehospital "cannot intubate, cannot oxygenate" scenario, comparing the use of the Quick Trach® and Ventrain® needle emergency front-of-neck airway devices. We studied the time needed to achieve oxygen insufflation when ambulance nurses had to use one of these devices in a stressful scenario, examined complications of this procedure and evaluated user experience.

Part 2 of this thesis focuses on ventilation during prehospital advanced life support.

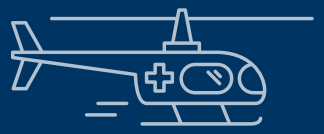
In Chapter 5, we studied the time needed to complete two insufflations when ambulance personnel provide manual chest compressions and ventilations in a 30:2 ratio. With this insight, the current standard setting of a three-second pause in mechanical chest compression devices might be challenged and improved. Determining the optimal pause of mechanical chest compression devices is important to strike the balance between sufficient time to oxygenate with two insufflations, and not interrupting chest compressions for too long to prevent unnecessary decrease in cardiac output.

Part 3 of this thesis explores the role of physicians in prehospital advanced life support.

In Chapter 6 we compared the competencies of ambulance nurses and prehospital physicians to determine the additional competencies of the prehospital physician which can be provided on the scene. This provides a theoretical framework of potential interventions of the prehospital physician, in addition to the care by ambulance nurses on the scene. These interventions would otherwise only be possible by transferring the patient to the hospital and form the potential benefit of dispatching a specialized mobile medical team to critical patients.

In Chapter 7 we studied actual prehospital cases in which the mobile medical team was dispatched and collaborated with ambulance nurses, to determine how often these additional competencies were actually provided on the scene. Furthermore, we studied how often mutual competencies were asked to be provided by the physician to determine a qualitative difference in mutual competencies.

In Part 4 of this thesis we discuss the current findings from our studies, including directions for future research and provide a summary of the findings of this thesis.



Chapter 2

Optimizing airway management and ventilation during prehospital advanced life support in out-of-hospital cardiac arrest - a narrative review

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ABSTRACT

Airway management and ventilation are essential components of cardiopulmonary resuscitation to achieve oxygen delivery in order to prevent hypoxic injury and increase the chance of survival. Weighing the relative benefits and downsides, the best approach is a staged strategy; start with a focus on high-quality chest compressions and defibrillation, then optimize mask ventilation while preparing for advanced airway management with a supraglottic airway device. Endotracheal intubation can still be indicated, but has the largest downsides of all advanced airway techniques. Whichever stage of airway management, ventilation and chest compression quality should be closely monitored. Capnography has many advantages and should be used routinely. Optimizing ventilation strategies, harmonizing ventilation with mechanical chest compression devices and implementation in complex and stressful environments are challenges we need to face through collaborative innovation, research and implementation.

INTRODUCTION

History

Opening the airway and giving insufflations has been part of resuscitation since Biblical times.[1] In more recent times, initial resuscitation included moving the arms of the victim to create a breathing-like pattern of the chest. Later, Peter Safar MD combined artificial respiration with chest compressions, creating the fundament of modern cardiopulmonary resuscitation.[2] Besides chest compressions, lay people were taught the mouth-to-mouth ventilation and professionals were taught bag-mask ventilation, followed by endotracheal intubation. The initial sequence of Airway, Breathing and Circulation (ABC) during CPR was changed to CAB by starting with chest compressions because initially in most cases sufficient oxygen is still available in the circulatory system. In subsequent guideline updates, the focus on compressions further increased with a progressing ratio of chest compressions to ventilations from 5:1, to 15:2, to the current 30:2. This compression to ventilation ratio has remained unchanged in the last iterations of the guidelines.

Currently, there is a renewed interest in airway management, ventilation and capnography during CPR; endotracheal intubation is gradually losing its position as the gold standard in prehospital airway management during CPR and different ventilation strategies are studied. In addition, there is increasing awareness for the interplay between individual components of CPR like airway management and ventilation and for the importance of human factors on clinical performance. The interaction between chest compressions, airway management and ventilation during out-of-hospital cardiac arrest is subject of ongoing research.[3]

Physiology

The two goals of CPR are A) to deliver oxygen to the tissues so that hypoxic injury is alleviated and B) to restore the patient's own circulation. In the very first minutes of cardiac arrest due to a shockable rhythm, also known as the electrical phase, the content of oxygen in the blood and tissues (especially the heart) is mostly sufficient and therefore immediate defibrillation is more important than ventilation.[4] Within minutes the oxygen levels decrease and the circulatory phase starts, making ventilations increasingly important.(figure 2.1)[5] Optimizing CPR will lead to an increase in oxygen delivery and myocardial adenosine triphosphate (ATP) which increases the chance of successful defibrillation.[6] In hypoxic cardiac arrest, providing ventilations during CPR is obviously even more important as it is the treatment for cause of the arrest.

Although debated, international guidelines recommend giving ventilations during CPR.[7] CPR with ventilations is associated with an improvement in survival, when compared to compression-only CPR.[8, 9] In the advanced life support setting, a higher arterial oxygen partial pressure has been associated with both an increased incidence of return of spontaneous circulation (ROSC) as well as improved survival.[10, 11] Another benefit of ventilation is to remove carbon dioxide.[12] During CPR, this helps to compensate the metabolic acidosis which almost always occurs in cardiac arrest.

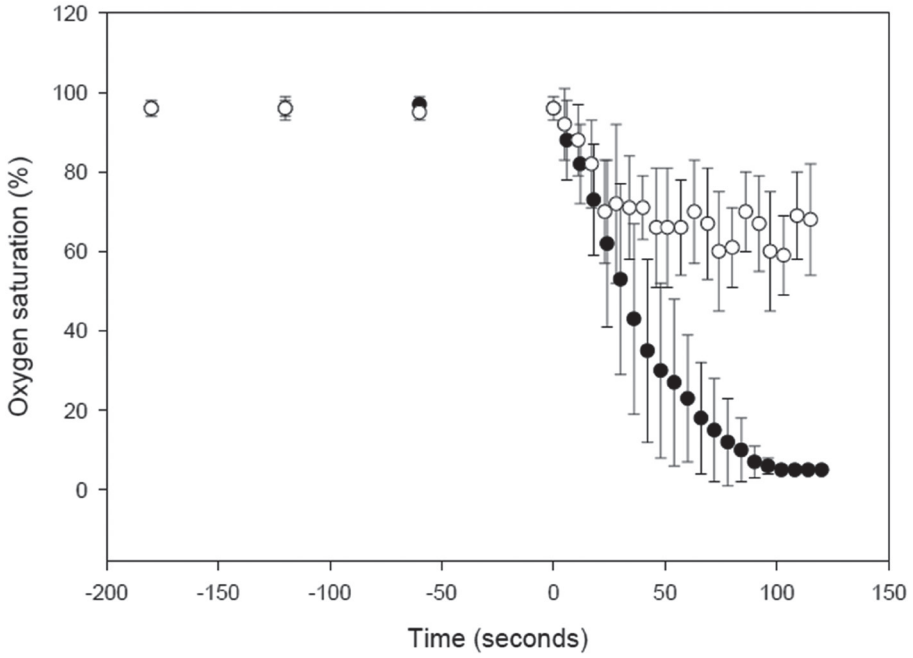

Figure 2.1 *Reprinted with permission from Dorph E, et al.* Oxygen delivery and return of spontaneous circulation with ventilation:compression ratio 2:30 versus chest compressions only CPR in pigs. Resuscitation 2004;60(3): 309-318. Mean (±S.D.) arterial oxygen saturation (%) during the 3 min no-flow period and the initial 2 min of BLS for chest compressions only (●) and ratio 2:30 (o). End of no-flow period and start of BLS period is set to zero (0) seconds.

On the other hand, ventilation during CPR may also have a physiological downside. None of the physiologic mechanisms that lead to venous return to the heart, such as the relaxation of the right ventricle after contraction, an active muscle pump in the legs during walking and negative intrathoracic pressure due to breathing, are functional during cardiac arrest. Venous return therefore only depends on moments of negative intrathoracic pressure, generated by chest recoil in the decompression phase of chest compressions. Potentially, positive pressure ventilations can lead to high intrathoracic pressure, impeding venous return and thus decreasing CPR effectiveness.[13] The same dilemma is relevant when considering PEEP during CPR.

Aim of this review

This review focusses on airway management and ventilation during prehospital resuscitation for adult out-of-hospital cardiac arrest, aiming to support prehospital care and guide future research and innovation. Practical tips are provided for clinicians who work in prehospital emergency care, to help them "snatch life out of the jaws of death".[14]

AIRWAY MANAGEMENT

A patent airway is necessary to transport oxygen to the lungs. Even when airway obstruction is not the primary cause of cardiac arrest, a patient in cardiac arrest cannot maintain a patent airway due to loss of muscle tone and protective reflexes. Gastric content regurgitation with subsequent airway contamination and aspiration also occurs frequently. Therefore, airway management is a key intervention in every resuscitation attempt.

The most common airway strategy in clinical practice is a step-wise approach, depending on the available resources and stage of the resuscitation. Laymen and first responders are trained to provide mouth-to-mouth ventilation with the use of the head tilt and chin lift technique, and a facemask when available. Basic Life Support level Emergency Medical Services (EMS) providers typically use basic airway maneuvers and self-inflating bags (or bag valve mask, BVM) while advanced airway management, including supraglottic airway devices and endotracheal intubation, is provided by advanced level providers like (critical care) paramedics, nurses or physicians.

We emphasize that airway management affects many other aspects of resuscitation, like scene management, ventilation, chest compression quality (including interruptions), defibrillation and treating the underlying cause of the arrest. Looking at airway management in isolation from these aspects leads to an oversimplification of the complex setting that prehospital care providers are faced with.

Bag valve mask (BVM) ventilation

BVM ventilation is a practical technique to begin with during advanced life support because it requires very little preparation and is a fast way of commencing oxygenation. Adequate ventilation with a BVM requires an open airway and a proper seal with the facemask, a challenge that is underestimated, especially in the setting of the stressful initial phase of an out-of-hospital cardiac arrest, with many distracting factors.[15] Some suspect suboptimal effectiveness of BVM ventilations in this setting, which may result in reduced oxygenation and decrease in survival compared to advanced airway devices.[16] It is therefore important to optimize BVM technique to be able to provide an adequate tidal volume with the lowest possible pressure, to prevent gastric insufflation. To help achieve a patent airway, an oro- or nasopharyngeal airway can be employed. A low threshold for the use of these devices seems reasonable because it facilitates adequate BVM ventilation and thus oxygenation, with a low risk of complications. BVM ventilations should be synchronized with chest compressions in a compression to ventilation ratio of 30:2.

Traditionally, the rescuer providing BVM ventilations manages the airway and facemask with the one-handed "CE grip" BVM technique, while squeezing the bag with the other hand. However, a modified 2-rescuer CPR technique leads to superior ventilation while maintaining quality of chest compressions.[17, 18] This strategy includes the optimal BVM technique: one rescuer holds the face mask with two hands in a grip with the thumbs pointing caudally, while providing jaw thrust with the other fingers.[19-21] The other rescuer gives two BVM ventilations after thirty chest compressions.(figure 2.2)

Figure 2.2 Modified 2-rescuer CPR technique to provide a good seal with the facemask and adequate jawthrust, optimizing ventilation during CPR.

Other advantages of the modified 2-rescuer CPR technique are prevention of unintentional simultaneous chest compressions and BVM ventilations, which can happen without the use of this technique when the rescuers get distracted. Furthermore, there is no need for communication between the two rescuers to synchronize the compressions and BVM ventilations. And finally, the rescuer providing the BVM ventilations often also has a task to lead the resuscitation. With this technique, there is more cognitive bandwidth available to organize the scene.
Aspiration is often mentioned as a reason to proceed from BVM ventilations to an advanced airway device during CPR. Data on the incidence of aspiration in patients with BVM only compared to patients with advanced airway devices is conflicting, however aspiration occurs frequently in CPR regardless of the airway technique.[22-24]

Supraglottic airway devices

A supraglottic airway device (SAD) is placed in the oropharynx and is proven to have an important role in emergency airway management. A variety of SADs is available. Advantages when compared to endotracheal intubation are a shorter time for preparation, faster and easier insertion, significant decrease in the need to pause compressions and higher success rate of insertion (even for less experienced rescuers).(figure 2.3)[16, 25] The incidence of aspiration is comparable between SADs and endotracheal intubation because regurgitation typically occurs soon after the onset of cardiac arrest, before prehospital care providers arrive.[26] Because SAD insertion is less complex than intubation, becoming and remaining competent is more feasible for prehospital care providers. The main limitations of SADs are leakage of air during ventilation and dislocation during transport. When ventilating with a SAD, air leakage can be prevented by providing CPR in the 30:2 ratio instead of ventilating during continuous compressions.

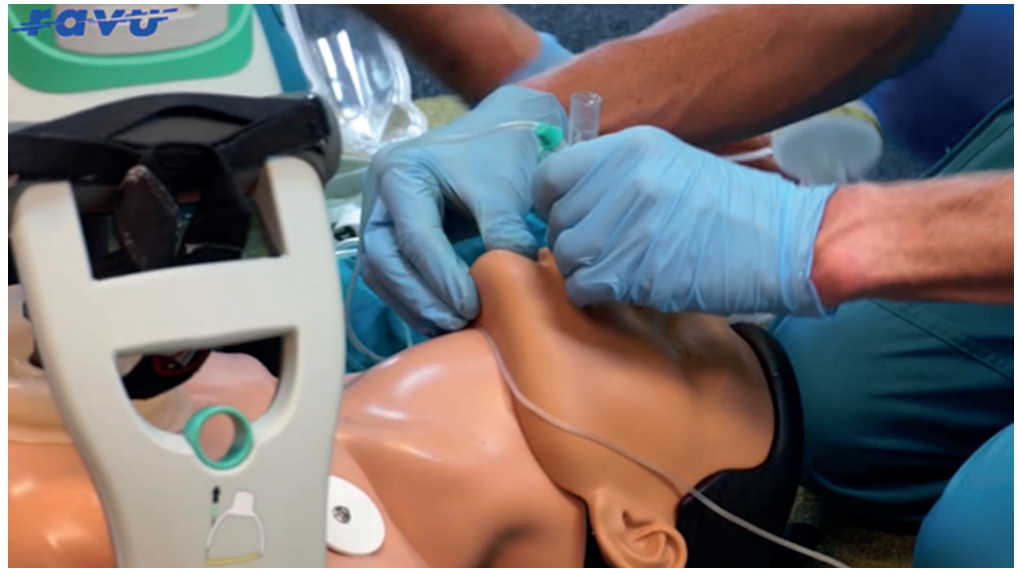

Figure 2.3 Supraglottic airway device (i-gel) placement during mechanical chest compressions with the LUCAS by a Dutch ambulance nurse.

Although large RCT's are still limited and some studies show no difference in outcome, other studies show beneficial effects on outcomes that when a SAD is placed as primary advanced airway device as opposed to endotracheal intubation.[16] Recent trials show that when a SAD was used in cardiac arrest patients, they have a higher chance of (neurological intact) survival while the incidence of complications is comparable.[26, 27] This has led to recommendations for advanced airway management shifting towards the use of a SAD for prehospital resuscitation, especially when providers have limited experience with intubation.[28, 29]

Endotracheal intubation

Advantages of an endotracheal tube during CPR are airway protection from gastric content, ability to handle high airway pressures during ventilation and it frees the providers hands to perform other interventions. An additional argument for intubation is the ability to give continuous chest compressions with asynchronous ventilations, increasing the amount of chest compressions per minute.

All these arguments in favor of endotracheal intubation have been challenged in the past years; Aspiration usually occurs before EMS arrival and therefore is not prevented by an endotracheal tube, high airway pressure has a negative effect on cardiac output and a SAD also frees the providers hands (even faster).[26] CPR with an endotracheal tube does not result in

more chest compression when compared to CPR with BVM, and if that would even be the case, CPR in the 30:2 ratio creates equal cardiac output when compared to continuous chest compressions.[5, 30] Moreover, the majority of RCT's on endotracheal intubation fail to show a clear survival benefit over SAD's.[16, 31]

In contrast, endotracheal intubation has numerous disadvantages, such as the challenge of becoming and staying competent for providers with limited experience, resulting in limited intubation success rates, undesirable interruptions in chest compression during intubation, and distraction from high quality chest compressions and treatment of the cause of the cardiac arrest due to the preparation and focus required for successful intubation.[32, 33]

Endotracheal intubation still remains an alternative for emergency airway management when BVM and SAD fail to facilitate oxygenation during CPR. In these situations, care must be taken to ensure the quality and safety of the intubation. Main goals in this regard are a short procedure time, continuing chest compressions during intubation, a high first pass success rate, the use of waveform capnography and controlling ventilation after intubation.

There are different ways to achieve high intubation quality standards in an EMS system. First pass success rate should be optimal, by letting experienced providers perform intubation.[34] Providers need to perform more than 240 intubations in order to achieve a 90% success rate with high quality during CPR.[35] In many settings, this level of experience can only be achieved by anesthesiologists. This is confirmed by studies on prehospital intubation where the success rate for experienced anesthesiologists was above 99%.[36] Current guidelines allow for a five second pause in chest compressions for intubation.[37] However, once chest compressions are interrupted, the compressions are sometimes paused for (much) more than five seconds.[32] We therefore suggest not to interrupt chest compressions at all during intubation. A stylet or bougie is helpful to increase success of intubation in this challenging setting.[38-40]

The use of videolaryngoscopy may be helpful to increase success of intubation when less experienced providers are confronted with a patient in cardiac arrest with an indication for intubation and expert help is not (yet) available.[41-43] For experienced providers, videolaryngoscopy may be helpful in preventing chest compression interruptions and may further increase first pass success.[43-45] Videolaryngoscopy, in addition, has the advantage of recording the intubation procedure which can help monitoring quality and facilitate education.[46]

Endotracheal intubation is also indicated when the patient achieves ROSC, as part of post-resuscitation care. Maintaining high quality and safety standards is also relevant in these patients because rapid sequence induction (RSI) can result in serious complications in hemodynamically unstable patients. It is therefore important to only consider endotracheal intubation in the prehospital setting when this can be provided by an advanced prehospital team meeting current quality guidelines, or alternatively transporting the patient to a cardiac arrest center with a timely pre-alert.[47]

Front of neck airway (FONA)

When other airway management techniques are not successful in creating a patent airway, front of neck airway (also known as emergency cricothyroidotomy) is a rescue technique. Although there are various techniques, the "scalpel-bougie-tube" technique is often recommended.[48] In particular in the prehospital environment, the use of simple, available and familiar equipment for this procedure, in combination with sufficient practice, increases success rate to establish FONA.[49] Although some EMS regions train their paramedics in establishing a surgical airway with satisfactory success rate, attention should be given to continuous education to maintain self-confidence.[50, 51] A non-scalpel technique or device may be an alternative when prehospital providers are not allowed or confident to perform a surgical technique.

In conclusion, endotracheal intubation has been the 'gold standard' for airway management during CPR for many years, but has been largely replaced by supraglottic airway devices for prehospital airway management during CPR as supported by several studies.[16, 52] SADs are easier to use, with a higher first-pass success rate, thus faster in achieving oxygenation. Evidence suggests that the use of these devices lead to a comparable or even higher survival when compared to intubation.[16, 52] A staged airway strategy, with focus on oxygenation as primary goal, is recommended.[29]

VENTILATION

Although ventilation has been an essential element of CPR for years, there has been far less attention to ventilation in resuscitation science and practice when compared to chest compressions, airway management and drugs. Fundamental questions regarding ventilation during CPR remain largely unanswered. Ventilation has also been ignored as a possible important confounder in many large studies in the field of advanced life support.[53] From the perspective that cells need oxygen to survive, and CPR is the treatment to reverse the dying process, we cannot ignore oxygenation and ventilation as an essential part of CPR. In addition, ventilation is interconnected to other relevant aspects of CRP such as chest compressions, airway management and treatment of the cause of the arrest.

No ventilation or passive oxygenation

The dominant research question in studies on ventilation during CPR, is whether ventilation is required at all. It has been hypothesized that chest compressions generate air movement which might be sufficient for oxygenation, or that ventilations might be harmful during CPR due to positive intrathoracic pressure. CPR without ventilation became known as "compression only CPR". Most EMS who advocate compression only CPR place an oropharyngeal airway and a non-rebreathing oxygen mask to provide "passive oxygenation".[54] However, air movement generated by chest compressions does not exceed the anatomical dead space of the airway, making sufficient oxygenation unlikely.[55-58] Therefore, alternative ways whereby oxygen is insufflated with higher flow, like the endotracheal Boussignac tube, have been proposed.[59, 60] Although these techniques prevent the potential negative effect of ventilation, disadvantages include more atelectasis, the need for alternative and sometimes rather complex actions and devices, and that high-flow oxygen techniques involving an endotracheal tube can only start later, following intubation.[61-63] Furthermore, hypercapnia, further aggravating acidosis must be considered. Because solid data on passive oxygenation are scarce (existing studies used different methods of passive oxygenation, study methodology is diverse, study size is usually small) and clear benefit in survival has not been demonstrated, passive oxygenation during prehospital advanced life support is currently not recommended.[7, 61, 64, 65]

Synchronous (30:2) versus asynchronous ventilation during continuous compressions

Current guidelines recommend to synchronize chest compressions to ventilations with a 30:2 ratio before intubation, and to ventilate asynchronous during continuous compressions following intubation.[37] The ratio of 30:2 seems the optimal ratio to achieve oxygen delivery.[7, 66] BVM ventilation during ongoing chest compressions is believed to generate a high insufflation pressure leading to gastric insufflation. On the other hand, stopping compressions for BVM ventilations lead to a fast decrease in cardiac output. A large cluster-randomized trial assessing the effects of synchronous (30:2) and asynchronous BVM ventilations on mortality, suggested a higher survival for synchronous (30:2) CPR.[67] Possibly, synchronous compressions and ventilations (30:2) are better because BVM ventilations without simultaneous chest compressions result in better oxygen insufflation compared to insufflations during chest compressions. In addition, experimental data employing a porcine model showed no differences in carotid blood flow when comparing 30:2 CPR with continuous compressions.[5]

Influence of mechanical chest compression devices

Mechanical chest compression devices may influence ventilation during CPR, in particular in the 30:2 mode. Both Autopulse® and LUCAS®, two of the most frequently used mechanical chest compression devices, pause compressions for three seconds after 30 compressions, to give two ventilations. After the three second pause, compressions are automatically resumed. This timeframe is probably too short, given that prehospital care providers need a median of 5.5 seconds to provide two BVM ventilations during manual CPR.[68] We therefore expect that in a significant number of pauses, providers are unable to give two insufflations during the compression pause or tidal volumes provided are too small. This may have a negative impact on oxygenation and outcome.[53, 69] The decrease in ventilation quality might outweigh the increase in chest compression quality and could thus explain the lack of survival benefit for mechanical chest compression devices in large randomized trials.[70, 71] In these trials however, ventilation parameters were not measured or published when mechanical compression devices are used.[53]

Ventilation frequency

For asynchronous ventilation during ongoing compressions, ventilation frequency can be adjusted. An optimal ventilation frequency, sufficient for adequate oxygenation, but as few as possible to prevent a high intrathoracic pressure with a decrease in venous return, is assumed.[72] The current recommended ventilation frequency of 10 ventilations per minute is based on animal studies.[73] Subsequent observational clinical studies showed higher ventilation frequencies to be associated with no worse and at times even a positive effect on survival.[74-76] Apparently, at ventilation frequencies between 15-20/min the negative effect on cardiac output do not seem to outweigh the positive effect on oxygenation.[77] It has been postulated that higher ventilation frequencies are particularly beneficial for prolonged cardiac arrest.[78] A higher ventilation frequency also leads to more CO_2 removal counteracting metabolic acidosis.[12]

Tidal volumes

Tidal volumes during CPR should be large enough to oxygenate, but as small as possible to prevent high airway pressure and subsequent gastric insufflation in the non-intubated patient. A tidal volume of 1000 ml did not lead to a higher PaO2 than 500 ml.[79] Currently, tidal volumes of 500-600 ml are recommended.[7] CPR course materials often mention insufflating enough for a visible chest rise. However, recent data suggests this might lead to too small tidal volumes because tidal volumes of around 380 ml already result in visible chest rise.[80] In clinical practice, large tidal volumes can be administered because adult BVM devices usually have a volume of around 1.5L. To limit over inflation, use of an alternative grip of the bag, or smaller (like pediatric) self-inflatable bags have been suggested.[81, 82] Pediatric self-inflating bags provide tidal volumes of around 365 ml versus 779 ml for adult self-inflating bags. Both lead to a comparable oxygen saturation but lower airway pressure and less gastric insufflation when a pediatric self-inflating bag is used.[83, 84] An insufflation time of one second is recommended to balance the disadvantages of a short versus long insufflation time.[37]

Oxygen

During CPR, ventilations should be given with 100% oxygen to maximize oxygen delivery.[29] Although there are no clinical trials comparing different oxygen concentrations during CPR, a preclinical study showed better outcomes with increasing oxygen concentrations.[85] A positive association of PaO2 and outcome was found in two clinical observational studies.[10, 11] After achieving ROSC, oxygen should be titrated to an oxygen saturation of 94-98%, since hyperoxia has been claimed to negatively affect survival.[37, 86, 87]

Positive End-Expiratory Pressure (PEEP)

The use of PEEP during CPR can be considered as undesirable from the perspective that positive intrathoracic pressure impairs venous return. Surprisingly, recent data suggest an improvement in outcome when a small amount of PEEP is used.[88, 89] An other study showed a positive association between airway pressure during CPR and survival.[90] A possible explanation is an improvement in oxygenation and a decrease in pulmonary vascular resistance, thereby improving blood flow generated by chest compressions. However, further randomized clinical studies are needed to determine the precise effects of PEEP during CPR.

Impedance Threshold Device (ITD)

An impedance threshold device creates a negative intrathoracic pressure during CPR. It is integrated in the ventilation circuit between the airway and the self-inflating bag and includes a valve to allow air to exit during chest compression, but blocks air flow back into the chest during decompression.[91] In this way, negative intrathoracic pressure is generated, aiming to increase venous return. Several studies, in particular those where active decompression (ACD) was employed demonstrated some positive effect on outcome.[92-96] A large randomized clinical trial failed to show a beneficial effect, though a post-hoc analysis of the data revealed that the outcome improved with the ITD when patients received high quality CPR.[97, 98] Although, the ITD is currently not recommended because the quality of the data on ITD was considered insufficient, ITD and ACD combined with controlled sequential elevation of the head and thorax to decrease intracranial pressure improves cerebral blood flow during CPR.[99, 100] In an observational study this 'bundle of care' was associated with an increase in survival, however, further studies are necessary to determine the place of the ITD during CPR and the effect of the 'bundle of care' on survival.[101, 102]

CAPNOGRAPHY

Waveform capnography has an important role in various aspects in prehospital resuscitation. First and foremost, it represents the gold standard to confirm correct tube position.[29, 103]
In addition, capnography can be used to monitor the quality of chest compressions, ROSC detection, monitoring of ventilation frequency and prognostication.[37, 104, 105] Furthermore, as some causes of cardiac arrest lead to a lower or higher end-tidal CO2 than expected it can be used for differential diagnosis.106 Noteworthy, artefacts in the waveform due to chest compressions might influence quantification of end-tidal CO2 displayed on the monitor.[107] After ROSC, ventilation can be adjusted according to end-tidal CO2.

APPLICATION IN THE PREHOSPITAL PRACTICAL CONTEXT

Implementing guidelines and achieving high performance CPR in the prehospital setting is by no means an automatic process. Particularly when evidence is contradictory, as for airway management and ventilation during advanced life support, clinical practice varies widely.[108]
The prehospital emergency environment is demanding and diverse and prehospital systems differ around the globe. Even when practice guidelines are up-to-date and a clear implementation strategy is present, successful implementation can be challenging and time-consuming.[109]

Several tools facilitate guideline implementation and can help to achieve high quality and safety standards in clinical care; First of all, training staff is essential to improve performance and make an impact on outcome in cardiac arrest.[110] Secondly, increasing experience by dispatching a particular group of providers to out-of-hospital cardiac arrest will help prehospital treatment and decision making.[111-113] Dispatching prehospital physicians enlarges the spectrum of resuscitation interventions, further improving patient outcomes.[114-116] Thirdly, ergonomics are very useful but often underutilized. Optimizing the design of a prehospital airway bag, for instance, decreases procedure time, reduces errors and decreases the cognitive load of providers.(figure 2.4)[117] Also, easy to use, automated devices can help achieve guideline-compliant performance, and at the same time help to reduce stress levels of prehospital providers.[[118]] Use of a ventilator during CPR, for instance, can help to achieve certain targets such as ventilation frequency after intubation (although attention is needed for the ventilator settings).[[119, 120]]

Finally, feedback during and after prehospital resuscitation can help to improve performance; Besides chest compression feedback devices, ventilation feedback devices have become available and have shown positive effects on performance. Their effects on outcome remain to be determined.[121, 122] Structural feedback, audits and implementation checks of the lessons learned are helpful to increase performance, but also for innovation and for creating a culture of excellence.[14, 123, 124]

Figure 2.4 Reprinted with permission from Swinton P, et al. Impact of drug and equipment preparation on pre-hospital emergency anaesthesia (PHEA) procedural time, error rate and cognitive load. SJTREM 2018;26:82. The Adult SCRAM (Structured CRitical Airway Management) Bag is designed to improve performance of prehospital intubations.[117]

ROLE OF THE ANESTHESIOLOGIST IN PREHOSPITAL RESUSCITATION

Anesthesiologists can make an important contribution in many aspects of prehospital resuscitation, from an operational to the strategic level, although their presence in prehospital care differs per country and prehospital system.[125, 126] Of course, additional training to provide care in a prehospital setting is very important. Dispatching anesthesiologists in prehospital care as part of a critical care response tier within an EMS system, will increase intubation success.[127] Equally important however, is their competence in deciding to refrain from intubation.[1278]
In addition, the expertise of anesthesiologists exceeds airway management. This is reflected in a study where the presence of a prehospital physician (anesthesiologists being the vast majority) was often regarded as useful by ambulance staff, even though no additional interventions were done on the scene.[115] Whether or not through airway management, other interventions or clinical decision making, prehospital anesthesiologists have the potential to improve patient outcomes.[116, 129]

On a management level, anesthesiologists can work as EMS medical director or collaborate with EMS regarding education, guidelines, research and innovation. In the United Kingdom, prehospital emergency medicine has evolved into a recognized subspecialty by the Royal Colleges of Anaesthetists and Emergency Medicine.[130] Finally, anesthesia societies have the expertise to develop guidelines for prehospital care.[131]

FUTURE RESEARCH

Future research in the field of prehospital airway management and ventilation during CPR should focus on means to optimize implementation of the basics and innovating CPR techniques;

- The quality of initial BVM ventilations by prehospital providers is unknown and how this can be improved remains to be determined. Whether avoiding BVM ventilations and proceeding directly to SAD placement for paramedics leads to improved outcome also warrants further research.
- When to intubate and how to increase intubation success for providers with limited experience are relevant research questions.
- In the context of ventilation, little is known about the influence of mechanical chest compression devices on ventilation and how can this be optimized through device settings like chest compression pause duration.
- From a more fundamental perspective, attention is needed to determine the optimal strategy for intrathoracic pressure during CPR; Both the use of PEEP and the ITD warrants further research.
- With respect to capnography, the role of end-tidal CO2 for diagnosing the underlying cause of cardiac arrest and how paramedics can use this information in the resuscitation process should be assessed.
- Determining which out-of-hospital cardiac arrest patients benefit from prehospital physicians deserves further research.

SUMMARY

Airway management and ventilation are vital elements of every prehospital resuscitation attempt in out-of-hospital cardiac arrest. Oxygenation during CPR is important for survival, however, the best strategy to achieve optimal oxygenation, both regarding airway management and ventilation technique remains to be determined. Supraglottic airway devices seem to provide advantages over endotracheal intubation in many settings and capnography yields more relevant information than tube position alone. The impact of mechanical chest compression devices on ventilation during CPR deserves further attention. Efforts should be made to increase quality and safety of airway management and ventilation during CPR, because this has the potential to improve survival after cardiac arrest. Focus on human factors and ergonomics help improve performance in the challenging prehospital environment. Anesthesiologists can make an important contribution to clinical practice, education, innovation and research. We hope that an increasing number of health care professionals, both in- and outside the anesthesia domain, will initiate and collaborate in research in this exciting and relevant field.

Practice points

- Develop an airway and ventilation strategy during CPR within your organization. Make it as simple and effective as possible. Supraglottic airway devices are often the preferred advanced airway technique in the complex prehospital setting to achieve fast and adequate oxygenation.
- On arrival at an out-of-hospital cardiac arrest as a prehospital provider, the first priority is to manage the scene, optimize chest compression quality and defibrillations. Then, ensure adequate insufflations with 100% oxygen. A modified 2-rescuer CPR technique enables the use of two hands for good basic airway management and mask seal when providing BVM ventilations.
- Do not rush to advanced airway management as long as insufflations are adequate. Make sure your team, equipment and setting is optimal. Place advanced airways during ongoing compressions and always use waveform capnography.
- Control ventilation frequencies during asynchronous compressions and ventilations. There are five strategies you can use: stay with 30:2 (preferably with the modified 2-rescuer technique), give 1 ventilation per 10 compressions (make the provider who is providing chest compressions count out loud “8-9-10” during compres sions), monitor frequency by looking at the capnography on the defibrillator, use a metronome or feedback device or consider using a mechanical ventilator.
- Use capnography as a tool to improve chest compression quality, ROSC detection, indication of cause of cardiac arrest and subsequent treatment and prognostication.
- Although the most experienced provider usually goes to the head-end of the patient for airway management and ventilation, often that provider is also expected to organize the scene and the team. Don’t expect to manage both things at the same time perfectly. Designate another provider as team leader, or when this is not possible, make yourself hands-off as soon as possible after you managed the airway.
- Train providers frequently and monitor performance on objective parameters from actual cases. Debrief teams and use lessons learned to improve equipment, procedures and training.

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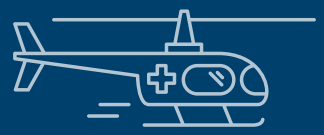
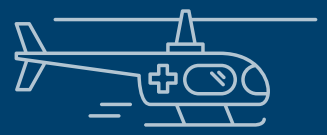


PART 1

Airway management



Chapter 3

Tracheal Intubation during Advanced Life Support using Direct Laryngoscopy versus Glidescope® Videolaryngoscopy by Clinicians with Limited Intubation Experience: *A Systematic Review and Meta-Analysis*

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PART I

ABSTRACT

The use of the Glidescope® videolaryngoscope might improve tracheal intubation performance in clinicians with limited intubation experience, especially during cardiopulmonary resuscitation CPR). The objective of this systematic review and meta-analysis is to compare direct laryngoscopy to Glidescope® videolaryngoscopy by these clinicians. PubMed/Medline and Embase were searched from their inception to July 7, 2020 for randomized controlled trials, including simulation studies. Studies on adult patients or adult sized manikins were included when direct laryngoscopy was compared to Glidescope® videolaryngoscopy by clinicians with limited experience in tracheal intubation (< 10 intubations per year). Primary outcome was intubation first-pass success rate. Secondary outcomes were time to successful intubation and chest compression interruption duration during intubation. Risk of bias was assessed with the Cochrane risk of bias tool. Certainty of evidence was assessed using Grading of Recommendations Assessment, Development and Evaluation (GRADE). We included 4 clinical trials with 525 patients and 20 manikin trials with 2547 intubations. Meta-analyses favored Glidescope® videolaryngoscopy over direct laryngoscopy regarding first-pass success (clinical trials: risk ratio [RR] = 1.61; 95% confidence interval [CI]: 1.16-2.23; manikin trials: RR = 1.17; 95% CI: 1.09-1.25). Clinical trials showed shorter time to achieve successful intubation when using the Glidescope® (mean difference = 17.04 sec; 95% CI: 8.51-25.57 sec.). Chest compression interruption duration was decreased when using the Glidescope® videolaryngoscope. The certainty of evidence ranged from very low to moderate. When clinicians with limited intubation experience have to perform tracheal intubation during advanced life support, the use of the Glidescope® videolaryngoscope improves intubation and CPR performance compared to direct laryngoscopy.

INTRODUCTION

Airway management is an essential part of advanced life support to facilitate ventilation of the lungs. During cardiopulmonary resuscitation (CPR), many professionals still favor tracheal intubation, although supraglottic airway devices (SAD) are increasingly used as primary advanced airway technique. However, when SADs fail to facilitate oxygenation in situations such as aspiration, drowning or trauma, tracheal intubation is still indicated. In addition, in the current COVID-19 pandemic tracheal intubation is regarded as the best airway technique during CPR to minimize aerosol generation by chest compressions [1,2].

The challenge with tracheal intubation during CPR is to achieve first-pass success, while fast, safe and without interruption of chest compressions. More experienced clinicians have a higher intubation success rate, but gaining and maintaining sufficient experience in tracheal intubation is challenging, especially for EMS organizations [3-5]. It takes a minimum of 50 tracheal intubations to achieve an intubation success rate of 90% within two attempts, under optimal (non-emergency) conditions[6]. More than 240 tracheal intubations are needed to perform trachea intubation during CPR with 90% success rate and high quality standards[7]. EMS clinicians often perform less than 10 tracheal intubations per year [8,9]. Getting a clinician with sufficient intubation experience on the scene within an acceptable time is often a challenge and sometimes not possible, like in remote and military settings. There are several risks when tracheal intubation is performed by personnel with limited experience, including oropharyngeal injury, significant interruption of chest compressions, and incorrect tube placement with consecutive hypoxia [10-12].

Videolaryngoscopy has the potential to increase the tracheal intubation success rate when clinicians with limited experience are confronted with a patient with an indication for tracheal intubation. Furthermore, videolaryngoscopy may decrease interruptions in chest compressions during CPR. The Glidescope® was the first commercially available videolaryngoscope. The hyperangulated blade includes a camera, connected to a video screen, which improves visualization of the larynx (Figure 3.1). The tracheal tube can then be inserted into the airway by using a rigid stylet (Gliderite® Stylet).

Figure 3.1 A: The Glidescope® videolaryngoscope with the former GVL blade (left) and recent LoPro blade (right), and the Gliderite® rigid stylet. B: The portable GlidescopeGo®, used by an EMS clinician in a simulated prehospital advanced life support setting.

The objective of this study was to perform a systematic review and meta-analyses on the use of the hyperangulated Glidescope® videolaryngoscope for tracheal intubation by clinicians with limited intubation experience regarding first pass success rate and time to intubation, when compared to direct laryngoscopy. The secondary aim was to determine differences in chest compression interruptions during CPR. As the Glidescope® videolaryngoscope is one of the most widely used videolaryngoscopes and prehospital care clinicians often have an annual tracheal intubation exposure of < 10 tracheal intubations we searched for studies comparing direct laryngoscopy to Glidescope® videolaryngoscopy in oral tracheal intubation by clinicians with limited experience in tracheal intubation. With this study we aimed to provide an answer to the question; Should clinicians with limited intubation experience use the Glidescope® for tracheal intubation?

MATERIALS AND METHODS

The protocol of this systematic review and meta-analysis has been registered in the international prospective register of systematic reviews PROSPERO (review record CRD420180-96251) and is included as Appendix 3.A. This review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, see Appendix 3.B for the PRISMA checklist[13]. Primary outcome is first-pass success rate of tracheal intubation, secondary outcomes are time needed for successful intubation and duration of chest compression interruption for CPR.

Eligibility Criteria

Studies were included if they met all of the following criteria:

1. Comparison of direct laryngoscopy to Glidescope® videolaryngoscopy (either conventional Glidescope® or Glidescope® Ranger) for tracheal intubation
2. Randomized and quasi-randomized controlled trials
3 Clinicians had limited experience in tracheal intubation, defined as less than 10 intubations per year
4. Adult patients or adult-sized manikins
5. Contained any outcome of interest (first-pass success rate, and/or time to intubation, and/or hands-off time during CPR)

Studies on nasotracheal intubation were excluded.

Information Sources and Search Strategy

MEDLINE/PubMed and Embase were systematically searched (1966 to July 7 2020) for randomized trials comparing tracheal intubation using direct laryngoscopy versus Glidescope® videolaryngoscopy. The following search terms were used in MEDLINE/PubMed: (Glidescope®) OR (video laryngoscop*[tiab]). In Embase the search term (Glidescope® or video laryngoscop*). ti,ab,kw was used. Bibliographies of selected manuscripts were hand searched for additional relevant studies.

Study Selection

The first author (KW) performed the search. In duplicate and independently, the first two authors (K.W., H.S.) performed the bibliographic review of the search results. Disagreement was resolved by discussion and arbitrated if necessary by a third independent researcher (BP).

Data Collection and Data Items

Two reviewers extracted data including the year of publication, country of origin, sample size, operator background, operator training, whether intubation was performed on a real patient or manikin, in which setting the intubation was performed, rate of successful intubation at first attempt, time required to intubate, and hands-off time during CPR. We contacted investigators for missing data if necessary.

Risk of Bias in Individual Studies

Risk of bias of the individual studies was independently reviewed by two investigators. The Cochrane risk of bias tool was used to determine selection bias, performance bias, detection bias, attrition bias, reporting bias, and other bias in the included studies[14].

Data Synthesis and Analysis

Because the setting of actual patient care and differences in design of simulations studies can influence the results, the analysis was divided in three subgroups. The three main groups are:

1. Intubations performed in the clinical setting
2. Intubations performed in a simulation setting, using manikins
3. Intubations performed in a simulation setting, using manikins with a difficult airway scenario

Differences in first-pass intubation success rate is expressed in risk ratio (RR) and differences in time to intubate and hands-off time during CPR are expressed in mean difference (MD) in seconds. Interquartile ranges were converted into standard deviations. The random effects method of Mantel-Haenszel was used to generate a pooled RR or MD across studies. We assessed statistical heterogeneity using Cochrane's Q statistic (with $P < 0.05$ considered significant) and expressed the quantity using the I2 statistic and 95% confidence interval (CI). We followed the Cochrane handbook classification for importance of I2. To explore heterogeneity, subgroup analyses were done for specific clinical scenarios (normal airway, difficult airway, etc.). Statistical analyses as well as forest plots were made using Review Manager (RevMan) [Computer program], Version 5.2. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2012. The overall certainty of evidence was assessed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) method[[15]. The GRADE tables were made with the GRADEpro GDT online software [GRADEpro GDT: GRADEpro Guideline Development Tool [Software]. McMaster University and Evidence Prime, 2021. Available from gradepro.org].

RESULTS

Study Selection

The literature search was performed on July 7th 2020. A total of 1022 citations were identified from Medline (PubMed) and Embase (Ovid). We excluded 943 citations on initial

screening of title and abstract of the article and 13 on screening of the full article. Of the remaining articles, 42 articles were excluded because there was no data on the primary or secondary endpoint, it regarded only pediatric patients, it regarded nasal intubation, there was no comparison between direct laryngoscopy and Glidescope®, or intubation was performed by experienced clinicians. The references of the 55 excluded articles are included as Appendix 3.C. Three articles were included after discussion by the first two authors. This resulted in 24 inclusions and 997 exclusions. (Figure 3.2)

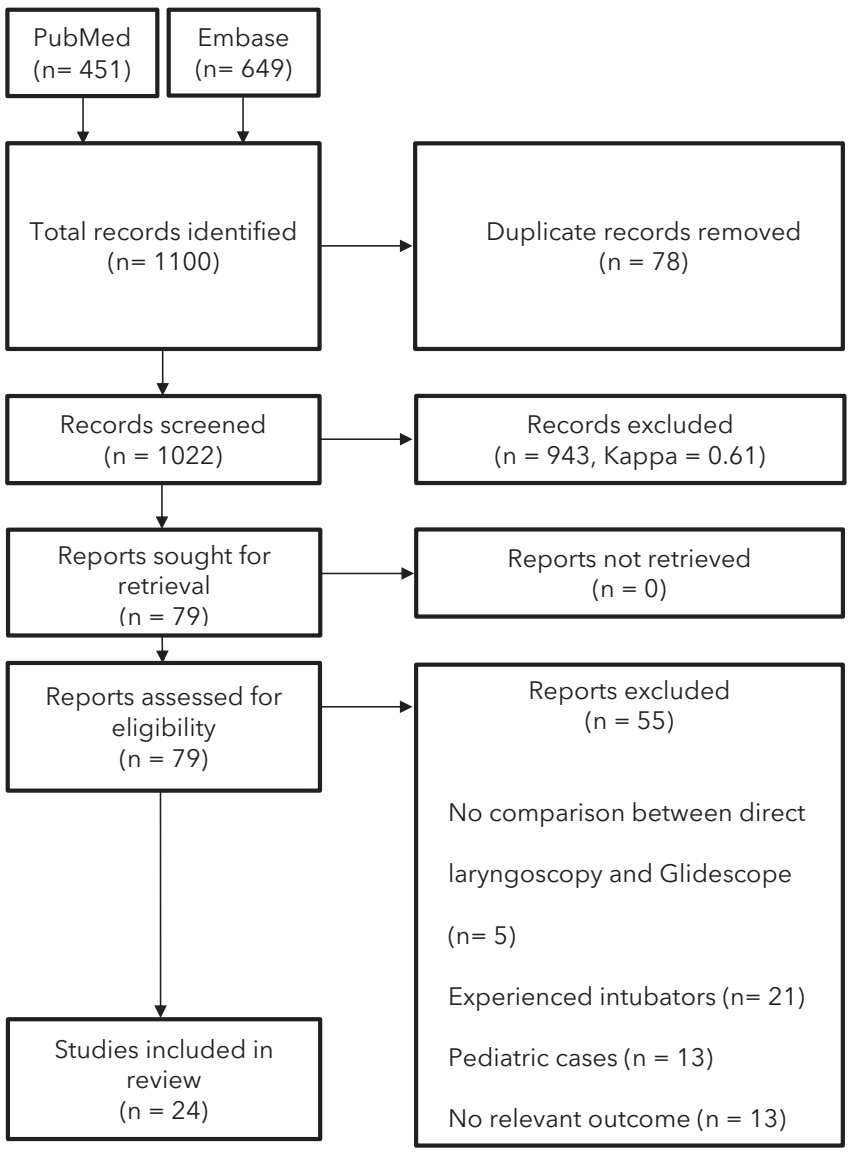

Figure 3.2 PRISMA diagram

Study Characteristics

We identified four randomized trials in which patients were intubated in the clinical setting and 20 randomized trials in which the intubation was performed on a manikin [16-39].
See Table 3.1 for the study characteristics. A total of 525 clinical intubations were included as well as 2547 manikin intubations. Of the clinical studies, three were performed on patients in the Operating Room (OR) and one was performed during CPR. The patients included in the OR setting were ASA 1 and 2 patients in elective situations, without a known or anticipated difficult airway.

Of the manikin studies, nine studies had a protocol with only a normal airway, eleven stu dies included a protocol with a manikin with a normal airway as well as a difficult airway, and one study solely included a protocol with a manikin with a difficult airway. Difficult airway protocols included cervical spine immobilization, intubation during chest compressions, tongue edema or pharyngeal obstruction, a Cormack-Lehane grade 3 view, intubation on the floor, or a combination of two or more of these circumstances. When a study allowed participants to run the same scenario more than once, the data of the first scenario was included for meta-analysis.

In the trials using a manikin all participants used both intubation techniques. In all trials except one, the operators had no prior intubation experience. In the trial in which the operators had prior intubation experience, all operators had performed less than 10 intubations in their career. [25]

Clinical studies

First author, year	Country of origin	Number of patients	Randomized per group	Operators	Training	Patients
Nouruzi, 2009 [38]	Essen, Germany	200	DL: 100 GS: 100	Students (paramedic, nurse & medical)	Manikin training	ASA 1-2 predicted non difficult airway
Ayoub, 2010 [36]	Beirut, Lebanon	42	DL: 21 GS: 21	Medical students	Manikin training	ASA 1-2 predicted non difficult airway
Hirabayashi, 2010 [37]	Shimotsuke, Japan	200	DL: 100 GS: 100	Non-anaesthesia residents	Short demonstration and 5-6 practices on a manikin	ASA 1-2 predicted non difficult airway
Park, 2015 [39]	Seoul, Republic of Korea	83	DL: 34 GS: 49	Inexperienced emergency physicians	Airway session of 8 hours	CPR patients
4		525	DL: 255 GS: 270			

Manikin studies

First author, year	Country of origin	Number of intubations	Randomized per group	Operators	Training	Scenario
Lim, 2004 [16]	Singapore	80	DL: 20 GS: 20	Medical students	Instructions and 3 minutes practice	Normal airway CL grade 3
You, 2009 [20]	Ulsan, Korea	41	DL: 20 GS: 21	Medical students	Lecture of 30 minutes	Normal airway
Lin, 2009 [17]	Hualien, Taiwan	164	DL: 41 GS: 41	Medical students	Instructions and 5 attempts with both devices	Normal airway CL grade 3
Malik, 2009 [18]	Galway, Ireland	318	DL: 53* GS: 53*	Medical students	Instruction of 5 minutes and 5 attempts	Normal airway Cervical immobilisation Pharyngeal obstruction
Powell, 2009 [19]	Sheffield, UK	42	DL: 21 GS: 21	Non-anaesthesists	Individual standard demonstration	Normal airway
Cinar, 2011 [21]	Ankara, Turkey	242	DL: 121 GS: 121	Paramedic students	Lecture and demonstration	Normal airway
Kaki, 2011 [22]	Jeddah, Saudi Arabia	100	DL: 50 GS: 50	Non-anaesthesists	Standardized instruction and practice	Normal airway
Kim, 2011 [23]	Seoul, Republic of Korea	80	DL: 20 GS: 20	Paramedic students	Training of one hour	Normal airway CPR on the floor
Shin, 2011 [25]	Seoul, Republic of Korea	128	DL: 32 GS: 32	Interns with <10 tracheal intubations	Instruction of 20 minutes and 3 intubations on a manikin	Normal airway Chest compressions
Stroumpoulis, 2011 [26]	Athens, Greece	88	DL: 44 GS: 44	ACLS providers	Brief presentation and 5 minutes of practice	Normal airway
Wass, 2011 [24]	Rochester, USA	100	DL: 25 GS: 25	Medical students	Tutorial of 5-10 minutes	Normal airway Pharyngeal obstruction
Xanthos, 2011 [27]	Athens, Greece	180	DL: 45 GS: 45	Doctors inexperienced in airway management	Instruction of 20 minutes and practice on manikin	Normal airway Chest compressions
Xanthos, 2012 [28]	Athens, Greece	192	DL: 96 GS: 96	Medical and nursing graduates	Instruction of 20 minutes and practice on manikin	Normal airway
Biermann, 2013 [29]	Amsterdam, the Netherlands	78	DL: 39 GS: 39	Unexperienced registrars in internal medicine	Explanation and demonstration	Normal airway
Tung, 2013 [30]	Vancouver, Canada	68	DL: 34 GS: 34	Medical students	Standardized video instruction and 10 minutes of practice	Normal airway
Wang, 2013 [31]	Hualien, Taiwan	120	DL: 20 GS: 20	Medical students	Demonstration of 3-5 minutes and practice 1-3 times on bodies	Normal airway On the floor Cervical immobilisation Cervical immobilisation on the floor
Ambrosio, 2014 [32]	San Diego, USA	40	DL: 19 GS: 21	First-year non anaesthesia residents	Manikin training, ended upon 1 successfull intubation with both DL and Glidescope®	CL grade 3 + cervical immobilisation
Kim, 2014 [33]	Seoul, Republic of Korea	156	DL: 39 GS: 39	Medical students	5 intubations	Normal airway Cervical immobilisation
Bahhatiq, 2016 [34]	Makkah Mukarramah, Saudi Arabia	200	DL: 50 GS: 50	Paramedic students	Lecture of one hour, demonstration of 10 minutes and practice one time	Normal airway Cervical immobilisation
Pieters, 2016 [35]	Nijmegen, the Netherlands	130	DL: 65 GS: 65	Medical students	Demonstration of 5 minutes, no practice	Normal airway
20		2547	DL: 1273 GS: 1274			

Table 3.1 *) The number of intubations in this table include only the first scenario with normal airway. (ASA = American Society of Anesthesiologists, CL = Cormack-Lehane, CPR = Cardiopulmonary resuscitation, DL = Direct laryngoscopy, GS = Glidescope® videolaryngoscopy, USA = United States of America).

Certainty of Evidence across Studies

The evidence was rated as low to moderate certainty regarding first-pass success rate and as very low to moderate certainty regarding time to intubation when using Glidescope® videolaryngoscopy versus direct laryngoscopy. See Appendix 3.D for the GRADE table. Only one study reported chest compression interruptions[39].

Risk of Bias within Studies

Risk of bias within all included studies (both clinical and manikin studies) is illustrated in Figure 3.3 and Figure 3.4 [14]. The performance bias attributes the blinding of participants and personnel. As it is impossible to blind participants and observers for the device used, all included studies score a high risk of bias on this domain.

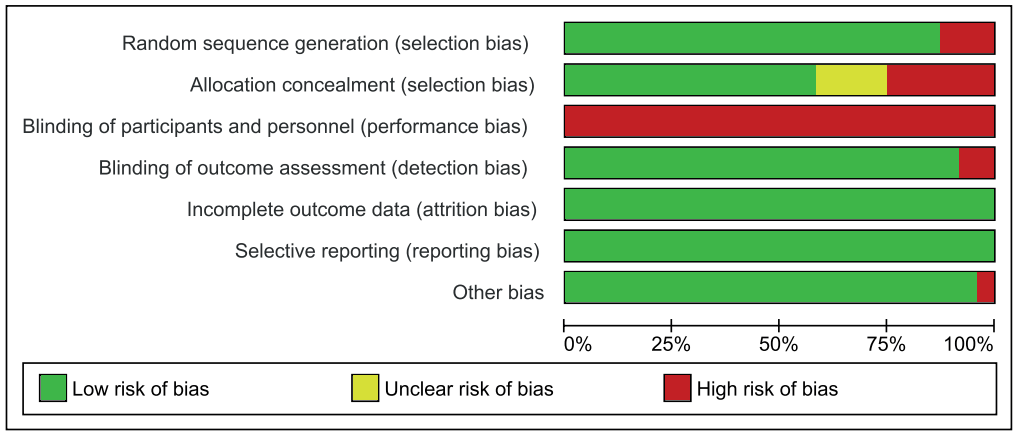

Figure 3.3 Risk of bias graph

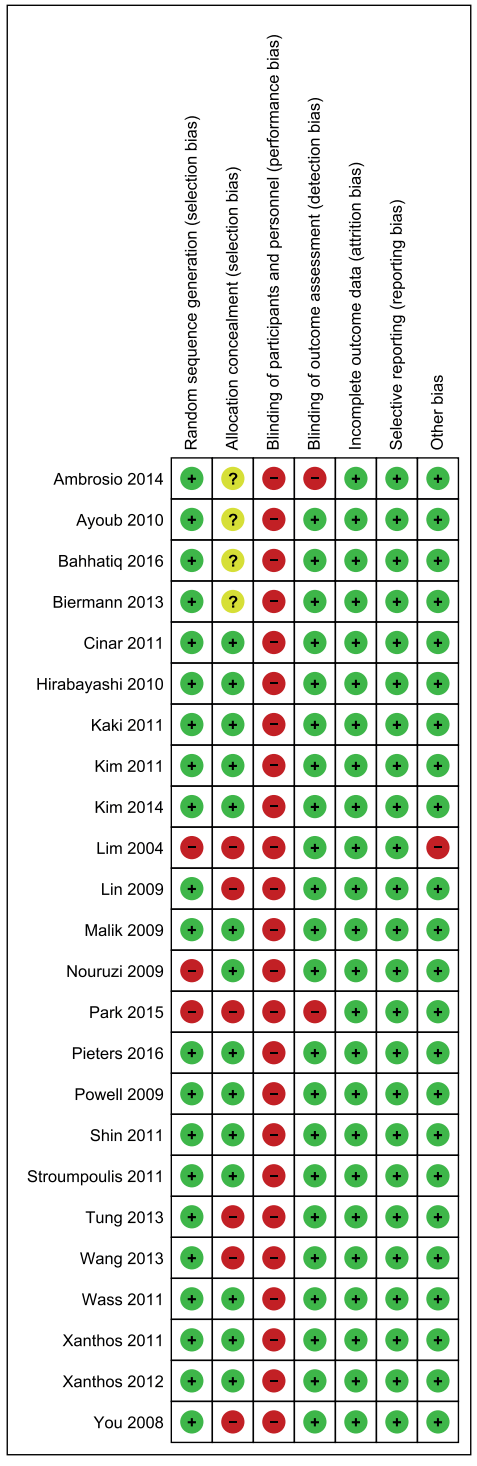

Figure 3.4 Risk of bias summary

Outcomes

Intubation First-Pass Success Rate

All included trials presented data on intubation success and time needed for intubation (Table 3.2). The pooled RR for first-pass success across the clinical studies was 1.61 (95% CI 1.16, 2.23; P = 0.004) (Figure 5.5). The level of certainty of evidence was moderate.
The pooled RR for first-pass success in the manikin studies was 1.17 (95% CI 1.09, 1.25; P < 0.0001) (Figure 3.6). There was substantial between-study heterogeneity. All three sub-group analyses revealed a significant effect in favor of the Glidescope® videolaryngoscope. The overall certainty of evidence was rated as low for these trials, see Appendix 3.D for GRADE table.

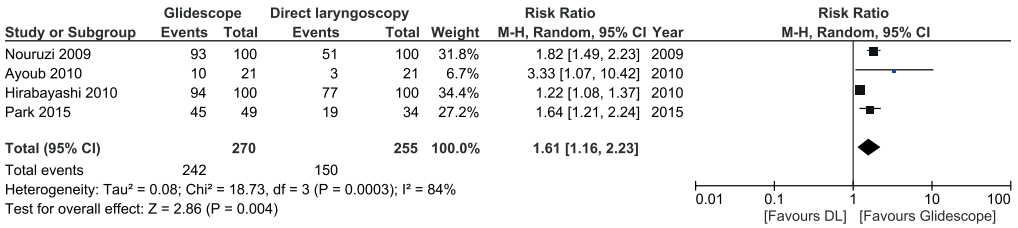

Figure 3.5 Risk ratios (RR) of tracheal intubation with first-pass success in clinical trials comparing direct laryngoscopy to Glidescope® videolaryngoscopy. The DerSimonian and Laird random effects method was used to determine the pooled estimate. Individual study point estimates of the RR are shown by the squares. The 95% CI of the point estimate are shown by the horizontal lines. The vertical line represents an RR of 1.00 corresponding with no difference between direct laryngoscopy and Glidescope® videolaryngoscopy; DL = direct laryngoscopy

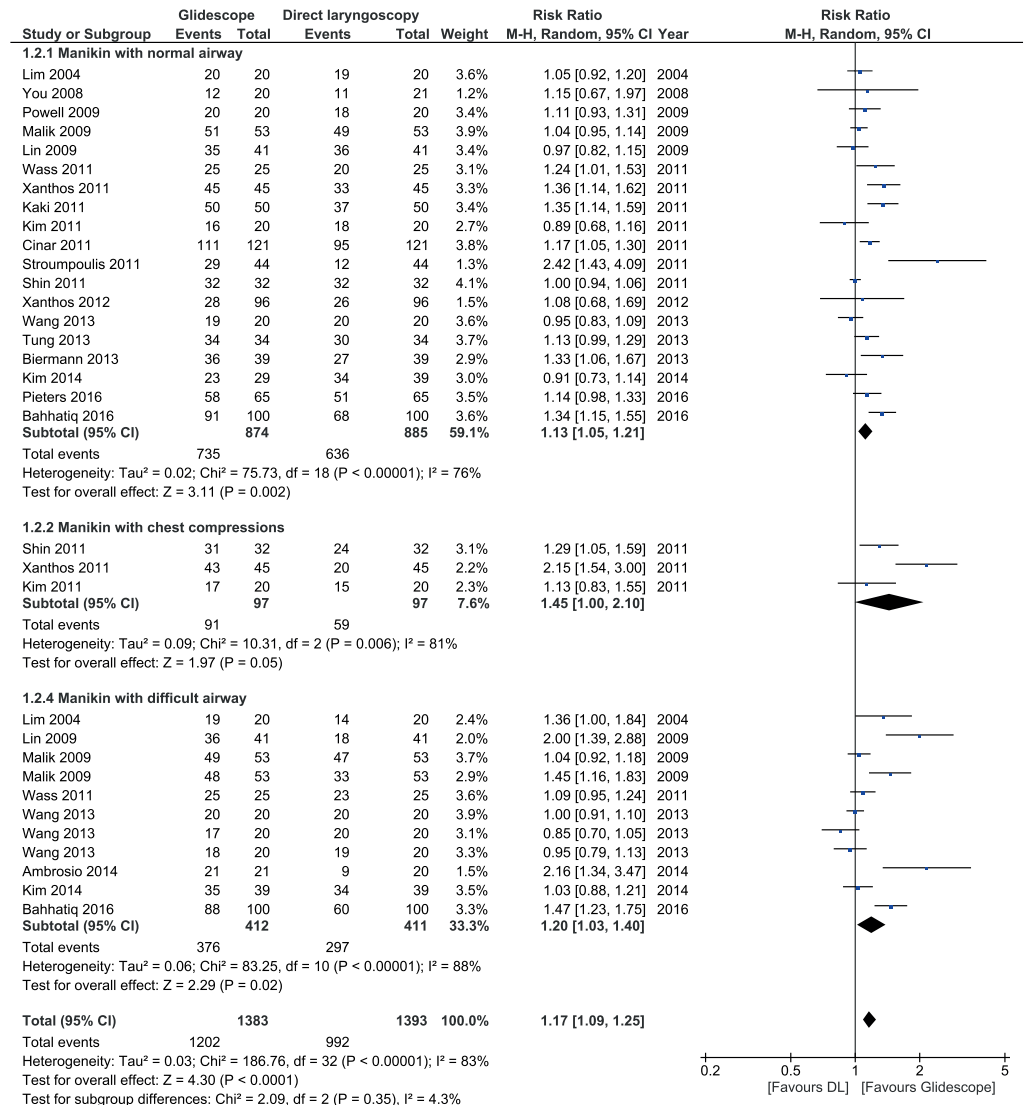

Figure 3.6 Risk ratios (RR) of tracheal intubation with first-pass success in manikin trials comparing direct laryngoscopy to Glidescope® videolaryngoscopy. The DerSimonian and Laird random effects method was used to determine the pooled estimate. Individual study point estimates of the RR are shown by the squares. The 95% CI of the point estimate are shown by the horizontal lines. The vertical line represents an RR of 1.00 corresponding with no difference between direct laryngoscopy and Glidescope® videolaryngoscopy; DL = direct laryngoscopy

Time to Intubation

The time required to intubate was available in all included studies (Table 3.2). The forest plots in Figure 3.7 and Figure 3.8 represent the clinical and manikin trials, respectively. The pooled MD across the clinical trials favors the Glidescope® videolaryngoscope (MD 17.04 sec., 95% CI 8.51, 25.57 sec.; P < 0.0001). There was substantial between-study heterogeneity and the overall certainty of evidence was graded as moderate. Of the manikin trials, only the subgroup analyses with the difficult airway scenarios showed a significant difference in mean intubation time in favor of the Glidescope® videolaryngoscope (MD 12.51 sec, 95% CI 1.46, 23.56 sec.; P = 0.03). There was considerable between-study heterogeneity. The other subgroups showed no significant difference in intubation times. The overall certainty of evidence was rated as very low for the manikin trials, because of inconsistency and indirectness (see Appendix 3.D for GRADE table).

	Successful first intubation attempt			**Time to intubation (sec.) +/- SD**		
First author, year	**Direct laryngoscopy**	**Glidescope®**	**P**	**Direct laryngoscopy**	**Glidescope®**	**P**
Clinical studies						
Nouruzi, 2009 [38]	51/100 (51.0%)	93/100 (93.0%)	P < 0.001	89.0 +/- 35.0	63.0 +/- 30.0	P < 0.01
Ayoub, 2010 [36]	3/21 (14.3%)	10/21 (47.6%)	P = 0.04	70.7 +/- 7.50	59.3 +/- 4.4	P = 0.006
Hirabayashi, 2010 [37]	77/100 (77.0%)	94/100 (94.0%)	P = 0.03	72.0 +/- 47.0	64.0 +/- 33.0	P = 0.13
Park, 2015 [39]	19/34 (55.9%)	45/49 (91.8%)	P < 0.001	62.0 +/-40.0	37.0 +/- 19.3	P < 0.001
Manikin with normal airway						
Lim, 2004 [16]	19/20 (95.0%)	20/20 (100%)	P = 1	14.5 +/- 5.20	24.5 +/- 18.1	P = 0.02
You, 2009 [20]	11/21 (55.0%)	12/20 (57.0%)	P > 0.05	30.5 +/- 18.5	26.6 +/- 14.3	P = 0.35
Lin, 2009 [17]	36/41 (87.8%)	35/41 (85.3%)	P = 1	40.6 +/- 5.30	61.4 +/- 4.80	P < 0.001
Malik, 2009* [18]	49/53 (92.4%)	51/53 (96.2%)	P = 0.68	30.7 +/-16.5	25.1 +/- 15.7	P = 0.08
Powell, 2009 [19]	18/20 (90.0%)	20/20 (100%)	P = 0.49	20.8 +/- 6.40	26.2 +/- 11.1	P = 0.07
Cinar, 2011 [21]	95/121 (78.5%)	111/121 (91.7%)	P = 0.006	25.1 +/- 14.0	22.6 +/- 10.0	P = 0.11
Kaki, 2011 [22]	37/50 (74.0%)	50/50 (100%)	P < 0.001	60.3 +/- 8.40	18.7 +/- 0.40	P < 0.001
Kim, 2011 [23]	18/20 (90.0%)	16/20 (80.0%)	P = 0.15	18.3 +/- 5.50	21.4 +/- 5.60	P = 0.24
Shin, 2011 [25]	31/32 (96.9%)	32/32 (100%)	P = 0.36	16.5 +/- 6.70	14.3 +/- 3.90	P = 0.03
Stroumpoulis, 2011 [26]	12/44 (27.3%)	29/44 (65.9%)	P < 0.001	17.0 +/- 4.00	16.0 +/- 5.00	P > 0.05
Wass, 2011 [24]	20/25 (80.0%)	25/25 (100%)	P = 0.05	46.0 +/- 43.0	50.0 +/- 33.1	P = 0.71
Xanthos, 2011 [27]	33/45 (73.3%)	45/45 (100%)	P = 0.001	12.0 +/- 10.4	13.0 +/- 9.60	P = 0.64
Xanthos, 2012 [28]	26/96 (27.1%)	28/96 (29.1%)	P = 0.87	21.5 +/- 4.80	21.7 +/- 5.50	P = 0.79
Biermann, 2013 [29]	27/39 (69.2%)	36/39 (92.3%)	P = 0.02	39.0 +/- 12.0	75.0 +/- 40.0	P < 0.001
Tung, 2013 [30]	30/34 (88.2%)	34/34 (100%)	P = 0.11	17.4 +/- 6.60	17.7 +/- 4.50	P = 0.45
Wang, 2013 [31]	20/20 (100%)	19/20 (95.0%)	P = 1	20.5 +/- 8.50	21.0 +/- 9.60	P = 0.86
Kim, 2014 [33]	34/39 (87.1%)	23/29 (58.9%)	P = 0.008	33.2 +/-18.0	26.6 +/- 9.50	P = 0.18
Bahhatiq, 2016 [34]	68/100 (68.0%)	91/100 (91.0%)	P < 0.001	31.5 +/- 26.0	22.0 +/- 17.8	P < 0.001
Pieters, 2016 [35]	51/65 (78.4%)	58/65 (89.2%)	P = 0.1	29.3 +/- 12.5	26.0 +/- 25.2	P = 0.35
Manikin with chest compressions						
Shin, 2011 [25]	24/32 (75.0%)	31/32 (96.9%)	P = 0.01	30.1 +/- 26.3	19.2 +/- 11.8	P = 0.006
Xanthos, 2011 [27]	20/45 (44.4%)	43/45 (95.6%)	P < 0.001	15.0 +/- 13.3	13.0 +/- 9.60	P = 0.42
Manikin with chest compressions on the floor						
Kim, 2011 [23]	15/20 (75.0%)	17/20 (85.0%)	P = 0.69	24.1 +/- 10.4	24.1 +/- 8.90	P = 0.99
Manikin with CL grade 3						
Lim, 2004 [16]	14/20 (70.0%)	19/20 (95.0%)	P = 0.09	156 +/- 241	30.5 +/- 52.8	P < 0.001
Lin, 2009 [17]	18/41 (43.9%)	36/41 (87.8%)	P < 0.001	98.7 +/- 10.2	64.3 +/- 6.50	P < 0.001
Manikin with cervical immobilisation						
Malik, 2009 [18]	47/53 (88.7%)	49/53 (92.5%)	P = 0.74	38.0 +/- 14.8	23.0 +/- 14.8	P < 0.001
Wang, 2013 [31]	20/20 (100%)	17/20 (85.0%)	P = 0.23	26.5 +/- 5.90	31.5 +/- 12.6	P = 0.12
Kim, 2014 [33]	34/39 (87.1%)	35/39 (89.7%)	P = 0.72	26.1 +/- 9.60	23.8 +/- 9.60	P = 0.49
Bahhatiq, 2016 [34]	60/100 (60.0%)	88/100 (88.0%)	P < 0.001	40.0 +/- 19.3	21.0 +/- 14.8	P < 0.001
Manikin with cervical immobilisation on the floor						
Wang, 2013 [31]	19/20 (95.0%)	18/20 (90.0%)	P = 1	26.0 +/- 7.80	36.0 +/- 8.50	P < 0.001
Manikin with cervical immobilisation and CL grade 3						
Ambrosio, 2014 [32]	9 / 19 (47.7%)	21 / 21 (100%)	P < 0.001	69.0 +/- 36.1	23.1 +/- 11.0	P < 0.001
Manikin with pharyngeal obstruction						
Malik, 2009 [18]	33/53 (62.3%)	48/53 (90.6%)	P = 0.001	38.0 +/- 16.3	21.0 +/- 11.1	P < 0.001
Wass, 2011 [24]	23/25 (92.0%)	25/25 (100%)	P = 0.49	34.0 +/- 23.0	38.0 +/- 30.4	P = 0.60
Manikin on the floor						
Wang, 2013 [31]	20/20 (100%)	20/20 (100%)	P = 1	24.0 +/- 6.70	29.0 +/- 6.30	P = 0.05

Table 3.2 Outcomes of clinical and manikin trials comparing Glidescope® videolaryngoscope to direct laryngoscopy. We created separate rows in the table for several studies as they used different scenarios in the same study. *) The data in this row include only the first scenario with normal airway in this study. (CL = Cormack-Lehane, sec. = seconds, SD = standard deviation).

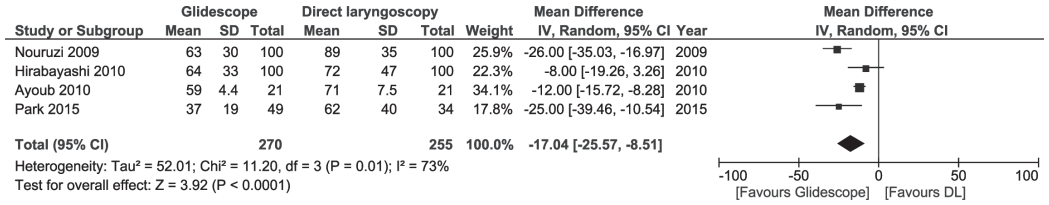

Figure 3.7 Mean difference in time to tracheal intubation (seconds) of direct laryngoscopy versus Glidescope videolaryngoscopy in clinical trials. The DerSimonian and Laird random effects method was used to determine the pooled estimate. Individual study point estimates of the RR are shown by the squares. The 95% CI of the point estimate are shown by the horizontal lines. The vertical line represents an RR of 1.00 corresponding with no difference between direct laryngoscopy and Glidescope® videolaryngoscopy; DL = direct laryngoscopy

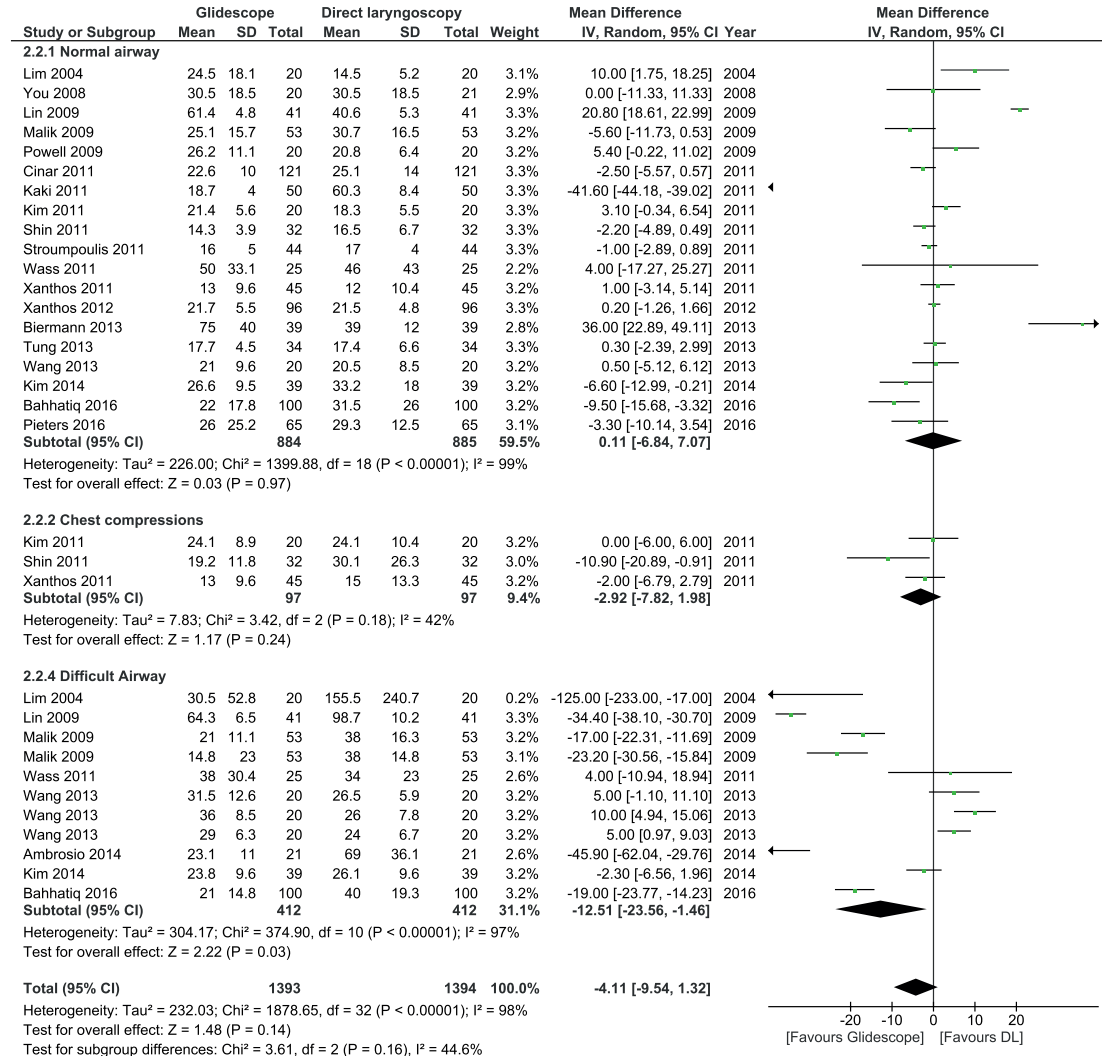

Figure 3.8 Mean difference (MD) in time to intubation (in seconds) in manikin trials comparing Glidescope® videolaryngoscope to direct laryngoscopy. The DerSimonian and Laird random effects method was used to determine the pooled estimate. Individual study point estimates of the RR are shown by the squares. The 95% CI of the point estimate are shown by the horizontal lines. The vertical line represents an RR of 1.00 corresponding with no difference betwee direct laryngoscopy and Glidescope® videolaryngoscopy; DL = direct laryngoscopy

Intubation during Cardiopulmonary Resuscitation

We included one clinical study performed in patients during cardiac arrest [39]. The first pass success rate of the Glidescope® group was higher than that of the DL group (91.8% versus 55.9%, P < 0.001). It took less time to complete tracheal intubation with Glidescope® than with DL (median time 37 vs. 62 sec.; P < 0.001). The median duration of chest compression interruptions during CPR was reduced from seven seconds (IQR 3-16 sec.) with direct laryngoscopy to zero seconds (IQR 0-0 sec.) with Glidescope® videolaryngoscopy.

Three manikin studies reported on tracheal intubation during chest compressions [23,25,27]. The RR of successful intubation with the Glidescope® was 1.45 (95% CI 1.00, 2.10; P = 0.05). There was substantial between-study heterogeneity. Time required for intubation was not significantly different. All three manikin studies used scenarios with uninterrupted chest compressions, so the difference in duration of chest compression interruptions was not an applicable outcome measure.

DISCUSSION

This systematic review and meta-analysis of the literature on tracheal intubation using direct laryngoscopy versus videolaryngoscopy with the Glidescope® videolaryngoscope by clinicians with limited intubation experience showed a significant improvement in first-pass success rate in both clinical and manikin randomized trials, a shorter time needed for intubation in clinical trials as well as in manikin trials with difficult airway scenarios. The only clinical trial in the CPR setting showed a positive effect on first-pass success rate and a reduction in chest compression interruptions when using the Glidescope® videolaryngoscope [39]. The positive effect on first-pass success was also seen in manikin studies with a CPR setting, although in lesser amount. Time needed for intubation during CPR was not longer for the Glidescope® videolaryngoscope in these manikin trials [23,25,27].

Many of the analyzed groups showed significant between-study heterogeneity. This could be a limitation for the interpretation of our results. Differences in the definition of successful and failed intubation existed in the included studies. Failed intubation was defined as intervention by senior staff and/or actual misplacement of the tube. Another explanation could be the difference in initial skill training in the clinicians. Nearly all studies used different approaches to train tracheal intubation clinicians. All manikin studies used a training varying from five minutes to one hour, the clinical studies a training of ten minutes to eight hours. This could also explain differences in success rates between studies and thus significant between-study heterogeneity.

Several limitations of our systematic review should be highlighted. First of all, the number of clinical studies is limited. Furthermore, in our analysis of the manikin studies, subgroups with different scenarios were included. Except for the manikin with a normal airway, all subgroups consisted of no more than three studies. To overcome these small number of studies in each subgroup, we pooled the manikin studies employing difficult airway scenarios as an entire group. Random effects model was employed. As a result, the pooled estimates are more conservative when significant between-study heterogeneity exists [40]. Our systematic review included both clinical and simulation trials with the use of manikins. A manikin can simulate reality only to a limited degree. Despite the resemblances, even the most advanced high fidelity simulation manikins are unable to fully recreate the feel and finer aspects of human airway anatomy [41]. Especially for clinicians with limited experience, intubation during prehospital resuscitation in an out-of-hospital cardiac arrest airway management can be far more challenging than in manikins. This might explain why clinical trials show a stronger effect in favor of the Glidescope® videolaryngoscopy. More (randomized) clinical studies are needed to confirm the effects, especially in the setting of prehospital CPR. Finally, our approach to focus on one type of videolaryngoscope lead to uncertainty whether or not the results are generalizable to other types of videolaryngoscopes.

Our findings provide specific insight in tracheal intubation with the Glidescope® videolaryngoscopy by clinicians with limited experience. Previous reviews often include a mix of experience levels and multiple types of videolaryngoscopes [42,43]. Griesdale et al. [43] published a systematic review comparing direct laryngoscopy with Glidescope® videolaryngoscopy. However, the authors included all studies, regardless of the level of experience of the clinicians. The increased success rate with the Glidescope® found in our review is not seen among experienced intubators in the systematic review by Griesdale et al. [43]. In their systematic review, two studies focused on inexperienced personnel; one of those is also included in our systematic review [38], the other employed nasotracheal intubation which was one of the exclusion criteria in our study [44]. Videolaryngoscopy was also shown to improve first-pass success rate in emergency intubations in less experienced clinicians in a recent systematic review by Arulkumaran et al. [42]. However, various types of videolaryngoscopes and different operator experience levels for tracheal intubation were included in this review.

The guidelines by the International Liaison Committee on Resuscitation and European Resuscitation Council recommend that tracheal intubation should only be performed by rescuers with a high intubation success rate [45,46]. However, clinicians with limited intubation experience can still be confronted with patients in whom bag-valve-mask ventilation and supraglottic airway device placement are not successful. Especially in the prehospital, remote or military setting, experienced airway clinicians may take an unacceptable long time to get to the patient. Tracheal intubation is a complex and high-risk procedure, especially when performed by clinicians with limited experience. Large studies on airway management during out-of-hospital cardiac arrest (OHCA) show first-pass success rates of 60-70% [47,48]. Multiple intubation attempts can distract EMS clinicians from ensuring high-quality chest compressions and treating the cause of the arrest. This might be the explanation of a recent study showing that multiple intubation attempts are associated with a decrease in survival [49]. It therefore seems important that efforts should be made to improve tracheal intubation first-pass success rate. When clinicians with limited intubation experience are confronted with a patient requiring tracheal intubation, the use of the Glidescope helps to improve first-pass success rate, time to intubation, and CPR quality. Videolaryngoscopy is also the intubation technique to be considered in (suspected) COVID-19 patients requiring tracheal intubation [1]. The current European Resuscitation Council Guidelines state that the rescuers choice on the use of videolaryngoscopy during CPR should be "according to local protocols and rescuer experience" [46]. With our review, we hope to provide the evidence needed to consider the use of the Glidescope® videolaryngoscope, particularly during CPR.

CONCLUSIONS

Tracheal intubation performed by clinicians with limited intubation experience (< 10 intubations per year) using the Glidescope® videolaryngoscope has a higher first-pass success rate and shorter time to intubation, when compared to direct laryngoscopy. Furthermore, intubation using the Glidescope® videolaryngoscope helps to minimize chest compression interruption during CPR. Although the number of clinical studies is limited, the use of the Glidescope® videolaryngoscope by clinicians with limited experience in tracheal intubation has important advantages when other initial airway techniques have failed. In particular in the setting of prehospital advanced life support, further clinical studies are needed to confirm these findings and determine the effects on outcome in out-of-hospital cardiac arrest.

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Citation

Kamil Wojciechowicz, Hans van Schuppen. Direct laryngoscopy vs glidescope video-laryngoscopy by the inexperienced. PROSPERO 2018 CRD42018096251 Available from: https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42018096251

Review question
Succesful intubation by inexperienced intubators using the glidescope videolaryngoscope compared to direct laryngoscopy in the prehospital setting

Searches
MEDLINE/PubMed and Embase was systematically searched (1966 to February 13th, 2018)

Types of study to be included
Randomized controlled trials performed both in humans as well as manikins

Condition or domain being studied
Prehospital patients in need to be intubated

Participants/population
Inexperienced intubators = less than 10 intubations in their career

Intervention(s), exposure(s)
Glidescope videolaryngoscope

Comparator(s)/control
Direct laryngoscopy

Context
comparison of direct laryngoscopy to Glidescope video-laryngoscopy

comparison of direct laryngoscopy to Glidescope Ranger video-laryngoscopy

made reference to either using the Glidescope video-laryngoscope or the Glidescope Ranger video-laryngoscope by inexperienced personnel

Main outcome(s)
successful first-attempt intubation

Additional outcome(s)
time to intubation

Data extraction (selection and coding)
An article was included if they 1) were randomized or quasi-randomized controlled trials, 2) compared direct laryngoscopy to Glidescope video-laryngoscopy, 3) addressed adult patients, 4) contained any outcome of interest (successful first-attempt intubation and/or time to intubation)

The article was excluded if 1) the operator was experienced in intubation, 2) nasotracheal intubation was performed. Disagreement was resolved by discussion and arbitrated if necessary by a third independent researcher.

Risk of bias (quality) assessment
Risk of bias will be assessed using the cochrane revmanager risk of bias tool in which all included articles will be graded between either "low" or "high" and in the case of insufficient information "unclear"

Strategy for data synthesis

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a quantitative synthesis will be used with relative risk (RR) as the summary measure for the successful first intubation outcome and the mean difference (MD), in seconds, as the summary measure for time to intubate. The random effects method of Mantel-Haenszel was used to generate a pooled RR or WMD across studies. We assessed statistical heterogeneity using Cochran's Q statistic (with P<0,05 considered significant) and expressed the quantity using the I² statistic and 95% confidence interval (CI). We followed the cochrane handbook classification for I² where 0-40% represents "might not be important heterogeneity," 30-60% "may represent moderate heterogeneity," 50-90% "may represent substantial heterogeneity" and 75-100%

Analysis of subgroups or subsets
The data for intubations on patients will be analyzed separate from the data extracted from studies performed on manikins. There will also be subgroups for "difficult" intubations e.g. cormack-lehane 3, oropharyngeal swelling and or neck stabilization during intubation

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Mr Kamil Wojciechowicz. AMC
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Type and method of review
Intervention

Anticipated or actual start date
18 August 2017

Anticipated completion date
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Funding sources/sponsors
none

Conflicts of interest

Language
English

Country
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Review Ongoing

Subject index terms status
Subject indexing assigned by CRD

Subject index terms
Humans; Intubation, Intratracheal; Laryngoscopes; Laryngoscopy

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10 May 2018

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Details of any existing review of the same topic by the same authors
non

Stage of review at time of this submission

Stage	Started	Completed
Preliminary searches	Yes	No
Piloting of the study selection process	Yes	No
Formal screening of search results against eligibility criteria	Yes	No
Data extraction	Yes	No
Risk of bias (quality) assessment	Yes	No
Data analysis	Yes	No

The record owner confirms that the information they have supplied for this submission is accurate and complete and they understand that deliberate provision of inaccurate information or omission of data may be construed as scientific misconduct.
The record owner confirms that they will update the status of the review when it is completed and will add publication details in due course.

Versions
23 July 2018

SUPPLEMENTAL MATERIAL 3 – REFERENCES OF EXCLUDED ARTICLES [1-55]

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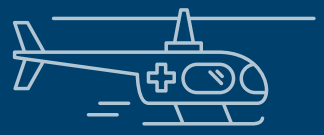
Author(s): *Hans van S chuppen, Kamil Wojciechowicz , Markus Hollmann, Benedikt Preckel*
Question: *Glidescope® videolaryngoscopy compared to direct laryngoscopy for endotracheal intubation by providers with limited intubation experience during advanced life support*
Setting: *cardiopulmonary resuscitation*

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Glidescope® videolaryngoscopy	direct laryngoscopy	Relative (95% CI)	Absolute (95% CI)		
First-pass success rate - clinical studies												
4	randomised trials	not serious[a]	serious[b]	not serious	not serious	none	242/270 (89.6%)	150/255 (58.8%)	**RR 1.61** (1.16 to 2.23)	**359 more per 1.000** (from 94 more to 724 more)	⨁⨁⨁◯ Moderate	CRITICAL
First-pass success rate - overall results of all manikin studies												
20	randomised trials	not serious[a]	serious[b]	serious[c]	not serious	none	1202/1383 (86.9%)	992/1393 (71.2%)	**RR 1.17** (1.09 to 1.25)	**121 more per 1.000** (from 64 more to 178 more)	⨁⨁◯◯ Low	CRITICAL
First-pass success rate - manikin studies with normal airway scenario												
19	randomised trials	not serious[a]	serious[b]	serious[c]	not serious	none	735/874 (84.1%)	636/885 (71.9%)	**RR 1.13** (1.05 to 1.21)	**93 more per 1.000** (from 36 more to 151 more)	⨁⨁◯◯ Low	CRITICAL
First-pass success rate - manikin studies with chest compressions												
3	randomised trials	not serious[a]	serious[b]	serious[c]	not serious	none	91/97 (93.8%)	59/97 (60.8%)	**RR 1.45** (1.00 to 2.10)	**274 more per 1.000** (from 0 fewer to 669 more)	⨁⨁◯◯ Low	CRITICAL
First-pass success rate - manikin studies with difficult airway scenario												
8	randomised trials	not serious[a]	serious[b]	serious[c]	not serious	none	376/412 (91.3%)	297/411 (72.3%)	**RR 1.20** (1.03 to 1.40)	**145 more per 1.000** (from 22 more to 289 more)	⨁⨁◯◯ Low	CRITICAL
Mean intubation times - clinical studies												
4	randomised trials	not serious[a]	serious[b]	not serious	not serious	none	270	255	-	MD **17.04 lower** (25.57 lower to 8.51 lower)	⨁⨁⨁◯ Moderate	CRITICAL
Mean intubation times - overall results of all manikin studies												
20	randomised trials	not serious[a]	very serious[d]	serious[c]	not serious	none	1393	1394	-	MD **4.11 lower** (9.54 lower to 1.32 higher)	⨁◯◯◯ Very low	CRITICAL
Mean intubation times - manikin studies with normal airway scenario												
19	randomised trials	not serious[a]	serious[d]	serious[c]	not serious	none	884	885	-	MD **0.11 higher** (6.84 lower to 7.07 higher)	⨁⨁◯◯ Low	CRITICAL
Mean intubation times - manikin studies with chest compressions												
3	randomised trials	not serious[a]	not serious	serious[c]	not serious	none	97	97	-	MD **2.92 lower** (7.82 lower to 1.98 higher)	⨁⨁⨁◯ Moderate	CRITICAL
Mean intubation times - manikin studies with difficult airway scenario												
8	randomised trials	not serious[a]	very serious[d]	serious[c]	not serious	none	412	412	-	MD **12.51 lower** (23.56 lower to 1.46 lower)	⨁◯◯◯ Very low	CRITICAL



Chapter 4

Comparing the QuickTrach® and Ventrain® in a Simulated 'Can't Intubate, Can't Oxygenate' Scenario *– a Randomized Controlled Trial*

PART I

Maik Berendsen
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Markus W. Hollmann

Submitted

ABSTRACT

Background

Emergency clinicians can encounter a 'can't intubate, can't oxygenate' (CICO) scenario, in which an emergency front-of-neck airway (eFONA) technique is indicated to achieve oxygenation. In the Netherlands, most ambulance services use either the QuickTrach® or the Ventrain® needle cricothyrotomy device. Here we report on a randomized controlled trial with a simulated CICO situation, to compare the QuickTrach® and the Ventrain® regarding the time needed to achieve oxygen insufflation.

Methods

After an airway course including the study devices, ambulance nurses were randomized to the QuickTrach® or the Ventrain® in a simulated CICO scenario with a porcine airway model in a manikin. The scenarios were recorded with video and prespecified events were timed. The porcine airway models were used only once. Afterwards an anatomical dissection of each model was done by a pathologist to determine complications.

Results

We were able to run 20 of the planned 58 scenarios. In these scenarios, eight participants were allocated to the QuickTrach® and 12 participants were allocated to the Ventrain®. The median time interval from decision to achieve oxygen insufflation was 182.5 seconds in the QuickTrach® group and 93 seconds in the Ventrain® group (p=0.23). In the QuickTrach® group one device was placed subcutaneously, in the Ventrain® group one cannula was placed in the esophagus. In the Ventrain® group, we observed two cases with a kink in the cannula and one cannula broke during the procedure. Participants rated the Ventrain® as easy to use more often than the QuickTrach®.

Conclusions

Although this RCT had to stop early, some valuable lessons could be learned from this study; Participating EMS clinicians valued the simulated CICO scenario as realistic and stressful, and the Ventrain® was found easier to use. Both devices showed unsuccessful attempts and complications, warranting improvement in design of the devices and training.

INTRODUCTION

Airway management is an essential part of initial treatment by emergency care providers. When the airway is obstructed and bag-valve-mask (BVM) ventilation, supraglottic airway device, and endotracheal intubation is not possible, a "can't intubate, can't oxygenate" (CICO) situation occurs [1]. The CICO situation is rare but clearly life threatening. It is also one of the most challenging clinical scenarios for Emergency Medical Services (EMS) clinicians. An alternative route for oxygenation must be created, by gaining rapid percutaneous access to the airway: the so called emergency Front-Of-Neck Airway (eFONA), also known as CICO rescue and formerly known as cricothyrotomy or cricothyroidotomy [1].

EFONA is a life-saving procedure, and can be performed by needle, scalpel, or device techniques [2,3]. Although scalpel techniques are often regarded as superior and recommended, not all EMS clinicians are trained or legally allowed to use these techniques [3,4]. Moreover, EMS clinicians who are trained in surgical eFONA techniques, can experience insufficient self-confidence to provide this rare and invasive procedure [5]. Therefore, fast and effective techniques that can be easily trained and used by a wide range of EMS clinicians are essential. In the Netherlands, the Rusch® QuickTrach® I Emergency Cricothyrotomy Kit is the eFONA device most frequently used by EMS. Recently, the Ventrain® Emergency Kit became commercially available and was adopted in a few EMS regions. There are no comparative data on the use of these devices by EMS clinicians in a realistic setting. Moreover, complication rates of these airway devices have not been compared.

The primary objective of this study was to compare the success rate and time needed from eFONA decision to oxygen insufflation of the QuickTrach® and Ventrain® used by Dutch ambulance nurses in a simulated adult CICO situation. Secondary objectives are complication rates of the use of these devices and user experiences. We hypothesized that the Ventrain® has a higher success rate and shorter time needed to achieve oxygen insufflation than the QuickTrach®. The primary research question of this study was: In an adult CICO situation in the prehospital setting, does the QuickTrach® or the Ventrain® have the highest chance of first-pass success, and shortest time to oxygen insufflation?

METHODS

Setting

In the Netherlands, emergency prehospital care is provided by advanced life support level ambulances, staffed by ambulance nurses. These registered nurses have a previous relevant specialty training in emergency care, intensive care, coronary care or anesthesia. In addition, these specialized nurses follow a formal ambulance training program of seven months, to become registered ambulance nurses. Although there are national ambulance care protocols, equipment can vary per EMS region 6. Ambulance nurses are trained to use both basic and advanced airway management techniques, including supraglottic airway devices and endotracheal intubation (without the use of anesthetics or relaxants). In critical patients, Helicopter Emergency Medical Services (HEMS), mainly staffed by anesthesiologists, can provide additional treatment on the scene 6-8. Ambulance nurses can however be confronted with a CICO situation before HEMS has arrived. Therefore, they need to be able to perform an eFONA immediately when needed. Ambulance nurses are not trained in scalpel cricothyroidotomy for

eFONA. The majority of Dutch EMS are equipped with the QuickTrach®, but various other devices are also used. The Ventrain® has gained increasing interest by Dutch EMS regions.

Devices

The Rusch® QuickTrach® I Emergency Cricothyrotomy Kit (VBM Medizintechnik GmbH) consists of a large-bore over-the-needle uncuffed cannula with an internal diameter of 4.0 mm, length of 42 mm and a universal 15 mm breathing circuit connector (Figure 4.1) [9,10]. After percutaneous placement of the needle in the airway, a safety clip is removed, the cannula is advanced in the airway over the needle, the needle is removed and the BVM is connected to the device to ventilate the patient [11].

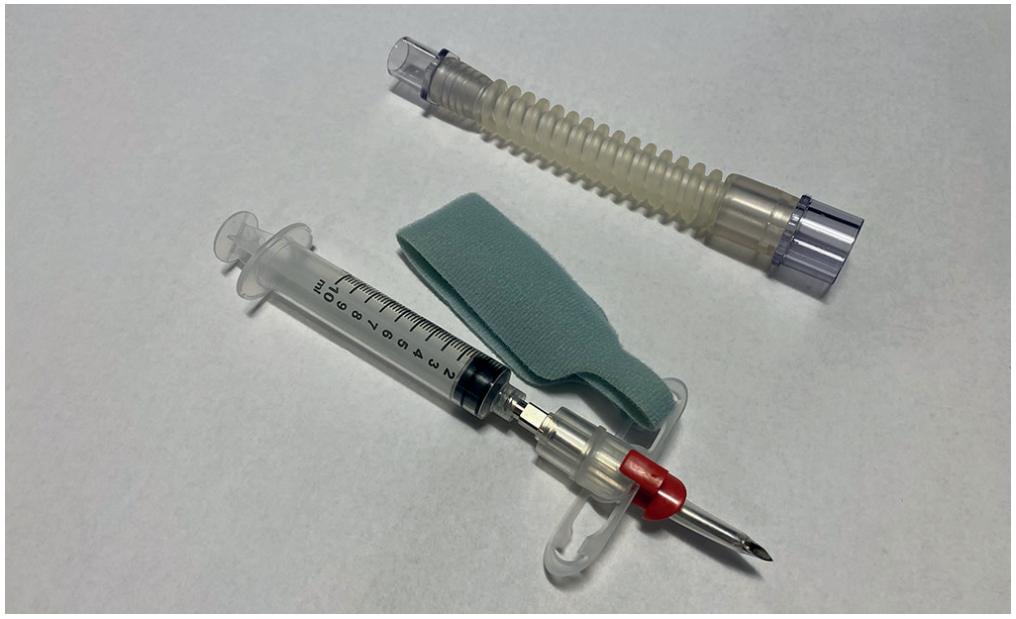

Figure 4.1 The Rusch® QuickTrach® I Emergency Cricothyrotomy Kit.

The Ventrain® Emergency Kit (Ventinova Medical B.V.) consists of the Cricath® cricothyrotomy cannula and the Ventrain® ventilation device (Figure 4.2). The Cricath® is a flexible over-the-needle uncuffed cannula with an internal diameter of 2.0 mm, length of 70 mm and a female Luer-lock connector [12]. The Ventrain® is a flow-controlled ventilation system and can provide both insufflation and active expiration, by using Bernoulli's principle [13,14]. This enables the Ventrain® to ventilate through small-lumen cannulas with minute volumes up to 7 L/min [13,15]. To use the Ventrain®, it needs to be connected to an oxygen source with a minimal flow of 15 L/min, and to the in-situ Cricath® on the patient side with a Luer-lock connection [16].

The above-mentioned kits will be referred to as QuickTrach® and Ventrain®.

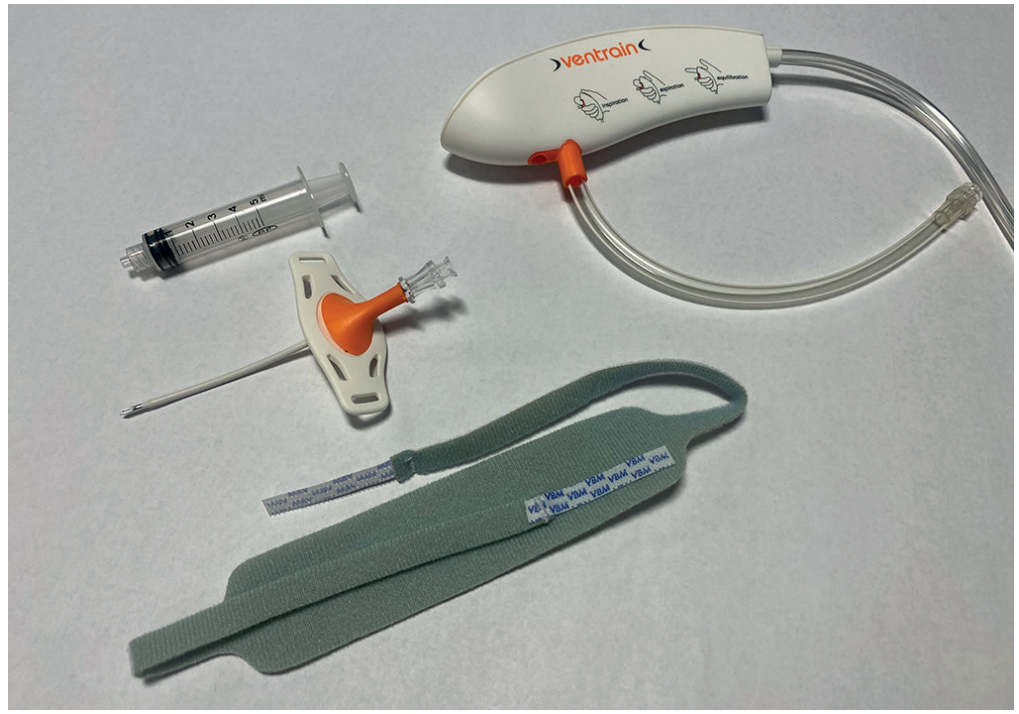

Figure 4.2 The Ventrain® Emergency Kit

Study Design and Population

This is a randomized controlled trial employing a porcine airway model integrated in a resuscitation manikin (Fig. 4.3). A simulated CICO situation was created to create the stressful conditions in which devices have to be used. Either the QuickTrach® and Ventrain® were used by ambulance nurses to compare success rate, time needed for the procedure and user experience. The Medical Ethical Committee approved the trial including the use of the animal airway model, and determined that the Medical Research Involving Human Subjects Act did not apply (waiver number W16_372 #16.437). The trial was registered in the Netherlands Trial Registry (Trial NL7333). The CONSORT checklist is added as appendix (Appendix 4.A) and the extension of simulation research was followed [17,18].

Participants in the study were Dutch ambulance nurses. The only exclusion criterion was the performance of an eFONA during the past year. Invitations were sent to three Dutch ambulance regions between 23 September 2018 and 8 October 2018, to participate in an airway management study, including an airway workshop and one simulation scenario. The specific goal of the scenario was not shared with the participants. After registration and inclusion, written informed consent was obtained. A random sequence of the devices was made using an online randomization tool allocating the QuickTrach® or the Ventrain® in a 1:1 ratio. Participants were unaware of the specific research objective and their allocation beforehand.

Training and simulated scenari

The study was held at the experimental surgical laboratory of our university medical center. In order to assure that all participants had the right skills level to use the specific eFONA equipment before the scenario, the ambulance nurses first followed a one-hour airway course. This included two skills stations with specific instructions by the company representatives of the QuickTrach® and the Ventrain®. This way, all participants were taught how to use the specific device as intended by the manufacturer. Immediately after the course, the participants were directed to the simulated CICO scenario individually. The allocated device was given at the moment eFONA had to be performed during the scenario.

Airway Model

A porcine model was used and integrated in a resuscitation manikin to achieve a realistic setting during the scenario (Figure 4.3). The porcine tissues were obtained from pigs of either sex, after being used outside the context of this trial. The porcine models had similar anatomical characteristics as humans: the measured diameter of the trachea of the porcine model was within the range of the estimated trachea diameter in humans (15 to 25 mm) [19]. In our model, the porcine larynx and trachea was covered with porcine subcutaneous tissue and skin. This model was integrated in the neck region of a standard Basic Life Support training manikin (AmbuMan® Basic, Ambu). Prior to the trial, the model was tested and improved various times by multiple experts to ensure that a realistic and model was achieved. Each participant performed the scenario on a fresh and unused porcine model, labelled with a specific number.

Scenario

A realistic scenario was created at the animal research laboratory in the Academic Medical Center in Amsterdam, to confront the participants with a clear CICO scenario in which an eFONA had to be performed (Figure 4.3, Appendix 4.B). The ambulance nurses were dressed up in their uniforms and wore original equipment and we made use of an advanced defibrillator simulator including a decreasing tone of the pulse oximeter corresponding with the desaturation (ALSi, Secta Medical). A room was decorated to simulate a dinner setting and the resuscitation manikin was face painted as if it was cyanotic. In this scenario, the participating ambulance nurse arrives on scene and finds a cyanotic patient with an occluded airway due to aspiration of a foreign body. A second ambulance nurse (actor with EMS experience) who arrived on the scene earlier is providing BVM ventilations and provides a short status update, stating that the patient choked in a piece of steak. Multiple attempts to remove it were unsuccessful, making both supraglottic airway device placement and endotracheal intubation impossible. Only very limited oxygen insufflation is possible by employing BVM with manual airway management, but oxygenation is becoming worse. It is clearly visible that the airway is occluded with remains of food, making airway instrumentation impossible through the oral or nasal route. A simulation monitor was already attached to the patient with ECG and pulse oximetry visible and was used with a standard preprogrammed scenario; From the start of the scenario the oxygen saturation drops from 80% to 50%, and simultaneously the patient becomes bradycardic, in a two-minute period, after which these vital signs stayed the same. When the ambulance nurse decided to perform eFONA, they were provided with either the QuickTrach® or the Ventrain®, depending on the randomization. The eFONA equipment was given in original package. A new device was used for every scenario. The scenario stopped and the procedure ended at the moment when the ambulance nurse insufflated oxygen through the device without resistance.

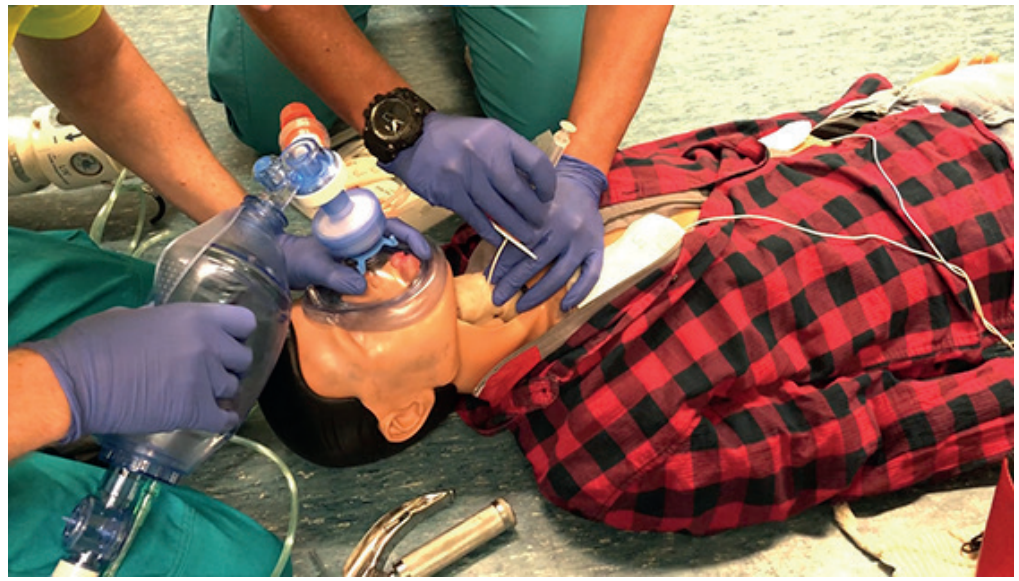

Figure 4.3 Study participant performing emergency front-of-neck access with the use of the Ventrain® Emergency Kit

Data Collection

Two cameras recorded the scenario; A camera recorded overview images of the scenario whilst a second (handheld) camera was used to register a detailed video of the procedure (Appendix 4.C). After the scenario, the exact times of the following prespecified events were registered, based on the video recordings:

A. Start of the scenario (participant entering the room)
B. Decision to perform eFONA (pronouncing eFONA decision and/or asking for eFONA device)
C. Start procedure (device needle touches the skin)
D. Aspiration of air (with syringe on the device)
E. Oxygen insufflation (with either self-inflating bag or Ventrain®)

After timing of these events, relevant time intervals were calculated (Figure 4.4). The time interval from the decision to perform eFONA to oxygen insufflation was the primary outcome.

After the scenario, the porcine cervical model was removed from the manikin and examined macroscopically in order to determine whether the cannula was correctly placed in the trachea. After the scenario ended, the porcine model with the device in situ was collected in a plastic bag, labelled, and listed. Afterwards, the model was placed in a freezer at -88 degrees Celsius. The participants filled in a questionnaire immediately after the scenario regarding their experiences during the scenario, using numeric rating scales and Likert scales to determine aspects regarding their perception on the level of realism of the scenario, their stress level, and the use of the specific device (Appendix 4.D).

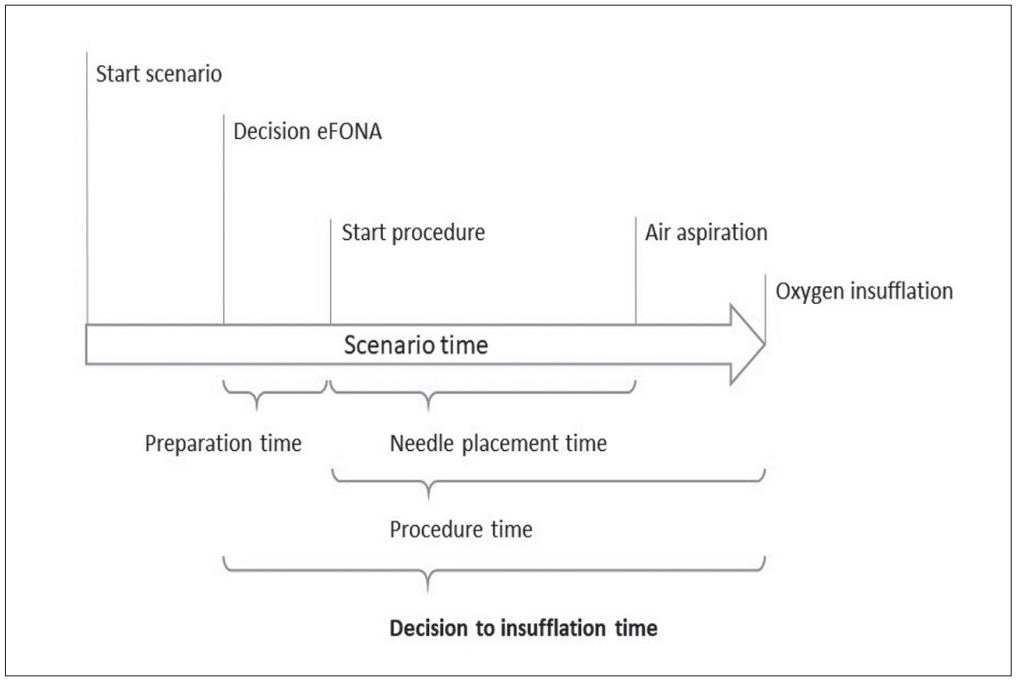

Figure 4.4 Events and intervals in the scenario

To identify complications the models were subjected to an anatomical dissection to by a forensic pathologist. For this, the models were slowly brought back to room temperature and the following features were examined: correct placement of the device; iatrogenic damage to the trachea, cricoid, thyroid and esophagus; and the presence of cartilage fractures. The examination was not blinded as the device remained in its position in the model to examine the position of the device.

Statistical Analysis and Sample Size Calculation

Using a power of 80%, an assumed standard deviation of 40 seconds and a two group T test with 5% two sided significance level; a sample size of 29 subjects per group will be required to detect a difference in mean procedural time of 30 seconds between the groups.
All data were recorded in a database in SPSS version 23 (Chicago, Ill). Data were tested on normality using the Shapiro Wilk test. Not all variables were normally distributed, so it was chosen to describe medians, interquartile ranges (IQR) and ranges. Students' T-test was used to compare means and in all cases a significance level with a p-value of 0.05 was used. Mann Whitney U tests were performed to test differences in medians of performance and complications between the QuickTrach® and Ventrain® groups.

RESULTS

While dealing with various challenges to organize this study and recruit participants, the laboratory where the study took place had to close unexpectedly (not related to this study). We had insufficient funds to move to another study site where the use of porcine models was allowed. Therefore, we were forced to terminate the study early, after the trials already included 20 participants.

Characteristics (n=20)	**Group A** (QuickTrach®)	**Group B** (Ventrain®)
Number of participants (n)	8	12
Gender (n)		
Male	4	6
Female	4	6
Healthcare work experience (median years)	20.7	22.7
EMS experience (median years)	6.7	11.4
Background specialty (n)		
Emergency nurse	0	2
Anesthetic technician	2	0
CCU nurse	1	0
Intensive care nurse	2	8
Combined	3	2
Time since previous CICO training		
< 1 year	2	5
1 year	2	4
1.5 year	0	1
≥ 2 years	4	2
Region (n)		
A	1	4
B	4	4
C	2	3
D	1	1

Table 4.1 Characteristics of study participants.
CCU: cardiac care unit, CICO: cannot intubate, cannot oxygenate, EMS: Emergency Medical Services, N: number.

None of the ambulance nurses who wanted to participate were excluded. One participant did not show up for the study. The baseline characteristics of the participants are listed in Table 4.1. The equipment of eFONA devices differs per ambulance region. In region A, the ambulance is equipped with a self-made device that consist of a long IV needle with oxygen tubing and a three-way connector. In region B, the ambulance is equipped with the Ventrain®. In region C and D the ambulance is equipped with the QuickTrach® device.

It was possible to register all prespecified events and calculate all relevant intervals for both groups (Table 4.2). The primary outcome is the median decision to insufflation time, which was 182.5 sec. for the QuickTrach® group and 93 sec. for the Ventrain® group (U=32.5, p=0.23). None of the predefined intervals showed a statistically significant difference. The duration of the decision to insufflation time and procedure time are given in boxplots for each group in

In the Ventrain® group, the connection between the hub and the Cricath® cannula broke during the scenario in one case. The scenario was paused, the cannula was repositioned as if it was not broken and participant was instructed to proceed. The time out of the scenario lasted for 28 seconds. The Cricath® was then placed correctly. Because the aim of this study was to determine the time needed to use the device, we subtracted the 28 seconds of the time-out from this case.

Time intervals (sec.)	**Group A** (QuickTrach®) (s)		**Group B** (Ventrain®) (s)		**P-value for difference in median** (Mann-Whitney U test)
N=20	8		12		
	Median (IQR)	Range	Median (IQR)	Range	
Time to eFONA decision (start scenario – eFONA decision)	32 (24-41.75)	20-46	28 (23.75-36.5)	22-46	*p*=0.64
Decision to insufflation time (eFONA decision – oxygen insufflation)	182.5 (108.25-234.5)	67-578	93 (73.75-206.75)	50-331	*p*=0.23
Preparation time (eFONA decision – start procedure)	36 (25.25-61.75)	21-79	36.5 (28.25-39.5)	21-80	*p*=0.97
Needle placement time (start procedure – air aspiration)	159.5 (22.5-250.75)	6-478	8 (4.25-123)	2-334	*p*=0.08
Procedure time (start procedure – oxygen insufflation)	157 (61.5-186.25)	31-517	57.0 (30.25-172.5)	29-302	*p*=0.15
Total scenario time (start scenario – oxygen insufflation)	206.5 (147.25-274.75)	103-616	130 (100.5-232.5)	78-354	*p*=0.16
Performance					
Median number of attempts	3 (1.25-4)	1-7	1 (1-3.75)	1-5	*p*=0.24
Correct placement in 1 attempt*	2 (25%)		7 (58%)		*p*=0.15

Table 4.2 Time intervals and performance of both groups*) correct placement verified by pathologist after scenario EFONA: emergency front-of-neck airway, N: number

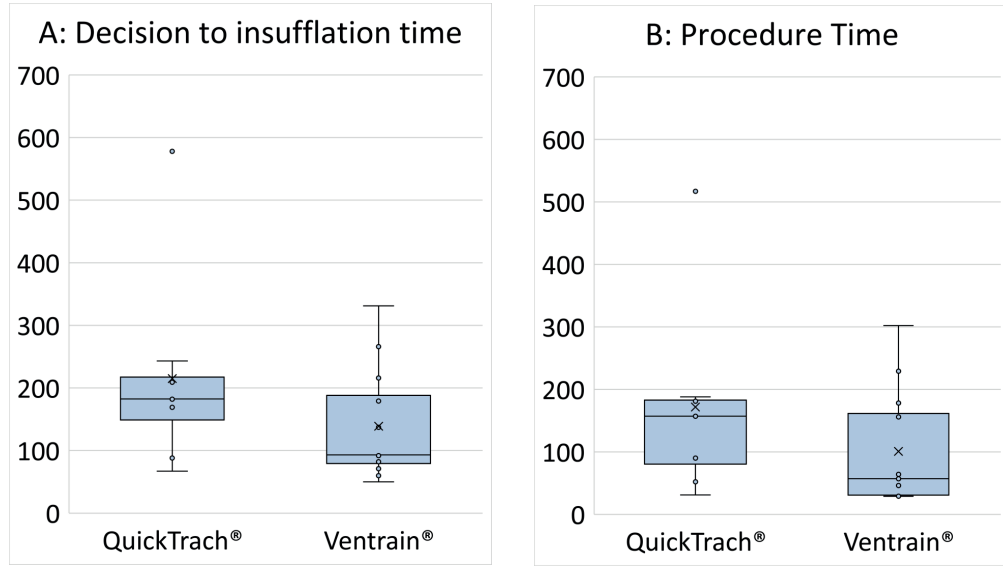

Figure 4.5 A: Boxplot of the eFONA decision to insufflation time with the QuickTrach® and Ventrain®. The X mark corresponds with the mean. B: Boxplot of procedure time with the QuickTrach® and Ventrain®. The X mark corresponds with the mean.

Incorrect placements and complications per device were evaluated by a forensic pathologist (Table 4.3). Results from the survey of the participants showed that the participants perceived the scenario as very realistic and experienced profound stress during the scenario (Table 4.4). In the Ventrain® group, the participants found the device easier to use (p=0.04).

Failures and complications	**Group A** (QuickTrach®) (n=7)	**Group B** (Ventrain®) (n=11)
Incorrect placements, n		
Placement through cricoid	0	1
Placement caudally from cricoid	1	0
Subcutaneous placement	1	0
Esophageal placement	0	1
Complications, n		
Submucous lesions	2	4
Kink in cannula	0	2
Fracture cartilage ring	2	0
Broken device	0	1

Table 4.3 Incorrect placements and complications

Survey questions (scale)	**Group A** (QuickTrach®) (mean)	**Group B** (Ventrain®) (mean)	**P value**
The scenario was realistic. (1-5)	4,0	4,8	0.03
On a scale from 0 to 10, how stressful was the scenario? (0-10)	6,7	5,8	0.31
On a scale from 0 to 10, how stressful was it to use this device? (0-10)	6,7	5,4	0.20
This device was easy to use. (1-5)	2,7	3,9	0.04
I would like to use this device again in such a scenario. (1-5)	4,1	3,8	0.60

Table 4.4 Results of the survey after scenario (means)
Scale 1-5: 1= totally disagree, 5=totally agreeEFONA: emergency front-of-neck airway, N: number

DISCUSSION

This randomized controlled trial using a simulated CICO situation employing a porcine model showed interesting insights in the use of both the QuickTrach® and Ventrain® eFONA devices, despite that this trial had to stop early. Participants rated the Ventrain® easier to use than the QuickTrach®. Other outcome measures, like the difference in the decision to oxygen insufflation (primary outcome) and other time intervals did not show statistical significance, possibly due to the small number of participants in each group. Both groups included cases in which the time interval of the decision to perform eFONA to oxygen insufflation was short and in other cases much more time was needed (range QuickTrach® 67-578 sec., Ventrain® 50-331 sec.). These findings can help to design an adequate powered future study, next to the other lessons learned in this study.

Complications like injury to the posterior wall of the airway were observed in both groups, like previously described in other studies [20,21]. In both groups we observed incorrect positioning of the needle device. When observing the scenarios, it appeared more difficult to insert the QuickTrach®, because participants frequently seemed to need significant force to introduce the QuickTrach®, although we did not measure the applied force. This seems to correspond with a previous study, suggesting to perform a pre-puncture surgical incision before QuickTrach® insertion 22. The pathologist reported two cases with fractures of the cartilage rings in the QuickTrach® group and none in the Ventrain® group. In the Ventrain® group, kinked cannulas were found in two cases although oxygen insufflation was possible. Perhaps the length of the cannula leads to a higher likelihood of reaching the posterior wall of the airway 23. Furthermore, in one case of the Ventrain® group, the Cricath® cannula broke during placement.

Previous studies evaluated and compared different emergency airway devices including the QuickTrach® and Ventrain®, as well as complication rates of the devices [21,24-27]. These studies are however not suitable for comparison with our study because of the lack of a simulated CICO scenario in these studies. In addition, some studies use synthetic model, other (smaller) animal models to target pediatric patients or use other variants of the studied devices, like the cuffed QuickTrach® II or QuickTrach® baby [28,29]. Our findings may not be generalizable to other countries or clinical settings, because backgrounds and training of EMS clinicians may vary and specific real-life settings and patients can be very different.

A CICO scenario is a rare event in which EMS clinicians need to have a low threshold for the decision to perform eFONA and they should be well trained to use the equipment they have. Data from clinical studies report a wide range of incidences for CICO scenarios, depending on time, setting, type of EMS clinician, and study methodology [2]. Data on the CICO incidence, eFONA use and its complications in the setting of Dutch EMS are lacking. Of 1871 patients in need of advanced airway management managed by one of the four Dutch HEMS, 30 patients (1.6%) received eFONA 30. This is comparable with the incidence of eFONA in London's Air Ambulance, which occurred in 88 (1.2%) of the 7256 patients in need of advanced airway management 31. In both studies, half of the eFONA procedures were used as primary airway suggesting that the indication for eFONA may already existed before HEMS arrival, but EMS clinicians were reluctant to perform eFONA. It is unclear, but possible, that EMS clinicians have a threshold to perform eFONA because they do not feel competent to use the equipment

needed. This could play an important role in decision-making. During the scenario in our study, none of the participants hesitated to perform eFONA and the median time to decision to perform eFONA was around 30 seconds. Qualitative studies in EMS clinicians on actual CICO cases are needed to further explore these important human factors 32.

Our challenging CICO scenario was perceived as both stressful and useful by the participating EMS clinicians. Significant levels of stress were reported, possibly due to the awareness of being a study participant (incl. recording of the scenario with cameras) and the challenge and realism of the scenario. The use of the porcine model added tissue fidelity to the simulation scenario, making it even more realistic. Despite the stress levels, our study was valued by the participating EMS clinicians. The ambulance nurses often told us that the workshop and scenario were very helpful in gaining the skill and confidence needed to manage a CICO scenario. We therefore suggest combining eFONA skills training for EMS clinicians with realistic scenario training, in order to integrate the skill in the context in which the skill needs to be performed, building the necessary self-confidence to perform eFONA in an actual CICO case [33].

Device manufacturers can also learn from the realistic simulations in our study, to improve the design of the devices. We estimate that the needle of the QuickTrach® could be improved to perforate the skin easier, and the cannula of the Cricath® could be made coil reinforced to prevent kinking. Furthermore, realistic simulation training is useful to observe if the devices are properly operated by clinicians in very stressful circumstances.

International guidelines recommend surgical techniques, like scalpel-bougie-tube, over devices [4]. Several studies showed the surgical technique is faster and more successful than techniques with a needle [3,34-36]. It seems feasible to teach surgical eFONA techniques to non-physicians [27,37]. On the other hand, however, maintaining sufficient self-confidence by frequent training could be a significant problem, potentially leading to the avoidance to perform surgical eFONA when indicated [5,32]. A separate arm with a surgical eFONA technique was not included in our study because of we estimated that this would not be feasible due to the larger number of participants. In addition, only eFONA devices with a catheter-over-the-needle design are used by Dutch EMS services.

Limitations

The main limitation of the study is the insufficient number of participants. Nonetheless, one statistically significant difference was found despite the smaller sample size, and other interesting observations were made. It is impossible to replicate a real-life situation completely. We tried to achieve a high level of realism by employing a porcine model to mimic the human cervical region, including a similar look and feel of human tissue, and size of the anatomical structures. Although certain aspects of the scenario could be made more realistic, the scenario was rated as realistic by the participants. Blinding was not possible. We tried to reduce risk of bias by using predefined objective events (e.g. participant enters the room, devices touches the skin).

The workshop that was held prior to the scenario, included skill training by the representatives of the manufactures of both devices. In this way, we were sure that participants were adequately trained to use the device. Because of the low incidence of CICO in real-life, it is likely that clinicians need to use the device long after their last training. We did not run scenarios with a long-time interval from the initial workshop, so skills retention of the use of these devices is not known. Although retention of skills is known to decrease over time, eFONA skills in paramedics have been shown to stay sufficient for up to three months [38]. Finally, participants only used one of the two devices, so they are not able to compare both techniques.

CONCLUSION

This incomplete randomized controlled trial, using a simulated CICO scenario employing a porcine airway model, was useful to gain insights into the use and performance of the QuickTrach® and Ventrain® eFONA devices. Participants rated the Ventrain® easier to use than the QuickTrach®. Prespecified time intervals and performance did not show significant differences, probably due to the small number of participants. Unsuccessful placements and complications were observed in both devices. It is worth considering running a realistic CICO simulation scenario after skills training in eFONA devices to practice CICO rescue. Simulation with stressful events can also help manufacturers to discover how the design of life-saving equipment can be improved.

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CONSORT 2010 checklist of information to include when reporting a randomised trial*

Section/Topic	Item No	Checklist item	Reported on page No
Title and abstract			
	1a	Identification as a randomised trial in the title	1
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)	3-4
Introduction			
Background and objectives	2a	Scientific background and explanation of rationale	5-6
	2b	Specific objectives or hypotheses	5-6
Methods			
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	6-8
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons	12
Participants	4a	Eligibility criteria for participants	8
	4b	Settings and locations where the data were collected	9
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	9-10
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	10
	6b	Any changes to trial outcomes after the trial commenced, with reasons	12-13
Sample size	7a	How sample size was determined	11-12
	7b	When applicable, explanation of any interim analyses and stopping guidelines	12
Randomisation:			
Sequence generation	8a	Method used to generate the random allocation sequence	8
	8b	Type of randomisation; details of any restriction (such as blocking and block size)	8
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	10
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	8
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those assessing outcomes) and how	10
	11b	If relevant, description of the similarity of interventions	9-10
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	11-12
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses	-
Results			
Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome	Table 1
	13b	For each group, losses and exclusions after randomisation, together with reasons	12
Recruitment	14a	Dates defining the periods of recruitment and follow-up	8
	14b	Why the trial ended or was stopped	12
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	
Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	Table 1
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)	Table 2
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended	Tables
Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory	-
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)	Table 3
Discussion			
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses	16
Generalisability	21	Generalisability (external validity, applicability) of the trial findings	16
Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence	15
Other information			
Registration	23	Registration number and name of trial registry	7-8
Protocol	24	Where the full trial protocol can be accessed, if available	1
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders	2

*We strongly recommend reading this statement in conjunction with the CONSORT 2010 Explanation and Elaboration for important clarifications on all the items. If relevant, we also recommend reading CONSORT extensions for cluster randomised trials, non-inferiority and equivalence trials, non-pharmacological treatments, herbal interventions, and pragmatic trials. Additional extensions are forthcoming: for those and for up to date references relevant to this checklist, see www.consort-statement.org.

Summary simulated "Can't intubate, can't oxygenate" scenario

Briefing study participant

Study participant is handed a radio, typically used by EMS. A call is made by an actor, in the role of the telecommunicator. The following information is given through the radio;

I have a priority call for you, for an adult man who is choking; The owner of a restaurant calls 112 because of a 42-year old man. He was eating in the restaurant and is now choking in a piece of steak. The man is turning cyanotic and can't get the piece of food out of his mouth. Two persons are providing first aid, giving a couple of back blows and performing the Heimlich maneuver. Both interventions had no effect. The situation is worsening and the patient collapsed on the floor. The restaurant is being evacuated so there is a safe and spacious scene. An EMS rapid response vehicle is also sent and will probably arrive first. The Helicopter Emergency Medical Service (HEMS) is dispatched but will take at least 20 minutes to arrive on the scene.

The study participant is held in the room for 2 minutes before entering the room.

Start of the scenario

Study participant enters the room. Two cameras are recording the scenario. The ALSi simulation monitor (Secta Medical) start with an oxygen saturation of 80% and sinustachycardia of 130/min, dropping to 50% and 60/min, over a 2 minute time window from the moment that the study participant enters the room.

Situation upon arrival and scenario

Patient is on the floor, next to the dinner table. His face is cyanotic and a piece of steak is visible in his mouth. The patient is a 42-year old male with an unknown medical history. There are no bystanders who can give any information. An ambulance nurse (actor) who arrived a few minutes before as a rapid responder already put the patient on the monitor with ECG and pulse oximetry. He is at the head end, providing oxygen with a bag-valve-mask, assisting in breathing with positive pressure.

The ambulance nurse at the head end gives a standardized briefing of the situation: "This is a male who choked on a piece of steak. He collapsed and is cyanotic. I have tried to remove the piece of meat but have not succeeded, including attempts with the Magills forceps. I think he has a trismus. Intubation and supraglottic airway is not possible. I can only get a little oxygen past this object through the BVM, so I'll keep the mask on his face."

The actor does not mention eFONA as the next step to let the participants make the decision themselves, but is instructed to keep the facemask on the face of the patient at all cost, making other airway interventions impossible. When the study participant states that he/she wants to perform eFONA, the actor hands over either the QuickTrach® or the Ventrain®, corresponding with the randomization. The actor does not give any instructions for the procedure to the participants. The scenario is ended when the eFONA device is successfully placed.

Appendix 4.B Scenario

http://shorturl.at/mBPQ9

Appendix 4.C Video of example cases

Findings by pathologist and survey participant

Subject number:

Porcine model number:

Success: yes / no / not sure

Complications according to pathologist:

Correct placement of the device

Damage to the trachea

Damage to the cricoid

Damage to the thyroid

Fracture of cartilage

Other remarks

Survey

1 = disagree, 5 = completely agree

1. The scenario was realistic:

1 2 3 4 5

2. On a scale of 0-10, how stressful was the scenario?

3. On a scale of 0-10, how stressful was the placement of the device?

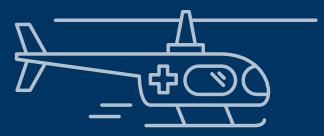
4. The device was easy to position:

1 2 3 4 5

5. I would like to use this device again in such a scenario:

1 2 3 4 5

6. Remarks:



PART 2

Ventilation

Chapter 5

Manual chest compression pause duration for ventilations during prehospital advanced life support - *an observational study to explore optimal ventilation pause duration for mechanical chest compression devices*

PART 2

Hans van Schuppen
Lotte Doeleman
Markus Hollmann
Rudolph Koster

Resuscitation 2022;180:24-30

ABSTRACT

Aim

Mechanical chest compression devices in the 30:2 mode generally provide a pause of three seconds to give two insufflations without evidence supporting this pause duration. We aimed to explore the optimal pause duration by measuring the time needed for two insufflations, during advanced life support with manual compressions.

Methods

Prospectively collected data in the AmsteRdam REsuscitation STudies (ARREST) registry were analysed, including thoracic impedance signal and waveform capnography from manual defibrillators of the Amsterdam ambulance service. Compression pauses were analysed for number of insufflations, time interval from start of the compression pause to the end of the second insufflation, chest compression pause duration and ventilation subintervals.

Results

During 132 out-of-hospital cardiac arrests, 1619 manual chest compression pauses to ventilate were identified. In 1364 (84%) pauses, two insufflations were given. In 28% of these pauses, giving two insufflations took more than three seconds. The second insufflation is completed within 3.8 seconds in 90% and within 5 seconds in 97.5% of these pauses. An increasing likelihood of achieving two insufflations is seen with increasing compression pause duration up to five seconds.

Conclusion

The optimal chest compression pause duration for mechanical chest compression devices in the 30:2 mode to provide two insufflations, appears to be five seconds, warranting further studies in the context of mechanical chest compression. A 5-second pause will allow providers to give two insufflations with a very high success rate. In addition, a 5-second pause can also be used for other interventions like rhythm checks and endotracheal intubation.

INTRODUCTION

Chest compressions and ventilations are the cornerstone of cardiopulmonary resusciation (CPR). Preceding advanced airway management, current guidelines recommend a ratio of 30 chest compressions to 2 ventilations.[1] An insufflation time of one second is recommended. Pauses in chest compressions to give two ventilations should be as short as possible, but should not exceed ten seconds.[1, 2] When Advanced Life Support (ALS) is provided by Emergency Medical Services (EMS) or resuscitation teams, airway management is provided and insufflations with oxygen are given to improve oxygenation during CPR.[3] Mechanical chest compression devices can be used to provide high quality chest compressions.

Both the LUCAS® and Autopulse® mechanical chest compression devices in the 30:2 mode provide a fixed 3-second pause after 30 compressions to provide two insufflations. This is based on a theoretical sum of the first insufflation of one second, the first exsufflation for one second, the second insufflation of one second, after which chest compressions are automatically resumed. In clinical practice however, providers may need some more time to provide two insufflations. Recently, technological developments enabled adjustment of this compression pause duration in some of the mechanical chest compression devices. Neither current resuscitation guidelines, nor the manufacturers, provide recommendation on the optimal compression pause duration for mechanical chest compression devices.

In this study, we aimed to explore the optimal compression pause duration for mechanical chest compression devices, allowing for two adequate insufflations by providers on one hand, and minimally interrupting chest compressions on the other hand. We hypothesized that providers frequently need more time than three seconds to provide two adequate insufflations. To assess the required compression pause duration, we first need to study the time needed to provide two insufflations in 30:2 CPR with manual chest compressions; In the context of manual chest compressions, the compression pauses are not fixed but providers are able to take the necessary time to give two insufflations with an adequate tidal volume and compressions are resumed after two successful insufflations have been provided. With the insight from this study in the setting with manual chest compressions, further studies in the setting of mechanical chest compression can be designed and interpreted, aiming to determine the optimal chest compression pause duration of mechanical chest compression devices for ventilations.

METHODS

Setting

In the Netherlands, dispatchers alert citizen responders, first responders, and two ALS level ambulances in case of (suspected) cardiac arrest.[4] ALS level ambulances are staffed with an ambulance nurse and a driver. These nurses are trained to perform ALS including advanced airway management, following national ambulance guidelines corresponding with the European Resuscitation Council guidelines. Regional standard operation procedures and specific devices vary.

The ambulance service of Amsterdam was equipped with a Lifepak® 15 monitor (Stryker Emergency Care, Redmond, WA, USA) and did not use mechanical chest compression devices in the study period. Airway management consisted of bag-valve-mask (BVM) ventilation initially, followed by either the i-gel® supraglottic airway device or endotracheal intubation.

Insufflations were provided by a self-inflating bag. Waveform capnography was started at advanced airway management, or earlier at the discretion of the ambulance nurse. After advanced airway management (i-gel® or intubation) was completed, CPR was changed from the 30:2 compression to ventilation ratio to continuous chest compressions with asynchronous ventilations (10 min-1). According to resuscitation guidelines, the ambulance nurse could decide to provide 30:2 CPR after i-gel® placement when there is excessive air leakage.[5]

Data source

This study was performed using data from ARREST (AmsteRdam REsuscitation STudies): an ongoing, prospective registry of all-cause out-of-hospital cardiac arrest (OHCA) in the province North-Holland.[6] Data sources were limited to the ambulance service of Amsterdam, because other EMS services in the ARREST region used mechanical chest compressions devices and were therefore not suitable for analysis. Informed consent was not required by law if the patient was deceased, and in case of survival, deferred informed consent was obtained after hospital discharge. Data sources of ARREST included data from the EMS dispatch center, AED recordings, data from the Lifepak® 15 defibrillator, EMS run report and hospital data. The medical ethics review board of the Academic Medical Center reviewed the study protocol and determined that the Medical Research Involving Human Subjects Act did not apply (number W17_089).

Sample size calculation

In order to achieve a 95% confidence interval of 0.25 second under or above the observed mean duration of the time needed to provide two insufflations, a sample size of 385 pauses in compressions was required. With at least three pauses with two insufflations per patient we needed 129 patients to reach the pauses necessary for the analysis.

Study design and data collection

All consecutive prehospital resuscitation attempts by EMS for OHCA in adults (≥18 years) between June to December 2017 were screened and included when A) there was a medical cause of the arrest, B) manual chest compressions and insufflations were given in the 30:2 ratio, C) the ambulance run report and Lifepak® 15 data were available, and D) a minimum of three compression pauses with two insufflations suitable for analysis were available. Patients were excluded when a significant airway or ventilation problem was the cause of the arrest (like anaphylaxis or asthma), based on information from the ambulance run report. All baseline characteristics were routinely collected in the prospective ARREST registry. Data from the Lifepak® 15 defibrillator were transferred to dedicated software (Code-stat® 10, Stryker EMS, Redmond, WA, USA).

Data analysis

In Code-stat® 10 software, the thoracic impedance signal, ECG and waveform capnography was visualized (Fig. 5.1). By using the thoracic impedance signal, all pauses in chest compressions during the resuscitation were identified.[7] The definition of a pause was the absence of chest compressions for > 1.5 seconds, when chest compressions are expected (no spontaneous circulation). If a pause was longer than ten seconds the pause was not included in the analysis. The start and end of a compression pause was annotated and categorized as a pause to give ventilations, to perform interventions (like a rhythm check or endotracheal intubation) or as an unclear pause (unclear impedance signal and/or capnography). All pauses to give two ventilations were eligible for inclusion, regardless of the airway management technique at that moment (BVM or i-gel®). Pauses used for ventilation were categorized by number of insufflations seen during the pause. When available, the waveform capnography signal was used to check and compare the identification of insufflations and ventilation subintervals.

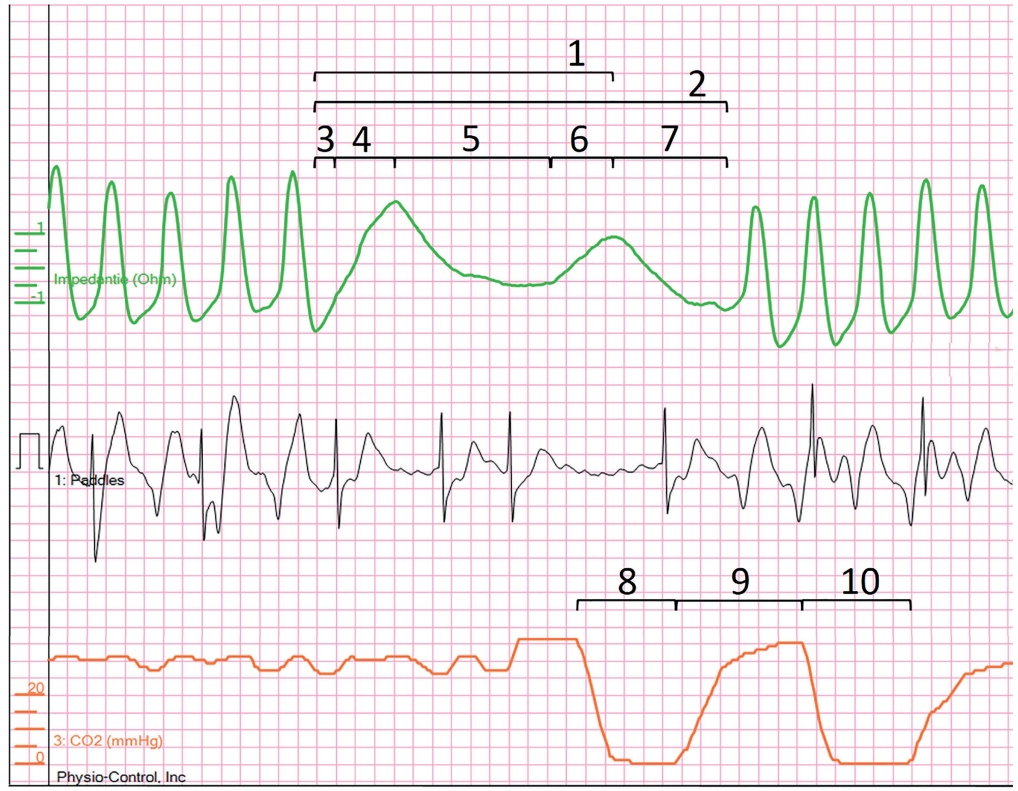


Figure 5.1 Time intervals during a chest compression pause with two ventilations. Green. Thoracic impedance signal. Black. Electrocardiogram. Orange. Waveform capnogram. Intervals. 1. time needed for two insufflations, 2. compression pause duration, 3. delay in starting the first insufflation, 4. first insufflation, 5. First exsufflation, 6. second insufflation, 7. Second exsufflation during the delay in resumption of chest compressions, 8. first insufflation in capnography, 9. first exsufflation in capnography, 10. Second insufflation in capnography. There is a three second delay in capnography signal due to side-stream measurement of CO2.

Our primary aim was to determine the time interval from the start of compression pause to the end of the second insufflation (Fig. 5.1, interval 1). This corresponds with the current pauses on mechanical compression devices are now programmed to accommodate only these actions, leaving out the second exsufflation and possible extra delay in resuming compressions. Secondary aims were to determine the likelihood of achieving two insufflations in relationship with compression pause duration, and in pauses with two ventilations: determining the com-

pression pause duration (Fig. 5.1, interval 2) and subintervals of in- and exsufflations (Fig. 5.1, intervals 3-10). These predefined intervals were annotated in Code-stat® in both the impedance signal and capnography waveform.

The analysis was done individually by HvS and LCD, after which cases were cross-checked by the other author. Any discrepancies were discussed and solved, when needed by a third assessor (RWK).

Statistical analysis

Statistical analysis was done in SPSS® (version 28.0, IBM® SPSS®, Chicago, IL). The likelihood of successfully providing two insufflations by a given compression pause duration was calculated on pauses intended for ventilation, leaving unidentified or intervention pauses out of the analysis. To calculate median time needed for two insufflations and compression pause duration, all pauses with two insufflations were used. Median values were reported with interquartile range. Cumulative curves were made, including the 90th percentile. To determine whether few patients with either very short or long pauses did influence the results of the whole group, we performed a sensitivity analysis on just the first three compression pauses with two insufflations per patient. Median duration of the ventilation subintervals were analysed on all pauses with two insufflations. Changes in ventilation- and compression pause duration over the course of the resuscitation were analysed.

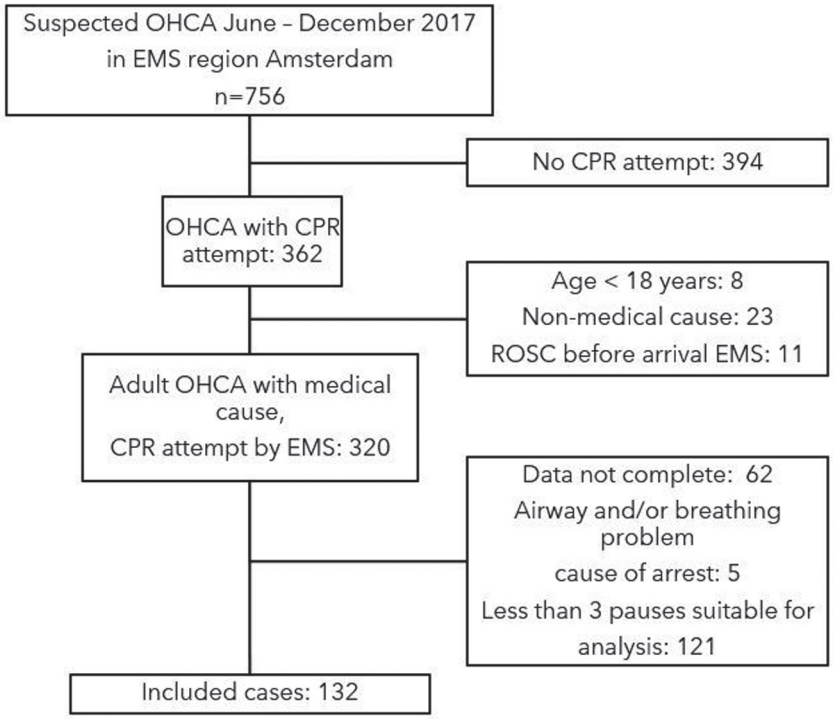


Figure 5.2 Flow diagram of inclusion. CPR. cardiopulmonary resuscitation, EMS (Emergency Medical Services) OHCA (out-of-hospital cardiac arrest) ROSC (return of spontaneous circulation)

RESULTS

Within the study period, 756 cases suspected for OHCA were screened for inclusion. CPR was attempted in 362 of these cases. After applying in- and exclusion criteria, 132 cases were suitable for analysis (Fig. 5.2). Characteristics of included cases are shown in Table 5.1. Analysis of the 132 cases yielded a total of 2634 pauses. Of these pauses, 1619 were intended for ventilations and in 1364 (84%) two insufflations could be identified (Table 5.2).

Gender	Male	74 (56%)
n (%)	Female	58 (44%)
Median age in years (range)		71 (18-92)
Airway management technique	BVM only	20 (15%)
n (%)	BVM → SAD	54 (41%)
	BVM → tube	57 (43%)
	BVM → SAD → tube	1 (1%)
	Unknown	0 (0%)
Moment of start capnography	During BVM ventilations	39 (30%)
n (%)	At start advanced airway management	64 (48%)
	Later during CPR	13 (10%)
	No capnography was used	7 (5%)
	Malfunction	2 (2%)
	Unknown	7 (5%)

Table 5.1 Characteristics of included cases (n = 132). Values are numbers (percentage). BVM: bag-valve-mask, CPR: cardiopulmonary resuscitation, SAD: supraglottic airway device

Total number of pauses	2634
Mean number of pauses per case	20.0 (range 4-63)
Pauses per category	
Ventilation pause	1619 (61%)
Intervention	510 (19%)
Unknown	505 (19%)
Mean number of ventilation pauses per case	12.3 (range 3-39)
Ventilation pauses per category	
No insufflation	38 (2%)
One partial insufflation	0 (0%)
One full insufflation	158 (10%)
One full and one partial insufflation	22 (1%)
Two full insufflations	1364 (84%)
Two full insufflations and one partial insufflation	9 (1%)
Three full insufflations	28 (2%)

Table 5.2 Characteristics of pauses in included cases. Values are numbers (percentage). Mean number of pauses with two insufflations per case 10.3 (range 3–38).

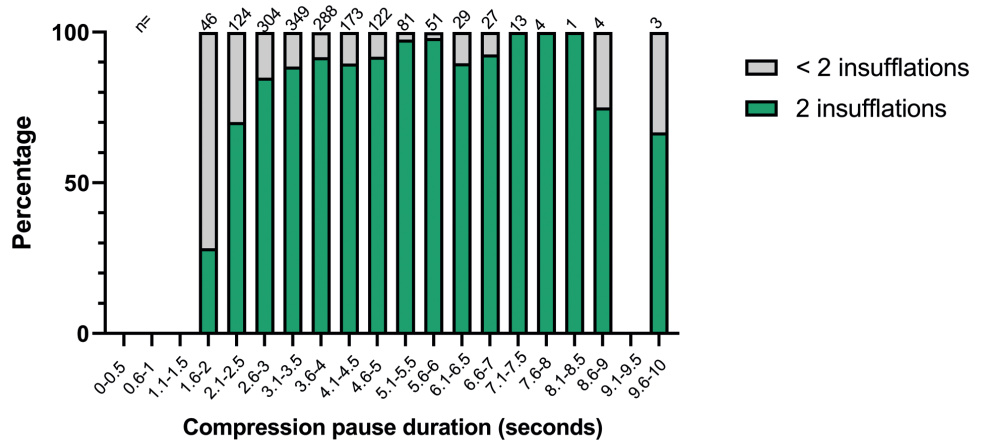


Figure 5.3 Likelihood of giving two insufflations versus less than two insufflations in a compression pause intended for ventilation, per compression pause duration. Number of pauses per pause duration is noted on top of bar.

The likelihood of successfully providing two insufflations within a compression pause to ventilate increases when a compression pause is longer (Fig. 5.3). This is observed with compression pause durations up until 5 seconds. Success rate is 97.5% at this length. Further lengthening did not improve the likelihood of providing two insufflations.

Further analysis was done on pauses with two ventilations; The cumulative percentage of time needed for two insufflations is shown in Fig. 5.4A. The median time needed to provide two insufflations was 2.5 (IQR 2.1-3.1) seconds. In 90% of pauses with two ventilations, the second insufflation was given within 3.8 seconds. Median compression pause duration for all pauses with two insufflations was 3.5 (IQR 3.0-4.3) seconds (Fig. 5.4B). In 90% of pauses with two ventilations, the compression pause duration was within 5.4 seconds.

An analysis on the first three compression pauses with two ventilations per case showed a negligible difference with all observed pauses (Appendix Table 5.A); The median time needed to provide two insufflations was 2.6 (IQR 2.1-3.3) seconds, with a 90th percentile at 3.8 seconds. Median compression pause duration was 3.6 (IQR 3.0-3.4) seconds.

In 28% of all pauses with two insufflations, giving two insufflations took longer than 3 seconds (Appendix Figure 5.A). In 98.5% of these pauses, two insufflations are provided within 5 seconds. There is no indication for a change in both the time needed for two insufflations and compression pause duration over the course of the resuscitation (Appendix Figure 5.B).

Analysis of subinterval medians for pauses with two ventilations showed a delay of 0.2 (IQR 0.1-0.4) seconds in starting the first insufflation after stopping chest compressions. The first and second insufflation took 0.6 (IQR 0.4-0.7) and 0.6 (IQR 0.5-0.8) seconds respectively, the first exsufflation 1.0 (IQR 0.8-1.3) seconds, and the delay until resumption of chest compressions 1.0 (IQR 0.7-1.3) seconds. When comparing intervals noted on the impedance signal with those noted on the capnography signal, insufflation times noted on the capnography signal were slightly longer: 1.0 (IQR 0.8-1.2) second for both the first and the second insufflation Appendix Table 5.B).

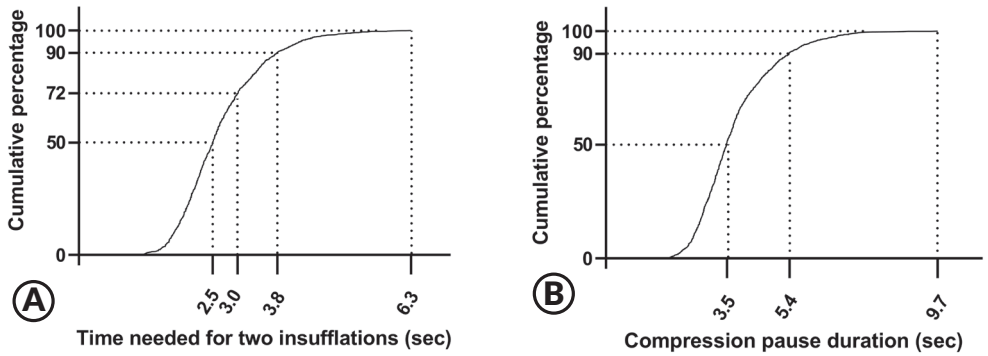


Figure 5.4 Cumulative percentages of compression pause durations of pauses with two insufflations. (A) Interval 1. Time needed for two insufflations with median (p50), p90 and p100. The percentage at 3 seconds is added because this is the timeframe of most mechanical chest compression devices. (B) Interval 2. Compression pause duration with median (p50), p90 and p100.

DISCUSSION

The main finding of this observational study is that when manual chest compressions are paused to give two ventilations, the second insufflation is completed within 3.8 seconds in 90% of the pauses with two ventilations. In 97.5% of all compression pauses with two ventilations, the second insufflation was given within 5 seconds. In the majority (87%) of chest compressions pauses to ventilate, two insufflations were identified. An increasing likelihood of providing two insufflations is seen in pauses up to 5 seconds. Shorter compression pauses (1-3 seconds) more often contain less than two ventilations. Insufflations are given with the recommended duration of one second per insufflation. Pause durations do not change over the course of the resuscitation.

Mechanical chest compression devices in the 30:2 mode may need to provide a compression pause of more than three seconds to have a high chance (>90%) to actually provide two insufflations. The current 3-second pause of many chest compression devices would be too short to facilitate two full insufflations in 28% of the pauses in our study. This finding in the context of manual chest compressions needs to be confirmed in a future study, in the context of mechanical chest compression. However, a fixed 3-second pause of a mechanical chest compression device could add time-pressure to provide two insufflations, possibly at the expense of an adequate tidal volume. We therefore suggest that the recommended chest compression pause duration to provide two ventilations is five seconds, based on our findings in this study. With a compression pause duration of five seconds, two insufflations can almost always be achieved. Should the two insufflations be provided faster than five seconds, the remaining time allows for the second exsufflation. In this way, high peak intrathoracic pressures are prevented because chest compressions are not started on a fully insufflated chest. A five second pause is well within the recommended maximum pause duration of ten seconds mentioned in current guidelines.[1]

Previous studies have provided limited information to guide ideal mechanical chest compression device settings regarding the time to allow for insufflations. In the large RCT's on mechanical chest compression devices, little data are provided on insufflations.[8] Previous work by Beesems et al. on manual chest compression pauses, determined a median chest compression pause duration of seven seconds to provide two ventilations in the 30:2 mode in the Basic Life Support (BLS) setting by analysing data from AED's of trained lay-persons and First Responders.[2] Survival was not decreased with increasing duration of compression pauses, even up to pauses of ten seconds. This finding led to the recommendation in ERC guidelines that rescuers may take up to ten seconds to provide two ventilations.[9] The findings by Beesems in the BLS setting cannot be applied to the ALS setting; In the ALS setting, one paramedic provides insufflations, while someone else provides chest compressions. This could lead to a shorter compression pause duration when compared to the BLS setting which is based on a single-rescuer giving both chest compressions and ventilations. Furthermore, first responders use a simple facemask, like the Pocket Mask®, to manage the airway. They might need more time to provide two insufflations when compared to ambulance nurses with more experience and a more advanced airway management technique. In a previous study by Ødegaard et al. in the prehospital ALS context, the median compression pause duration was 5.5 seconds (IQR 4.5-7).[10] In all pauses analysed, two insufflations were detected in only 51%. More or less than two ventilations was seen in 29% and in 20% no insufflations were seen. This study, however, does not show the time needed to achieve the second insufflation but only the total chest compression pause duration, so those data are of limited use to support a specific pause duration for mechanical chest compression devices. Our study showed a shorter median compression pause duration (3.5 versus 5.5 seconds).

Changing the compression pause to five seconds has the potential to improve survival. First of all, optimizing insufflations during mechanical chest compression may improve oxygenation during mechanical CPR. A previous study has shown that a higher arterial partial pressure of oxygen (paO2) is associated with a higher likelihood of return of spontaneous circulation (ROSC) and survival.[11] Furthermore, successfully providing 30:2 CPR has been associated with an improvement in outcome.[12] In addition, heart rhythm checks, which take place every two minutes during ALS, need to be done within five seconds as well. From a practical point of view, when using mechanical chest compression devices with a pause duration of five seconds, this pause can also be used for the rhythm check. In this way, manually pausing the device for a hythm check is not necessary. This also accounts for interrupting chest compressions for endotracheal intubation attempts. This can help to prevent undesirable long chest compression interruptions and make things easier in the resuscitation process.[13]

Several limitations in our study should be emphasized. A relatively high percentage of pauses (19%) were unsuitable for analysis because of an unclear thoracic impedance signal. It is conceivable, that these pauses in fact had poor or absent ventilations. Waveform capnography was not always present to double check the thoracic impedance signal clearly identifying ventilations. Furthermore, in our analysis we could not differentiate pauses in which ventilations were given with BVM or a supraglottic airway device. It is possible that this has an influence on pause duration. The Lifepak® 15 can provide a metronome to guide manual chest compressions and ventilations. We did not study the impact of the metronome on pause durations. The metronome may explain why pauses in our study are shorter than those reported by Ødegaard et al., although the impact seems limited in a study by Kern et al..[10, 14] The thoracic impedance signal is not suitable to determine tidal volumes delivered during ventilations.[15] Therefore, despite complying with the recommended insufflation time of one second, we cannot determine whether or not adequate tidal volumes were given.

Using the findings of this study as a basis, further research on the quality of ventilations during mechanical chest compression and the effects of a five second pause during mechanical chest compression on CPR quality metrics, ROSC and survival could be performed with a suitable study design. This will provide further insight how to improve ventilation during CPR when using mechanical chest compression devices.

CONCLUSIONS

When manual chest compressions are paused to give two ventilations, frequently (28%) more than the current 3-second timeframe of mechanical chest compression devices is needed to provide two insufflations. The optimal chest compression pause duration for mechanical chest compression devices appears to be five seconds, which warrants further studies in the context of mechanical chest compression. A 5-second pause will allow providers almost always (97.5%) to be able to provide two insufflations, while still staying within the recommended maximum timeframe of ten seconds. Additionally, a 5-second pause can also be used to perform a rhythm check during Advanced Life Support, which could reduce unnecessary long chest compressions interruptions. Further research is needed to study ventilation during mechanical chest compression and the impact of this strategy on CPR metrics and outcome.

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Time needed for two insufflations duration (sec)	First three pauses (n=396)	All pauses (n=1364)
Median	2.6	2.5
p25	2.1	2.1
p75	3.3	3.1
p90	3.8	3.8
Range minimum	1.1	1.1
Range maximum	6.1	6.3
Compression pause duration (sec)		
Median	3.6	3.5
p25	3.0	3.0
P75	4.4	4.3
p90	5.4	5.4
Range minimum	1.9	1.7
Range maximum	9.7	9.7

Table 5.A Time needed for two insufflations and compression pause duration in first three pauses per case versus all pauses.

Interval	**Description**	**Source**	**Median with IQR (sec)**
1	Time from start compression pause to end of second insufflation	Thoracic impedance signal	2.5 (2.1-3.1)
2	Time from start compression pause to resumption of chest compressions	Thoracic impedance signal	3.5 (3.0-4.3)
3	Time from start compression pause to start of first insufflation	Thoracic impedance signal	0.2 (0.1-0.4)
4	Time from start first insufflation to end of first insufflation	Thoracic impedance signal	0.6 (0.4-0.7)
5	Time from start first exsufflation to start of second insufflation	Thoracic impedance signal	1.0 (0.8-1.3)
6	Time from start second insufflation to end of second insufflation	Thoracic impedance signal	0.6 (0.5-0.8)
7	Time from start second exsufflation to resumption of chest compressions	Thoracic impedance signal	1.0 (0.7-1.3)
8	Time from start first insufflation to end of first insufflation	Waveform capnogram	1.0 (0.8-1.2)
9	Time from start first exsufflation to start of second insufflation	Waveform capnogram	0.8 (0.6-1.1)
10	Time from start second insufflation to end of second insufflation	Waveform capnogram	1.0 (0.8-1.2)

Table 5.B Median duration of all intervals.

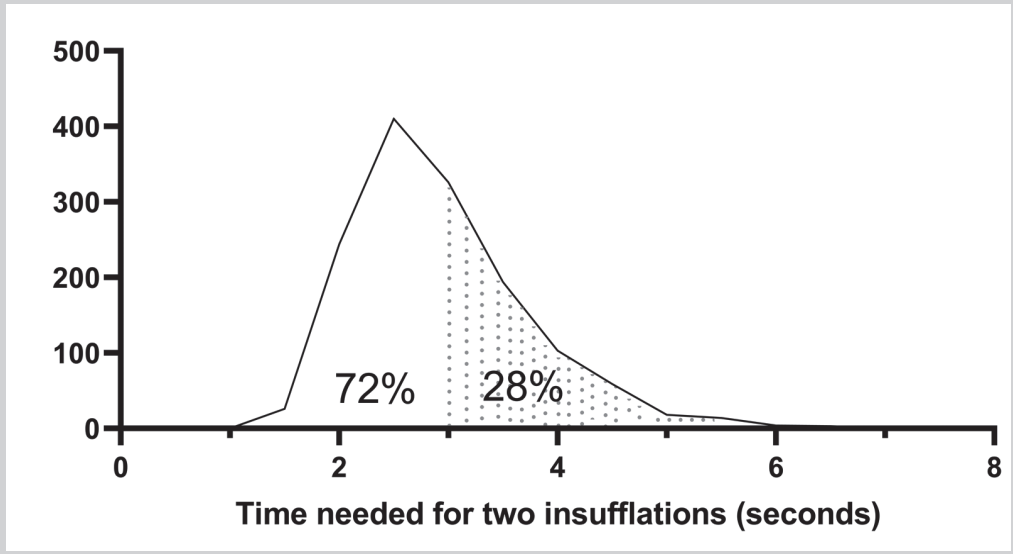


Figure 5.A Time needed for two insufflations, with proportion of intervals > 3 seconds.

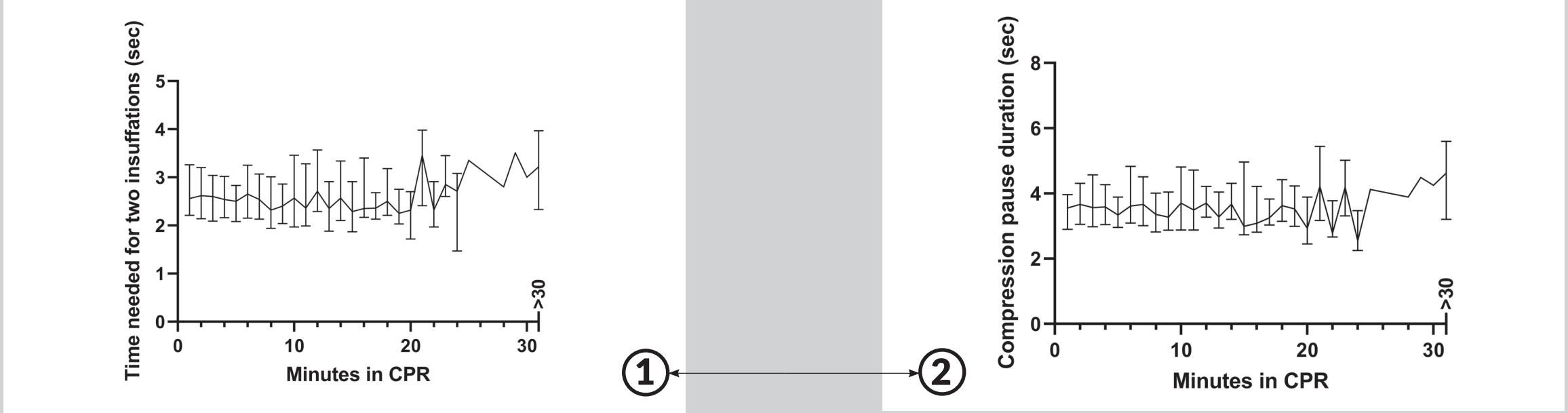
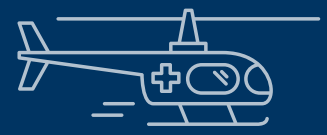
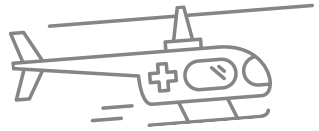


Figure 5.B Median time needed for two insufflations (1) and compression pause duration (2) over the course of the resuscitation since the start of CPR by emergency medical services. Brackets are interquartile ranges. CPR: cardiopulmonary resuscitation.



PART 3

Prehospital physicians



Chapter 6

Understanding the prehospital physician controversy.
Step 1: Comparing competencies of ambulance nurses and prehospital physicians.

PART 3

Hans van Schuppen

Joost Bierens

Eur J Emerg Med. 2011 Dec;18(6):322-7.

ABSTRACT

Objective

In many European countries prehospital care by emergency medical services (EMS) is supplemented by physician-staffed services. There is ongoing controversy on the benefits of a prehospital physician. Possible advantages are additional competencies of the physician. Similarities and differences in competencies of EMS providers and physicians have however never been studied. This study aims to compare competencies of ambulance nurses and HEMS physicians in the Netherlands to gain better insight in the controversy of the prehospital physician.

Methods

In this descriptive study, a quantitative inventory was made of the diagnostic, therapeutic and clinical judgment competencies of the ambulance nurse and physician, based on analysis of protocols, registration, equipment and personal interviews.

Results

We identified 438 mutual competencies of the ambulance nurse and physician and 62 physicianspecific competencies. The ambulance nurse masters 278 diagnostic, 131 therapeutic and 29 clinical judgment competencies. The physician masters 285 diagnostic, 175 therapeutic and 40 clinical judgment competencies. Seventy one percent of the physician-specific competencies are therapeutic and related to advanced life support.

Conclusions

The ambulance nurse and physician have various mutual competencies. In addition, the physician can provide specific competencies on the scene. Knowing the exact overlap and differences in competencies is the first step to understand the prehospital physician controversy. Our results can be used as a tool for the next step in research on prehospital care by EMS providers and physicians and to improve prehospital care.

INTRODUCTION

Prehospital emergency care in the Netherlands is mainly provided by ambulance services staffed by an ambulance nurse [1-3]. For critical patients, additional support is provided by mobile medical teams (MMT) staffed by a physician and a nurse. Three studies from the Netherlands concluded that outcome is better when additional support is provided by the MMT [4-6]. Studies from other countries confirm an improvement in outcome when a physician is added to the emergency medical service (EMS) [7-12]. In contrast, other studies concluded that outcome is equal when prehospital care is delivered with or without the presence of a physician [13, 14]. One of the main reasons for these conflicting results are the methodological difficulties of outcome related research in prehospital care. For this reason, it has been stated that outcome may not be a feasible study objective in research on the value of physicians in the prehospital setting and other research methods should be used [15-17].

To better understand the controversy of physicians in the prehospital setting, we decided to approach it from another, more fundamental perspective by studying the overlap and differences of the competencies between ambulance nurses and physicians. Although a few studies address this aspect, our study is the first that explores the exact overlap and differences in competencies of nurses and physicians in prehospital care [18-21].

METHODS

Setting

The Netherlands is a European country with more than 16 million inhabitants on 41.500 square kilometres. Prehospital emergency care is provided by ambulances and, when needed, additional support is provided by mobile medical teams (MMT) [1-3].

In contrast with other countries like the United Kingdom, there are no specific paramedics in the Netherlands. Ambulances are staffed by a registered nurse with extensive in-hospital and prehospital training and an ambulance driver, trained to assist the ambulance nurse. There are 695 ambulances and almost 2100 ambulance nurses. On a national basis, ambulances respond to more than one million calls annually, of which 454.000 are emergency dispatches. After each dispatch, ambulance nurses record data on an ambulance run report. Since 1992, ambulance nurses practice according to the National Protocol Ambulance Care (NPA). This is a set of 176 protocols based on a consensus that includes the input of all relevant national medical associations. Ambulance nurses maintain their competencies by attending four regional and two national refresher training days per year. To re-assess their competencies, they have to pass a theory exam each year, a scenario based exam once in every five years and attend the refresher courses of the Prehospital Trauma Life Support course (PHTLS®).

The MMT provides medical care in addition to EMS and consist of a specialized physician (anesthesiologist or trauma surgeon) and a registered nurse (ambulance nurse or emergency department nurse) to assist the MMT physician. Ten hospitals in the Netherlands provide an MMT service. All of these hospitals have a special equipped vehicle driven by a driver or the MMT nurse. Four of the MMTs (also) use a helicopter as a means of transport (helicopter emergency medical service, HEMS). In 2006, these four HEMS were manned by 50 physicians and 32 nurses and the HEMS stations performed 4557 (98%) of the 4672 MMT dispatches [22]. The

MMT physicians record data of the dispatch by using database software. The dispatch of the MMT is based on a set of formally established criteria: either based on the call to the dispatch centre (primary dispatch) or on the request of the ambulance nurse on the scene (secondary dispatch)[23]. Since 2007, the MMT practices according to the Guidelines for the Mobile Medical Teams in the Netherlands (GMN). MMT physicians maintain their competencies by working in-hospital and attending courses and educational activities to keep their registration as an anesthesiologist or trauma surgeon. Furthermore, MMT physicians attend to the annual national MMT meeting and refresher courses of relevant courses.

Design

This is a descriptive, non-experimental study based on a quantative analysis of different data sources. Protocols, registration systems and equipment of ambulance and MMT service have been analyzed on competencies of the ambulance nurse and MMT physician. A structured interview was held to confirm the inventoried competencies from the data sources and to cross check the results of the analysis.

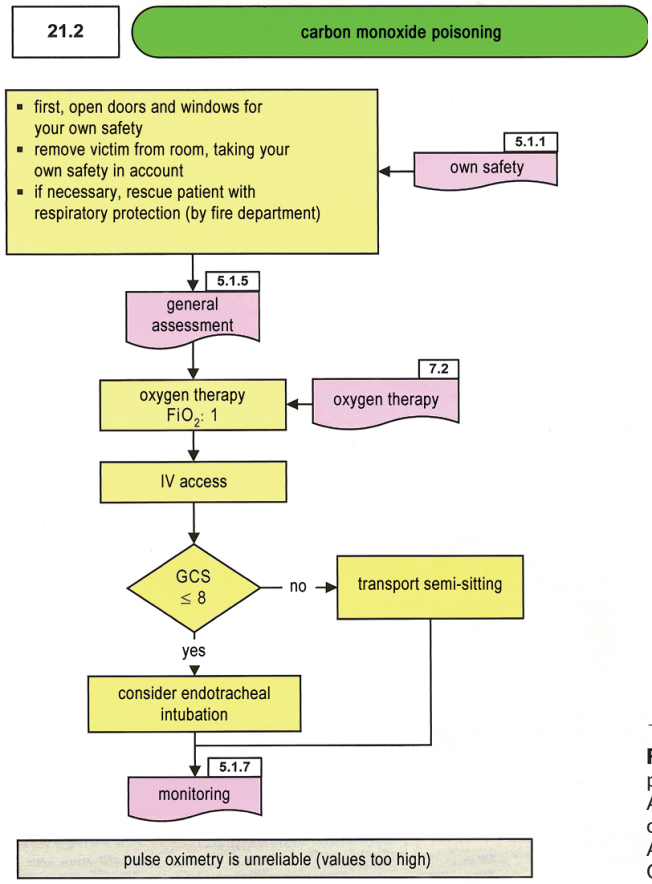


Figure 6.1 Protocol 'carbon monoxide poisoning' from the National Protocol Ambulance Care and the inventoried competencies (with kind permission of Ambulancezorg Nederland).
GCS, Glasgow Coma Scale.

Primary data analysis

All protocols of the NPA were analyzed by the first author (HvS) for diagnostic, therapeutic and clinical judgment competencies and checked by the second author (JB). Discrepancies have been discussed until full agreement had been reached. For example, analysis of the NPA protocol on 'carbon monoxide poisoning' (Fig. 6.1) showed the ambulance nurse will need 3 diagnostic competencies, 4 therapeutic competencies and 1 clinical judgment competency to be able to apply the protocol.

In addition, a blank ambulance run report and the inventory of the ambulance equipment have been analyzed for competencies. For example, the presence of a check-box for defibrillation on the ambulance run report indicates that the ambulance nurse is competent to defibrillate and the presence of a blood glucose meter in the ambulance indicates that the nurse is competent to measure the blood glucose level. The same method was used for the MMT physician; To identify the competencies of the MMT physician, the GMN, the MMT database software and MMT equipment have been analyzed for competencies.

After the analysis of these data sources, five ambulance nurses and five MMT physicians were interviewed in order to verify the similarities and differences in competencies. The interviewed ambulance nurses and MMT physicians were selected based on their profound knowledge of the competencies of the ambulance nurse or MMT physician, for example by being instructors. The ambulance nurses were asked:

1. Can ambulance nurses provide all competencies found in the ambulance data sources?
2. Which of the competencies found in the MMT data sources will an ambulance nurse not be able to provide?
3. Why can an ambulance nurse not provide that specific competency?

Similarly, the MMT physicians were individually interviewed as to whether an MMT physician would be able to provide the competencies found in the ambulance and MMT data sources. For this cross-check the same three questions were asked but vice versa. When there was no full agreement of the interviewees on a certain competency, the cross check was based on the majority of interviewees.

The methodology of data collection and data analysis was described in a research proposal that was accepted in 2007. No further adaptations have been made during the study with the exception that the analysis of the GMN has been added to the original protocol, because it became available in 2007. The Medical Ethics Committee of the VU University Medical Center approved the study. All collected data was processed in a spreadsheet in Microsoft Excel 2007©.

RESULTS

We identified 438 competencies of the ambulance nurse and 500 competencies of the MMT physician (table 6.1). (See Supplemental Digital Content 1 for a table with the most frequently mentioned competencies in the NPA and GMN)

Data source	Ambulance nurse	MMT physician
Protocols	367	269
Diagnostic	219 (60%)	162 (60%)
Therapeutic	123 (34%)	86 (32%)
Judgment	25 (7%)	21 (8%)
Equipment	57	56
Diagnostic	9 (16%)	6 (11%)
Therapeutic	48 (84%)	50 (89%)
Judgment	0 (0%)	0 (0%)
Registration	95	93
Diagnostic	70 (74%)	43 (46%)
Therapeutic	24 (25%)	50 (54%)
Judgment	1 (1%)	0 (0%)
Interviews*	58	200
Diagnostic	48 (83%)	115 (58%)
Therapeutic	6 (10%)	66 (33%)
Judgment	4 (7%)	19 (10%)
Total	438	500
Diagnostic	278 (63%)	285 (57%)
Therapeutic	131 (30%)	175 (35%)
Judgment	29 (7%)	40 (8%)

Table 6.1 Number of inventoried competencies of ambulance nurse and mobile medical team physician by data source and category. MMT, mobile medical team.
[a]The number of competencies shown are the competencies which were not inventoried from the protocols, equipment, or registration.

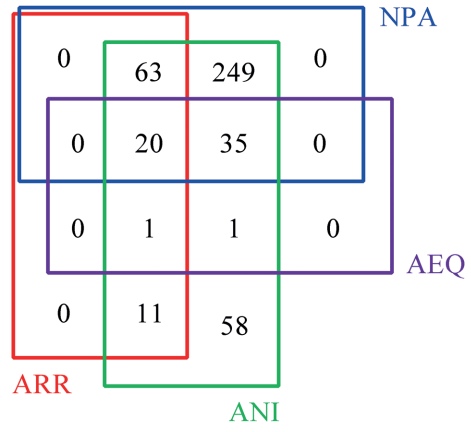


Figure 6.2 Venn diagram showing number of ambulance nurse competencies by data source. Total competencies: 438 Registration: Ambulance Run Report (n=95) Interviews: Ambulance Nurse Interviews (n=438) Protocols: National Protocol Ambulance Care (n=367)
Equipment: Ambulance Equipment (n=57)

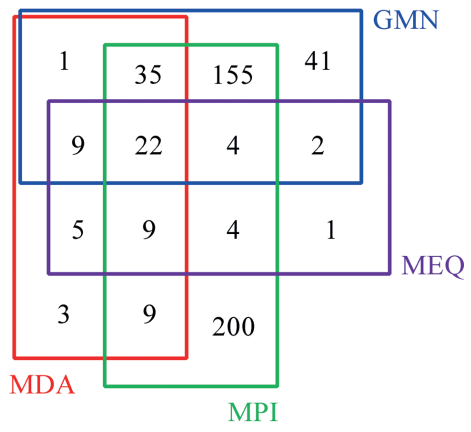


Figure 6.3 Venn diagram showing number of mobile medical team physician competencies by data source. Total competencies: 500 Registration: Mobile Medical Team Database (n=93)
Interviews: Mobile Medical Team Physician Interviews (n=438) Protocols: Guidelines Mobile Medical Teams in the Netherlands (n=269) Equipment: Mobile Medical Team Equipment (n=56)

Ambulance nurses

In the three studied ambulance data sources, we found 230 diagnostic competencies, 125 therapeutic competencies and 25 clinical judgment competencies. The interviews with the five ambulance nurses confirmed that all competencies inventoried from the ambulance data sources can be provided by the ambulance nurse. The ambulance nurse can provide 58 competencies from the MMT data sources that were not identified in the three ambulance data sources. For example, hallucinations are described as a symptom in the Guidelines Mobile Medical Teams in the Netherlands, but not in any of the ambulance sources. However, according to the interviewed nurses, ambulance nurses are competent to recognize a patient with hallucinations because of previous training in nursing school. Of the competencies from the MMT data sources, 62 competencies could not be provided by the ambulance nurse. According to the interviewed nurses, this was due to difference in education and training. For example, the ambulance nurse is not trained to perform a pericardiocentesis.

Mobile medical team physicians

In the three studied MMT data sources, we found 170 diagnostic competencies, 109 therapeutic competencies and 21 clinical judgment competencies. The interviews with the MMT physicians confirmed that all competencies inventoried from the MMT data sources can be provided by the MMT physician. Furthermore, they concluded that an MMT physician can provide all inventoried ambulance nurse competencies. There were 200 competencies from the ambulance data sources that were not identified in the MMT data sources. Without the presence of an ambulance however, 2 diagnostic and 18 therapeutic ambulance nurse competencies cannot be provided by the MMT, due to lack of necessary equipment. For example, the MMT does not carry a magnet to switch off an implantable cardioverter defibrillator (ICD) but the ambulance does.

DISCUSSION

Main results

The main finding of our study is that the MMT physician can provide all 438 ambulance nurse competencies plus an additional 62 competencies which cannot be provided by the ambulance nurse (see List of competencies specific for the Mobile Medical Team physician, Supplemental Digital Content 2). A large number of the diagnostic competencies (98%) can be provided by both ambulance nurse and MMT physician. The level of similarity in therapeutic competencies (75%) and clinical judgment competencies (73%) is less.

Most of the 62 MMT physician specific competencies are therapeutic competencies (71%) and related to advanced life support (airway management, resuscitation, anesthesia). These competencies are specific for the MMT physician because the difference in education and training (see: Comparison in education and training of ambulance nurse and MMT physician, Supplemental Digital Content 3).

Limitations

With this inventory we have not gained a comprehensive overview of all competencies of ambulance nurses and MMT physicians. There may be other competencies that were not mentioned in the studied data sources. This seems particularly the case for the clinical judgment competencies because the relatively low number of clinical judgment competencies found. The studied data sources are possibly less suitable to trace clinical judgement competencies. Protocols for example are more often based on quantative data (e.g. blood pressure) than on a clinical judgment (e.g. insufficient circulation). However, if certain diagnostic or therapeutic competencies have not been mentioned in the studied data sources, they are probably less relevant in the prehospital setting.

With this quantative inventory no information is obtained on the quality of the identified competencies. If there is a mutual competency of the ambulance nurse and MMT physician, there may still be a difference in quality of the competencies due to differences in training and experience [24]. It is also possible that the quality of a competency varies amongst ambulance nurses and MMT physicians, depending on individual background (e.g. the MMT physician can be an anesthesiologist or trauma surgeon) and experience (how often is a certain competency used?).

In the debate on the benefits of a prehospital physician, other relevant issues are beyond the scope of this study. For example, beneficial effects could also be the result of the ability to transport patients by helicopter, or an improvement of extrication procedures due to a higher exposure of vehicle entrapments.

We are aware that the results of this study are quite specific for the prehospital care system of the Netherlands. Nevertheless, there are three reasons why we think this study is interesting for the European emergency medicine community; First of all, the methodology of our study facilitates research in the complex prehospital emergency care setting and can also be used in other countries. In fact, it is relevant to obtain similar information on the competencies of nurses and physicians in other countries. The overlap in competencies may be larger or smaller, which may be a clue why the results of outcome studies on prehospital physicians vary. Secondly, this research method can also be helpful to compare EMS systems of different countries. And last, the additional competencies of the MMT physician are mainly related to advanced life support, airway management and anesthesia. We think these are also specific for all prehospital physicians in other European countries.

Implications for future research and prehospital care

This study has been initiated as a first step to better understand the role of physicians in the prehospital setting [15-17]. Our next step is to answer the questions: How often are the physician specific competencies provided? And, when a mutual competency is needed when both nurse and physician are on scene, who actually provides this competency and why? This study is now executed. Other relevant questions are: Are there differences in the quality of competencies amongst and between ambulance nurses and MMT physicians? The inventoried competencies in this study form the basis of this future research. In this way, future research might provide an answer to the question whether the additional competencies of the physician the main reason for the better outcome in certain groups of critical patients or a difference in quality of mutual competencies.

At the same time, the results of our study may already be useful to improve prehospital care. When ambulance nurses and MMT physicians know each other's competencies, an improvement of cooperation can be expected. In addition, the results of our study can be used to further improve primary and secondary dispatch criteria for the MMT [25]. The current HEMS dispatch criteria are mainly trauma related, but the additional competencies of the MMT physician are clearly also applicable in other medical emergencies. Finally, the specific and most frequently mentioned MMT physician competencies are related to advanced life support, airway management and anesthesia. Selection, education and training of MMT physicians should be focused on these competencies [26].

CONCLUSION

For many years, controversy exists on the possible benefits of a specialized physician in the prehospital setting. To better understand this issue, we have compared the competencies of ambulance nurses and MMT physicians. The ambulance nurse masters a wide range of competencies. When needed, the MMT physician can provide additional competencies on the scene. Most of these are therapeutic competencies and specific for MMT physician because difference in training and expertise. By analyzing competencies, we have gained valuable insight in the overlap and differences in competencies. With the results of our study, further research can now be started. These studies can help to improve the quality of prehospital emergency care.

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Ambulance nurse		MMT physician	
Diagnostic competency	**number of protocols**	**Diagnostic competency**	**number of protocols**
1. Blood pressure	20	1. Breathing (sufficiency)	10
2. Circulation (sufficiency)	18	2. Oxygen saturation (SpO_2)	9
3. Glasgow Coma Scale (GCS)	18	3. Auscultation	8
4. Electrocardiogram (ECG)	16	4. Disability (AVPU)	7
5. Breathing (sufficiency)	15	5. Wound/external bleeding	6
6. Frequency of breathing	15	6. Airway (clear?)	5
7. Heart rate	14	7. Signs of trauma	5
8. Events (history taking)	9	8. Neurotrauma	5
9. Asystole	9	9. Capnography	4
10. Shock	8	10. Circulation (sufficiency)	4
Therapeutic competency	**number of protocols**	**Therapeutic competency**	**number of protocols**
1. Intravenous drug administration	29	1. Oxygen therapy	13
2. Oxygen therapy	28	2. Ventilation	10
3. Ventilation	19	3. Endotracheal intubation	8
4. Intravenous access	15	4. Infusion therapy	6
5. Intravenous fluid administration	14	5. Prevent hypothermia	4
6. Chest compression	14	6. Stop bleeding	4
7. Endotracheal intubation	12	7. Needle thoracentesis	4
8. Epinephrine	10	8. Spinal immobilization	4
9. Spinal immobilization	9	9. Chest tube	4
10. Diazepam	9	10. Cricothyrotomy (surgical)	3
Clinical judgment competency	**number of protocols**	**Clinical judgment competency**	**number of protocols**
1. Indication for cervical spine immobilization	5	1. Airway threat is life-threatening	2
2. Medical care is necessary	3	2. Cricothyrotomy in compromised airway	2
3. Endotracheal intubation when GCS < 9	2	3. No intubation in difficult airway	2
4. Necessity of treatment to prevent serious condition	2	4. Intubation possible	2
		5. Sedation and relaxant necessary for intubation	2

Diagnostic competencies

1. Cold diuresis
2. Diafragm rupture
3. Hypocalcemia
4. Hypomagnesemia
5. Kidney failure
6. Malignant hyperthermia
7. Tracheobronchial injury

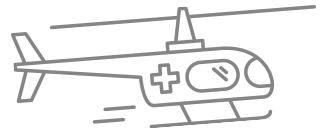
Therapeutic competencies

8. Amputation
9. Atracurium
10. Blood transfusion
11. Caesarean section
12. Calciumchlorid
13. Cefuroxime
14. Chest tube
15. Cricothyrotomy (surgical)
16. Dopamine
17. Ephedrine
18. Escharotomy
19. Etomidate
20. Fascia iliaca compartment block
21. Flumazenil
22. Gum elastic bougie
23. Hydrocortison
24. Hydroxycobalamine
25. HyperHaes®
26. Incision
27. Insulin
28. Intravenous access, central
29. Jet ventilation
30. Lidocaine
31. Laryngeal Mask Airway (LMA®)
32. Magnesium
33. Mannitol
34. Nasopharyngeal airway
35. Noradrenaline
36. Pericardiocentesis
37. Potassium
38. Procainamide
39. Propofol
40. Push foreign object from trachea into bronchus
41. Rocuronium
42. Ropivacaine
43. Succinylcholine
44. Sufentanil
45. Supraglottic airway
46. Suturing
47. Thoracotomy
48. Tracheotomy
49. Trachlight
50. Thrombolysis
51. Venesection

Clinical judgment competencies

52. Advance endotracheal tube in case of bronchus rupture
53. Cardiopulmonary bypass in hypothermia
54. Dialysis in hyperkalemia
55. Induction with s-ketamine in asthma/COPD
56. Intravenous lidocaine administration before endotracheal intubation in possibl intracranial hypertension
57. Intubation and ventilation in pneumonia
58. Magnesium in bronchial asthma/COPD
59. Push foreign object in further in bronchus
60. Resuscitation in hypothermia is beneficial
61. Supraglottic airway in "cannot intubate, cannot ventilate" situation
62. Thrombolysis in pulmonary embolus

	Ambulance nurse	**MMT physician**
Title/degree	Registered nurse (4 years)	Physician (6 years)
Specialty	Emergency department nurse, or Intensive care nurse, or Anesthesia nurse (1-3 years) Additional national ambulance care training (4 months)	Anesthesiologist (5 years) or Trauma Surgeon (6 years), or final-year resident in Anesthesiology or Surgery
Obligatory courses	Prehospital Trauma Life Support (PHTLS®) Pediatric Life Support course (in-service)	Advanced Life Support (ALS®) Advanced Trauma Life Support (ATLS®) Extrication course (ICET®) Advanced Pediatric Life Support (APLS®) Advanced airway management
Recommended courses	Trauma Nursing Core Course (TNCC®)	Major Incident Medical Management System (MIMMS®) Advanced HazMat Life Support (AHLS®) Emergency Management of Severe Burns (EMSB®)



Chapter 7

Understanding the prehospital physician controversy.
Step 2: analysis of on-scene treatment by ambulance nurses and helicopter emergency medical service physicians.

PART 3

Hans van Schuppen

Joost Bierens

Eur J Emerg Med. 2015 Dec;22(6):384-90.w

ABSTRACT

Objective

In our previous study we identified the similarities and differences in competencies of ambulance nurses and Helicopter Emergency Medical Service (HEMS) physicians in the Netherlands. This ensuing study aims to quantify the frequency with which the additional therapeutic competencies of the HEMS physician are utilised and to determine whether this is the main reason for usefulness as perceived by ambulance nurses and HEMS physicians.

Methods

A prospective observational study was carried out in a two month period, with one HEMS station covering six ambulance regions. Provider registration was recorded, supplemented by interviews of ambulance nurses and HEMS physicians. Competencies were categorised depending on whether the competency was specific for the nurse or physician, mutual or mutual with a qualitative difference.

Results

A total of 225 HEMS dispatches resulted in 117 cases with HEMS on scene in the study region and 78 patients were included. In 35 (45%) patients, the HEMS physician provided additional treatment: in 19 (24%) patients a physician specific therapeutic competency, in 9 (12%) patients a mutual competency with a qualitative difference and in 7 (9%) patients both categories. The presence of the HEMS physician was regarded more useful by both ambulance nurses (89% vs. 60%) and HEMS physicians (97% vs. 81%) when additional treatment was provided by the HEMS physician.

Conclusions

HEMS physicians provide additional treatment in 45% of patients. The additional treat ment increases the perceived usefulness of the HEMS physician. The presence of the HEMS physician was also regarded useful when the physician did not provide any additional treatment, possibly because of diagnostic competence and clinical decision making.

INTRODUCTION

For years, there has been ongoing debate on the role and effectiveness of prehospital physi cians [1, 2]. Outcome-related studies are rarely feasible in the prehospital setting and result in conflicting conclusions, which are often based on complex statistics [3-5]. Moreover, prehospital systems vary among different countries, making it very difficult to compare results [6, 7]. It has been suggested that other research methods rather than outcome studies are required to study requirements and performance of prehospital physicians [8, 9]. Furthermore, the debate is not limited to outcome. Prehospital treatment aimed at reducing symptoms and morbidity is relevant as well. Therefore, we chose for a non-outcome study to determine the scale of additional treatment by prehospital physicians and if this is the main reason for the perceived usefulness of the physician. To know whether the treatment provided by the physician really is an addition to the prehospital care provided by the ambulance crew, one must first compare the ambulance service and the Helicopter Emergency Medical Service (HEMS). In a previous publication, the step-one study, we described the exact overlap and difference in diagnostic, therapeutic and clinical decision making competencies of ambulance nurses and HEMS physicians in the Netherlands, based on analysis of protocols, equipment and registration [10]. The study showed that the ambulance nurse has 131 and the HEMS physician has 175 therapeutic competencies. There are forty-four HEMS physician specific therapeutic competencies, including ten invasive procedures (i.e. placing a chest tube, performing an escharotomy), twenty-three medications which are not carried by the ambulance nurse (i.e. etomidate, rocuronium, hypertonic fluid) and eleven other advanced procedures (i.e. airway management techniques, nerves blocks). Theoretically, an added value of the prehospital physician can be an additional treatment (i.e. a quantitative difference in competencies: one of the 44 competencies), a higher skill level than that of an existing ambulance nurse treatment (i.e. a qualitative difference in one of the 131 mutual competencies) or because of another aspect of clinical care apart from the therapeutic competencies (i.e. diagnostic competency or clinical decision making). Knowing the exact competencies enables us to take step two in unravelling the prehospital physician controversy by asking ourselves three questions: how often does the physician provide treatments that cannot be provided by the ambulance nurse? How often does the physician provide a certain treatment that can also be provided by the ambulance nurse, but is provided by the physician because of a greater level of competency? Is it solely the additional therapeutic competency that makes the prehospital physician useful?

Setting

Prehospital emergency care in the Netherlands is provided by ambulances staffed by a nurse and a driver [10-12]. Ambulance nurses are registered nurses with extra training and working experience in a relevant field, like the Emergency Department or Intensive Care. They receive a 7-month national postgraduate training in prehospital care to become certified as an ambulance nurse. Additional prehospital care can be provided by Helicopter Emergency Medical Services (HEMS), called Mobile Medical Teams (MMT), staffed by a physician and a nurse. The HEMS physicians are mainly anesthesiologists and occasionally trauma surgeons. They attended relevant life support, major incident, airway and rescue courses as well as flight-safety and crew resource management (CRM) training. The country is covered by four HEMS stations. HEMS dispatch is based on a set of formally established criteria: either based on the call to the dispatch centre (primary dispatch) or on the request of the ambulance nurse on the

scene (secondary dispatch). The ambulance nurse can decide to cancel a primary HEMS dispatch, based on their national protocol. In 2012, there were 500835 emergency dispatches of ambulances and 5489 HEMS dispatches [13]. Thus, HEMS is dispatched in 1.1% of the emergency ambulance dispatches. Both ambulance nurses and HEMS physicians have their own set of protocols and guidelines.

METHODS

Design

This was a prospective, observational study based on an analysis of prehospital cases in which both an ambulance nurse and a HEMS physician were involved. The Amsterdam HEMS and six ambulance regions took part in this study, accounting for 24% of the Dutch population in the north-west part of the country (area: 5569 km2). All dispatches of the Amsterdam HEMS during a two-month period were eligible for inclusion in this study. Patients who were treated by both the ambulance nurse and HEMS physician and in which all necessary data could be gathered were included. Exclusion criteria were: cancellation of the HEMS by the on-scene ambulance nurse, dispatch outside the study region, no actual cooperation of ambulance nurse and HEMS physician (e.g. patient was dead on arrival) or incomplete data set (e.g. run report could not be gained).

Primary data analysis

Data from both the ambulance run report and HEMS database of included patients were analysed on which therapeutic competencies were provided. Next, additional information was collected by semi-structured interviews with the involved ambulance nurses and HEMS physicians (separately). During the interview the following questions were asked:

1. Which of the registered therapeutic competencies did you provide?
2. Did you provide other therapeutic competencies that were not registered?
3. Did you ask the ambulance nurse/HEMS physician to provide a certain competency because the other was more competent?
4. Was the presence of the HEMS physician useful?
   of vital importance / yes / reasonable / not really / no / counterproductive / don't know

After analysis of the registration and the interviews, an overview was made on who provided which therapeutic competency in that specific patient, if there was any request to the other provider to provide a mutual competency and if the ambulance nurse and HEMS physician thought the presence of the HEMS physician was useful. The competencies which were provided by the ambulance nurse and HEMS physician were divided in categories AMBU1-3 and HEMS1-3, based on the quantitative and qualitative differences in competencies (table 7.1). These categories were based on our previous study [10]. In order to study the relationship between the additional therapeutic competencies and perceived usefulness, the percentage of a positive answer on the question on usefulness (either 'of vital importance', 'yes' or 'reasonable') was calculated in patients were the HEMS physician provided additional treatment (HEMS1 and/or HEMS2 competency) versus no additional treatment (none or only HEMS3 competencies).

category	quantitative difference	qualitative difference	description	example
HEMS1	+	n/a	Competency is specific for HEMS physician.	Performing rapid sequence induction (RSI), chest tube, escharotomy, etc.
AMBU1	+	n/a	Competency is specific for ambulance nurse.	None. In previous study shown to be not existing.[10]
HEMS2	-	+	Mutual competency provided by HEMS physician because higher quality, like in cases in which ambulance nurse asked HEMS physician to provide competency.	Endotracheal intubation when previous attempts by ambulance nurse had failed or in expected difficulty.
AMBU2	-	+	Mutual competency in which HEMS physician asked ambulance nurse to provide competency.	Placing splinting device in which the ambulance nurse has more experience.
HEMS3	-	-	Mutual competency provided by HEMS physician on own initiative.	Placing intravenous access when ambulance nurse was busy with other treatment.
AMBU3	-	-	Mutual competency provided by ambulance nurse on own initiative.	Ambulance nurse gives patient oxygen.

Table 7.1 Categories of analyzed competencies of HEMS physician and ambulance nurse, based on quantitative and/or qualitative difference, with description and example. N/a: not applicable, HEMS: Helicopter Emergency Medical Service, AMBU: Ambulance.

The data was analysed by HvS and checked by JB. Both authors are not affiliated with one of the ambulance regions, nor HEMS. The methodology of data collection and data analysis was described in a research proposal that was accepted by the Medical Ethics Committee of the VU University Medical Center. All collected data were processed in a spreadsheet in Microsoft Office Excel 2007 (Microsoft Corporation, USA). Additional analysis was made with SPSS Statistics 22 (IBM, USA). The data were analyzed with Fisher's exact test (two-tailed) and the Pearson Chi-Square test. P-values less than 0.05 were considered to be significant.

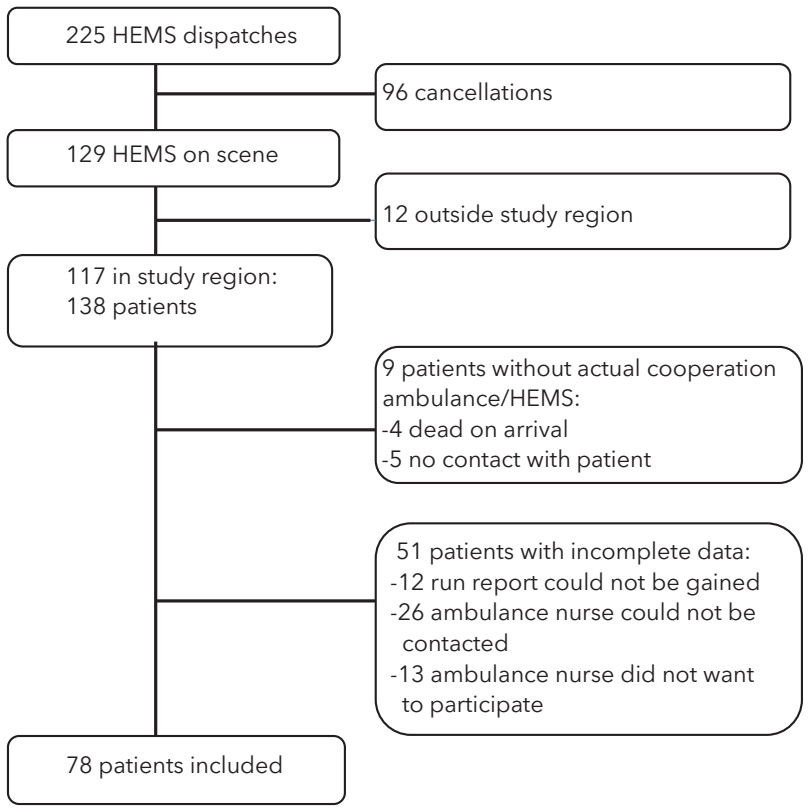


Figure 7.1 Inclusion and exclusion of dispatches and patients. HEMS, helicopter emergency medical service.

RESULTS

In the two-month study period, the HEMS of Amsterdam received 225 calls, which resulted in 117 (52%) times of actual on-scene presence of HEMS in the study region (Fig. 7.1). Because of 9 multi-casualty incidents, the total number of patients is 138. In 78 (57%) of these patients all data could be gathered (table 7.2). Based on the analysis of the ambulance and HEMS registration and the semi-structured interviews, a total of 686 therapeutic competencies were identified and divided into the previous described categories. Of these 686 therapeutic competencies, 435 were provided by ambulance nurses (all cat. AMBU3) and 251 were provided by HEMS physicians. Of these 251 competencies, 64 were specific for the physician (cat. HEMS1) and 23 were mutual competencies but provided by the HEMS physician because of a qualitative difference (cat. HEMS2). There were no instances where an HEMS physician asked the ambulance nurse to provide a competency because the ambulance nurse was more competent (cat. AMBU2). The ambulance nurse provides an average of 5.6 (range 0-11) and the HEMS physician 3.2 (range 0-12) therapeutic competencies per patient.

Included dispatches (n=75)	**N (%)**
Primary dispatch	65 (87%)
Secondary dispatch	10 (13%)
Dispatch criterium	
Trauma, including:	53 (68%)
Traffic accident	22 (28%)
Fall from height	15 (19%)
Penetrating trauma	2 (3%)
Non trauma:	25 (32%)
First on the scene	
Ambulance	66 (88%)
HEMS	9 (12%)
Included patients (n=78)	**N (%)**
Children (age 0-16)	18 (23%)
Revised Trauma Score (RTS)	
Average RTS	9.2
RTS 12	44 (56 %)
RTS 0	14 (18%)
Died on the scene (excl. dead on arrival)	4 (5%)
Means of patient transport:	
Transport per ambulance with physician	48 (62%)
Treatment on scene, transport by ambulance without physician	28 (36%)
Transport by helicopter	2 (2%)
HEMS1 and HEMS2 competencies	
Patients with one or more HEMS1 competencies*	26
Emergency anesthesia (rapid-sequence induction)	10 (13%)
High-dose analgesia (exceeding ambulance protocol)	9 (12%)
Antibiotics	4 (5%)
Other HEMS specific medication	7 (9%)
Patients with one or more HEMS2 competencies*	16
Endotracheal intubation during cardiac arrest	4 (5%)
Intravenous access	7 (9%)
Repositioning and immobilisation of fractures	3 (4%)
Medication	2 (3%)

Table 7.2 Characteristics of included dispatches, patients and HEMS1/HEMS2 competencies. HEMS1: therapeutic competency which is specific for HEMS physician. HEMS2: mutual therapeutic competency provided by the HEMS physician because of qualitative difference. *) overlap exists in these patients because in 7 patients both HEMS1 and HEMS2 competencies were provided.

In 35 (45%) out of 78 patients the HEMS physician provided treatment that exceeded the competency of the ambulance nurse (table 7.2). In 26 (33%) patients the HEMS physician provided a HEMS1 competency, in 16 (21%) patients a HEMS2 competency, with an overlap of 7 (9%) patients in which both HEMS1 and HEMS2 competencies were provided.

Figure 7.2 shows that 73% of ambulance nurses and 88% of the HEMS physicians were positive regarding the usefulness of the HEMS dispatch. The ambulance nurses were significantly less positive on usefulness as compared with the HEMS physicians (Pearson Chi-Square test: p:0.02). Figure 7.3 shows that a significant higher percentage of ambulance nurses (p<0.01) and HEMS physicians (p:0.03) gave a positive answer on the question on usefulness in patients were the HEMS physician provided additional therapeutic competencies versus patients where the HEMS physician provided no additional therapeutic competencies.

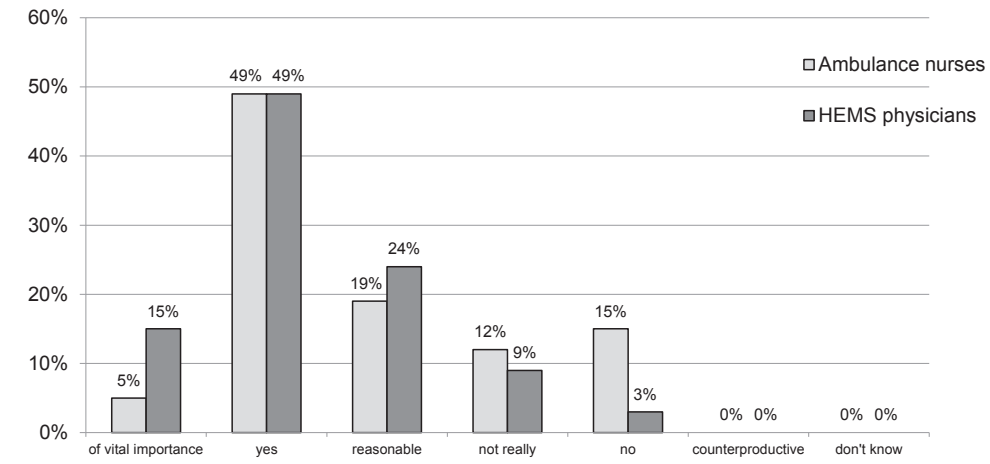


Figure 7.2 Response to question 'Was the presence of the HEMS physician useful?' according to ambulance nurses and HEMS physicians. HEMS, helicopter emergency medical service.

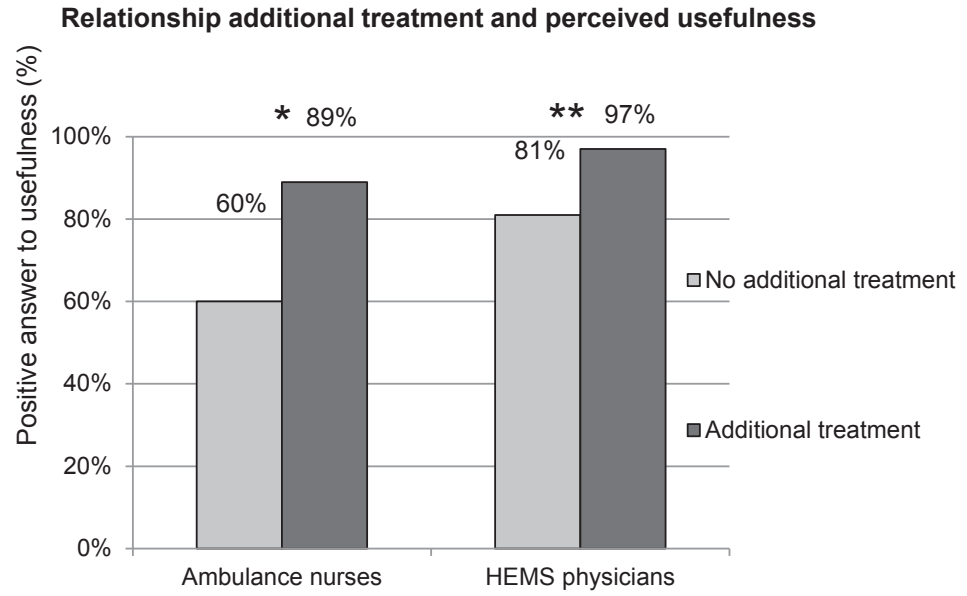


Figure 7.3 Percentage of positive answers to usefulness in the group of patients where the HEMS physician did not provide additional therapeutic competencies (none or only cat. HEMS3 competencies) versus the group of patients where the HEMS physician provided additional therapeutic competencies (cat. HEMS1 and/or HEMS2 competencies). Ambulance nurses 60% (95% confidence interval 45-75%) versus 89% (95% confidence interval 79-99%) *p<0.01; HEMS physicians 81% (95% confidence interval 69-93%) versus 97% (95% confidence interval 91-100%) **p<0.04. HEMS, helicopter emergency medical service.

DISCUSSION

Main results

This study shows that patients in which prehospital care is given by ambulance nurses in collaboration with a HEMS physician, the ambulance nurses provided the majority of therapeutic competencies, reflecting the provision of prehospital care by ambulance nurses who in general are first on the scene. In 45% of these patients, the physician provides treatment that exceed the therapeutic competencies of the ambulance nurse, either quantitatively (33%), qualitatively (21%) or both (overlapping 9%).

Extrapolating these results, each year approximately 1750 patients receive additional treatment by the HEMS which could otherwise not have been provided by ambulance nurses. This is based on 6000 HEMS dispatches per year with a cancellation rate of around 45% and an average of 118 patients per 100 dispatches (this study)[13, 14] .

A similar study from the UK showed that HEMS physicians provided treatment that exceeded ambulance protocols in 68 out of 100 patients [15]. The reasons of the higher percentage in comparison with our study are possibly the difference in dispatch criteria, geography and in competencies of the UK paramedics compared to the ambulance nurses in the Netherlands.

When the HEMS physician provided additional treatment, both ambulance nurses and HEMS physicians regarded the HEMS dispatch more useful. However, when the HEMS physician did not provide any additional competencies, both ambulance nurses and HEMS physicians still regarded the presence of the HEMS physician as useful in the majority of patients. During the interviews, the following reasons were given by both the ambulance nurses and the HEMS physicians:

- to have the possibility to provide treatment should the patient deteriorate
- other additional competencies, like diagnostic competencies and decision making
- HEMS was first on the scene
- simply the extra pair of hands (as reflected by the HEMS3 competencies)

Relevance

Our study indicates that the debate on the role and effectiveness of the prehospital physician should not be limited by the additional treatment which can be provided by the physician. It should also include qualitative differences in treatment which can also be provided by ambulance crew and non-therapeutic competencies of the HEMS physician. For example, the clinical judgment of the condition of the patient and the subsequent decision of the HEMS physician to pause the treatment by the ambulance crew and start with transporting first in order to get the patient to the hospital faster, could be life-saving although no measureable therapeutic interventions are provided by the prehospital physician. The impact of a physician on decision making in a HEMS system is previously described [9, 16]. This study also suggests that the debate on the prehospital physicians should not be limited to outcome. Other treatment goals may also useful in the prehospital setting, like adequate pain relief through high dose analgesia [15, 17, 18].

The data in this study show a difference in opinion on the usefulness of the prehospital physician between the ambulance nurses and HEMS physicians. This could be caused by some over-estimating of the HEMS physicians on their role or an incomplete insight in the additional competencies of the HEMS physicians by the ambulance nurses. Either way, a better insight in, and appreciation of, each others competencies will increase mutual understanding and the quality of prehospital care.

Limitations

We did not study the effect of the additional treatment on outcome. As stated in the introduction, this was a conscious decision and the study design to answer our research question is not sufficient to make any conclusions regarding outcome; This is not a randomized trial and confounders are difficult to identify and even more difficult to correct for. Lastly, many patients are needed before a significant result can be detected. An advantage of de-emphasizing outcome in the results is keeping a broader view on all aspects of prehospital care, like symptomatic treatment and deciding to end a resuscitation effort. We did not study diagnostic competencies and clinical decision making, for which other research methods have to be used [19]. In 51 out of 129 patients (39.5%), not all data could be gained (Fig. 7.1). Selection bias could have occurred in 13 patients, because the ambulance nurse did not want to participate. We estimate that this does not have a significant effect on the main results. Observer bias is not relevant because of the use of predefined criteria and little room for alternative explanation. We did not use a validated satisfaction survey. Potential conflict of interest exists for the HEMS physicians, like stated in the discussion section. The number of included patients is limited, so sub analysis on specific groups of patients is not feasible. This would be interesting, seen that other studies have concluded that notably in children additional competencies are needed [18, 20].

Future research

The results of this study leads us to step 3 in the research on the prehospital physician controversy. This next study should focus on which non-therapeutic competencies of the physician are useful and to determine predictors of patients needing physician specific treatment. Ultimately, this should increase our understanding on how to get the right person, at the right time, to the right patient. To date this complex issue is still not resolved [21-24].

CONCLUSION

In 45% of patients treated by ambulance nurses and HEMS physicians in the prehospital setting, the HEMS physician provides treatment which exceed the competencies of the ambulance nurse. This is either a therapeutic competency which is specific for the HEMS physician and/or a mutual competency which is provided by the HEMS physician because of a qualitative difference. There was a higher perceived usefulness when additional competencies were provided by the physician, but it was not limited by this factor. Probably other factors also contribute to the usefulness of a prehospital physician, like additional diagnostic competencies or clinical decision making. This insight in additional competencies can form the basis for initiatives to increase cooperation and thus increasing the quality of prehospital care and facilitate further steps in research on the controversy of the prehospital physician.

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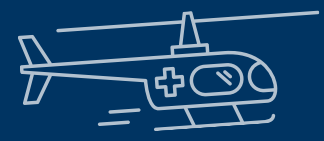
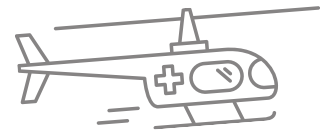


PART 4

Discussion, future perspectives and summary



Chapter 8

Discussion and
future perspectives

PART 4

Making sure oxygen is entering the lungs is a primary and essential goal of emergency care but in the prehospital setting this can be a great challenge. Airway obstruction, difficult laryngoscopy, cardiac arrest and the complex prehospital setting can make it difficult to achieve an open airway and ventilate the lungs in critical patients. Possible strategies to improve performance are more extensive training and exposure, improve design of existing devices, invention of new devices or a better interaction between the provider and the equipment that is used.

This thesis focuses on optimizing airway management and ventilation during prehospital advanced life support and the role of a prehospital physician; We present a review of the literature which shows that the Glidescope® videolaryngoscope can improve endotracheal intubation success rate when used by providers with limited experience in intubation. We studied two needle emergency front-of-neck airway devices in a simulated "cannot intubate, cannot oxygenate" scenario, and learned that it is very useful to test these interventions in a simulated stressful scenario. When patients receive cardiopulmonary resuscitation, mechanical chest compression devices should probably pause chest compressions for five seconds to allow providers to give two insufflations. Specialized physicians can bring additional treatment in the prehospital setting and do so in almost half of the cases they attend, although added value seems broader than additional treatment only.

The need for advanced airway management is relatively uncommon in the prehospital setting. On average, ambulance nurses in the Netherlands need to provide an advanced airway (endotracheal intubation or supraglottic airway device) about five times per year. Although endotracheal intubation has been regarded as the gold standard for airway management during resuscitation for many years, recent studies have shown that a supraglottic airway device maybe a good alternative or even superior to endotracheal intubation. This has led to a further decrease in the frequency of prehospital intubation by ambulance nurses, further limiting their experience. However, ambulance nurses can still be confronted with a patient with an indication for intubation, for example if a supraglottic airway device cannot be successfully placed during cardiopulmonary resuscitation. This leads to the situation that the ambulance nurse needs to perform intubation in patients who already have a small margin for oxygenation. In chapter 3 we describe that the Glidescope® videolaryngoscope gives providers with limited experience in endotracheal intubation a higher chance of successful endotracheal intubation, shorter procedure time and a decrease in interruption of chest compressions when the patient is in cardiac arrest. Further studies are needed to determine the impact of this improvement on patient outcomes, but with the available data it can be considered to recommend using videolaryngoscopy to perform endotracheal intubation by ambulance nurses. Currently, a few ambulance regions in the Netherlands already have started to implement videolaryngoscopy in their standard equipment and procedures, and this development should be accompanied with data collection on endotracheal intubation performance and patient outcomes.

When facemask ventilation and all advanced airway techniques are unsuccessful, emergency Front-Of-Neck-Airway (eFONA) is indicated. In chapter 4 we present insights from an incomplete randomized controlled trial describing the comparison of the QuickTrach® and Ventrain® eFONA devices in a simulated "cannot intubate, cannot oxygenate" (CICO) scenario. Ambulance nurses were trained in both devices and then had to perform eFONA with one of these devices in a simulated CICO case. Despite the fact that they were trained with the respective devices, we observed difficulties in performing this procedure when being under stress in a realistic albeit simulated setting. Both devices had unsuccessful placements and complications, and we have learned that the design of both devices can probably be improved. We recommend manufacturers of eFONA devices to test their products by providers in a simulated setting resembling real-live situations to learn how end-users will use the device in such a stressful situation, allowing the design to be improved. Basic skill training in the use of these devices seems to be insufficient for providers to be optimally prepared for actual CICO situations. Future studies should aim to determine what the minimum amount of skill training includes to be able to perform eFONA in a stressful realistic setting. The participants of our study valued the scenario, and we recommend standard training for CICO scenarios, following basic skill training in the use of these devices. After improvements in the design of the devices, and more intensive training, a follow-up study with a similar methodology is desirable to actually determine any difference in time needed to achieve oxygen insufflation of both eFONA devices.

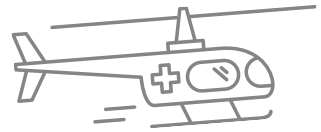
Airway management and ventilation are not provided in isolation of other aspects of emergency care. In patients with cardiac arrest, high quality chest compressions are essential. Chest compressions should be given with an adequate depth, with minimal interruptions, allow full recoil and should be altered with ventilations. Mechanical chest compression devices can be used to provide high-quality chest compressions. These devices pause chest compressions for three seconds to allow providers to give two insufflations. This pause duration has no scientific basis. In clinical practice, it is a challenge to provide two adequate insufflations in the current pause of three seconds. The optimal compression pause duration would allow providers to give two insufflations in the majority of pauses on one hand, and prevent unnecessary long chest compression interruptions on the other hand. In chapter 5 we describe a study to explore the optimal compression pause duration for mechanical chest compression devices to provide two insufflations. In the context of manual chest compressions in our study, more than three seconds were needed to provide two insufflations in a significant number of pauses in chest compressions. We therefore propose to alter the standard pause for ventilations of mechanical chest compression in these devices from three to five seconds. Currently, we are conducting a follow-up study on the ventilation performance in the context of mechanical chest compression. In other words: in what proportion of three-second pauses in mechanical chest compression can two insufflations be observed? In addition, it would be valuable to determine if these ventilations are given with an adequate tidal volume. Furthermore, new studies should be performed on the effects of a five-second pause in mechanical chest compression on ventilation performance during resuscitation. A pause of five seconds also allows for rhythm check during this interruption in chest compressions. This can make the process of resuscitation easier for emergency care providers. A chest compression pause duration of five seconds has the potential for better oxygenation, shorter rhythm checks and a simpler procedure and there has the potential to have a positive impact on survival.

When procedures are complex and are performed with low frequency, optimization is possible by concentrating these procedures to a smaller group of providers. In the Netherlands, mobile medical teams (MMT) are dispatched to critical patients to provide specialist care in

addition to Emergency Medical Services (EMS). In this way, treatments which would otherwise only be possible in hospital are now available on scene. In chapter 6 we provided a theoretical framework to identify these additional competencies. A total of 438 competencies of the ambulance nurse were identified and MMT physicians has the same and 62 additional competencies, based on analysis of protocols, equipment and registration. Knowing what additional treatment can be provided by the MMT physician on the scene provides valuable insight to optimize dispatch criteria and collaborate on scene, or to consider to cancel the MMT. This insight should therefore be included in education for ambulance services. Defining what the theoretical framework is in competencies of both EMS and HEMS, enables researchers to design and/or interpret research on prehospital physicians in various countries and prehospital systems. In other words, when a specific intervention by HEMS is useful for a specific group of patients in one country, it does not mean that HEMS should be dispatched to these patients in other countries because the EMS in other countries may be able to provide this intervention. Although much emphasis is given on additional treatments, it is also good to realize that additional care by the prehospital physician also includes extra diagnostic capabilities (e.g. ultrasound) and clinical decision-making (e.g. termination of resuscitation). When compared to the competencies of ambulance nurses, the largest differences were found in the domain of treatment and clinical decision-making and were related to airway management, advanced life support and anesthesia. Potential benefits of prehospital physicians can be these additional competencies, or a mutual competency with a qualitative difference, for example in endotracheal intubation. All these aspects deserve attention in education and research on prehospital physicians and should ideally be updated periodically due to changes in care by EMS and MMTs.

Knowing what the potential additional treatment of prehospital physicians is, the question then was how often this is needed during actual prehospital cases. In chapter 7 we describe a prospective observational study in which we found that in almost half of the cases, the physician provided treatment additional to ambulance care like emergency anesthesia, airway management and analgesia. Noteworthy is that ambulance nurses regarded the presence of a prehospital physician more useful in cases with additional treatment, but also regarded them useful when no additional treatment was provided. Possible explanations include the mentioned diagnostic and clinical decision-making competency, but could also be due to an increase in perceived patient safety because more therapeutic options are present should the patient deteriorate. These aspects could form a basis for on-scene dialogues between ambulance nurses and MMT physicians in cases where no additional treatment by the prehospital physician is required, for example when discussing if the physician needs to accompany the patient with transport to the hospital. The debate on the effects of a prehospital physician will probably continue, because of challenges in methodology of prospective intervention trials, various prehospital systems throughout the world, difficult interpretation of the effects of prehospital interventions on patient outcomes and a wide range of opinions and expectations on the subject both in the public and in professionals. With our studies, we hoped to provide a more systematical and objective way to approach this subject to help improve both research and collaboration on scene. Future studies can now focus on the impact of additional care by the MMT on specific patient categories like out-of-hospital cardiac arrest; Is there a higher likelihood that reversible causes of the arrest are detected when a MMT physician is on the scene? Is there an improvement in the performance of the resuscitation (e.g. chest compressions, ventilations, defibrillations) and return of spontaneous circulation when MMT is on the scene?

Research on improving resuscitation is as fascinating as it is challenging. Just like an actual resuscitation, we need to deal with many uncertainties, have to focus on the essentials, maintain an overview of the total context and need teamwork to achieve success. Combining clinical care with education, science and innovation provides the strong framework we need for future studies to be focused on the right questions, in the right context, with the right team members and aiming for the right solutions to improve survival. The first step in this journey is data collection. We cannot improve what we do not measure. The AmsteRdam REsuscitation STudies (ARREST) registry prospectively collects data of out-of-hospital cardiac arrests since 2005 and has led to many relevant studies since. The future of resuscitation science is to make ARREST an integral part of clinical care, quality evaluation, education and innovation. And that future is bright.



Chapter 9

Summary

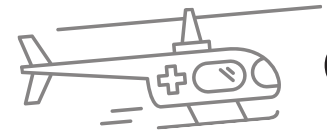
PART 4

In critical patients, like out-of-hospital cardiac arrest, it is essential to provide resuscitation including airway management and ventilation. The combination of unclear events, unclear background of the patient, the complex prehospital setting and the enormous time pressure provide a great challenge for prehospital emergency care providers to perform these critical interventions. In addition, many of these interventions, like tracheal intubation and emergency front-of-neck airway (eFONA), are infrequently provided by ambulance crew because of limited exposure to these cases. Still, managing the airway and achieving oxygenation is of paramount importance, while on the other hand this should not interfere with other critical interventions like chest compressions. It is therefore important to keep searching for possible ways how we can improve through training, development and testing of new devices and reorganizing systems of care. This thesis provides evidence to proceed in this direction.

In **chapter 1 and 2** an introduction and overview is provided with current in-depth insights in the subjects of this thesis. Starting with airway management in **Part 1,** we aimed to determine the possible benefits of the Glidescope® videolaryngoscope and Ventrain eFONA device. We compared these devices to the current standard of care by ambulance nurses who mainly use direct laryngoscopy for tracheal intubation and the QuickTrach® eFONA device for the "cannot intubate, cannot oxygenate" (CICO) scenario. In **chapter 3** we systematically reviewed trials comparing the use of the Glidescope® videolaryngoscope with direct laryngoscopy when used by providers with limited experience, defined by < 10 tracheal intubations per year. A total of 4 clinical trials with 525 patients were included, and 20 manikin trials with 2547 intubations were also found and separately analyzed. We found an increase in tracheal intubation first-pass success rate and clinical studies showed an decrease in procedure time. We also found a study describing a significant reduction in chest compression interruptions due to tracheal intubation when using the Glidescope®. In **chapter 4** we aimed to compare the time to achieve oxygenation when ambulance nurses use the eFONA devices QuickTrach® or Ventrain®, through a randomized controlled trial using a simulated CICO scenario with a manikin including a porcine airway model. Although the trial had to stop early and we could only include 20 of the planned 58 scenarios, we could still present some valuable lessons from this study. We observed a wide range in the observed time interval from the decision to preform eFONA to the moment of oxygen insufflation, which was the primary outcome of this study. Complications were observed in both devices, although the specific complications varied per device. Participants rated the scenario as realistic and stressful, and the Ventrain® as easy to use more often than the QuickTrach®. We observed unsuccessful attempts in both groups, indicating possible improvements for the design of these devices and skills training to learn how to use these devices correctly.

Part 2 focuses on ventilation during cardiopulmonary resuscitation (CPR). In **chapter 5** we described an observational study on the time needed to provide two insufflations when providing CPR with a chest compression to ventilation ratio of 30:2. Current mechanical chest compression devices typically provide a compression pause of 3 seconds to give two insufflations, but we question if this is the optimal pause duration. We included 132 out-of-hospital cardiac arrests with manual chest compression, and observed that the chance of successfully providing two insufflations increases with longer chest compression pauses, up to a pause duration of 5 seconds. In 28% of the pauses with two insufflations, giving two ventilations took longer than 3 seconds. A timeframe of 5 seconds seems the optimal compression pause duration for mechanical chest compression devices. This would also allow for interventions like heart rhythm checks.

In **Part 3** we aimed to explore the added value of physicians in the prehospital setting. In **chapter 6** we provide a theoretical framework of competencies based on analysis of national protocols, equipment, registration and interviews. Based on these data sources, we determined that ambulance nurses have 438 different competencies, including diagnostic, therapeutic and clinical decision competencies. Mobile Medical Team (MMT) physicians, as part of the Helicopter Emergency Medical Service (HEMS), have 500 competencies including the 438 ambulance nurse competencies and 62 additional competencies which were specific for the physician. The theoretical added value of the prehospital physician can be defined as the quantitative difference in competency with these additional competencies, and/or as a qualitative difference in one of the 438 mutual competencies. In **chapter 7** we analyzed 78 prehospital cases in which ambulance nurses and HEMS physicians collaborate, to determine how often HEMS provides additional treatment on scene. We found that additional treatment by the HEMS physician was provided in 45%, either by providing one of the 62 additional competencies in 24% of these cases, or providing one of the 438 mutual competencies on request of the ambulance nurse because a qualitative difference in competency in 12% of these cases, or both additional and mutual competencies in 9% of these cases. When the HEMS physician provided additional treatment on scene, there was an increased perceived usefulness of the presence HEMS physician in both ambulance nurses and HEMS physicians, based on individual interviews. When the HEMS physician did not provide any additional treatment, 60% of the ambulance nurses still regarded the presence of the HEMS physician as useful. Possibly this is due to competencies other than treatment, like diagnostic or clinical decision making.



Chapter 10

Summary in Dutch
- Nederlandse samenvatting

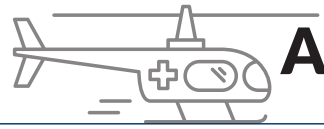
PART 4

Bij kritische patiënten, zoals een circulatiestilstand, is het essentieel om te starten met reanimatie inclusief luchtwegmanagement en beademing. De combinatie van de onduidelijkheid over wat er is gebeurd, onduidelijke voorgeschiedenis, de complexe prehospitale setting en de enorme tijdsdruk zorgen voor een grote uitdaging voor de prehospitale hulpverleners. Daarnaast worden veel van deze interventies, zoals endotracheale intubatie en nood luchtwegtechnieken (emergency front-of-neck airway, eFONA), weinig toegepast door een beperkte blootstelling aan situaties waarbij dit nodig is. Desalniettemin is het vrijmaken van de luchtweg en het oxygeneren van de patiënt van levensbelang, terwijl dit andere kritische interventies zoals borstcompressies niet mag tegenwerken. Daarom is het belangrijk om te blijven zoeken naar mogelijke manieren hoe we deze interventies kunnen verbeteren door training, het ontwikkelen en testen van nieuwe materialen en het reorganiseren van systemen. Dit proefschrift geeft een wetenschappelijke basis om verder te gaan in deze richting. In **hoofdstuk 1 en 2** wordt een introductie en overzicht gegeven met huidige inzichten in de onderwerpen van dit proefschrift.

Deel 1 richt zich op luchtwegmanagement, waarbij we proberen vast te stellen wat de mogelijke voordelen zijn van de Glidescope® videolaryngoscoop en de Ventrain® coniotomie set. We hebben dit vergeleken met de huidige standaard zorg door ambulanceverpleegkundigen, die met name directe laryngoscopie gebruiken voor intubatie en de QuickTrach® coniotomie set voor de situatie waarbij intubatie en oxygenatie niet mogelijk is ("cannot intubate, cannot oxygenate", CICO). In **hoofdstuk 3** hebben we de literatuur systematisch onderzocht om het gebruik van de Glidescope® te vergelijken met directe laryngoscopie, door hulpverleners met beperkte ervaring in intubatie, gedefinieerd als minder dan tien intubaties per jaar. Een totaal van vier klinische studies met 525 patiënten werden geïncludeerd, en 20 studies met simulatie poppen met 2547 intubaties werden gevonden en apart geanalyseerd. We vonden een toename in intubatie succeskans bij de eerste poging en de klinische studies lieten een kortere procedure tijd zien. We vonden ook een studie die een significante reductie beschreef in de onderbreking van de borstcompressies door de intubatie, als de Glidescope® werd gebruikt. In **hoofdstuk 4** beschrijven we een studie waarbij we het verschil in tijd tot oxygenatie wilde onderzoeken wanneer ambulanceverpleegkundigen de QuickTrach® of de Ventrain® gebruiken, door een gerandomiseerde studie met een gesimuleerd CICO scenario met het gebruik van een reanimatiepop en varkensmodel voor de luchtweg. Hoewel we de studie vroegtijdig hebben moeten stoppen en we daardoor maar 20 van de geplande 58 scenario konden includeren, konden we wel waardevolle lessen uit deze studie trekken. We hebben per coniotomie set een grote variatie van het tijdsinterval geobserveerd van de beslissing om de procedure te doen tot het moment van zuurstof insufflatie, wat de primaire uitkomstmaat was van deze studie. We hebben complicaties geobserveerd bij het gebruik van beide hulpmiddelen, hoewel de specifieke complicaties verschilden per hulpmiddel. De deelnemende ambulanceverpleegkundige vonden het scenario realistisch en stressvol en de Ventrain® werd vaker als makkelijk te gebruiken beoordeeld ten opzichte van de QuickTrach®. We hebben onsuccesvolle pogingen geobserveerd in beide groepen, wat een aanwijzing is voor mogelijke verbeteringen in het ontwerp van beide hulpmiddelen en de vaardigheidstraining om de deze apparaten correct te gebruiken.

Deel 2 richt zich op beademing tijdens reanimatie. In **hoofdstuk 5** beschrijven we een observationele studie over de tijd die nodig is om twee insufflaties te geven tijdens reanimatie met een ratio van borstcompressies tot beademingen van 30:2. Huidige mechanische thoraxcompressie apparaten geven meestal een pauze van de borstcompressies van 3 seconden om 2 beademingen te geven, maar de vraag is of dit de optimale pauzeduur is. We hebben 132 reanimaties buiten het ziekenhuis, waarbij manuele borstcompressies zijn gegeven, geïncludeerd in deze studie en geobserveerd dat de kans om twee succesvolle beademingen te geven toeneemt met een toenemende pauze duur, tot een tijdsinterval van 5 seconden. In 28% van de pauzes met 2 insufflaties duurde het langer dan 3 seconden om twee insufflaties te geven. Een tijdsinterval van 5 seconden lijkt de optimale borstcompressie pauzeduur voor mechanische thoraxcompressie apparaten. Dit tijdsinterval is ook geschikt om andere interventies te doen, zoals hartritme checks.

In **Deel 3** verkennen we de meerwaarde van artsen in de prehospitale setting. In **hoofdstuk 6** beschrijven we een theoretisch raamwerk van competenties gebaseerd op analyses van protocollen, materialen, registratie en interviews. Gebaseerd op deze bronnen hebben we vastgesteld dat ambulanceverpleegkundigen 438 verschillende competenties hebben, inclusief diagnostische, therapeutische en klinische besluitvorming competenties. Mobiel Medisch Team (MMT) artsen, hebben 500 competenties, inclusief de 438 competenties van ambulanceverpleegkundigen en 62 aanvullende competenties die specifiek zijn voor de arts. De theoretische meerwaarde van een prehospitale arts kan worden gedefinieerd als het kwantitatieve verschil in competenties door deze aanvullende competenties, en/of als een kwalitatief verschil in een van de 438 gemeenschappelijke competenties. In **hoofdstuk 7** beschrijven we een analyse van 78 prehospitale casus waarbij ambulance en MMT samenwerken, om vast te stellen hoe vaak de MMT arts aanvullende behandeling geeft ter plaatse. De MMT arts geeft aanvullende behandeling in 45% van de gevallen, door een van deze 62 aanvullende competenties toe te passen in 24% van de gevallen, of door het uitvoeren van een van de 438 gemeenschappelijke competenties op verzoek van de ambulanceverpleegkundige in 12% van de gevallen, of door zowel aanvullende als gemeenschappelijke competenties in 9% van de gevallen. Als de MMT arts aanvullende behandeling geeft ter plaatse is er een toename in de ervaren zinvolheid van het MMT bij zowel de ambulanceverpleegkundigen als de MMT artsen, gebaseerd op individuele interviews. Als de MMT arts geen aanvullende behandeling heeft gegeven ter plaatse, vindt 60% van de ambulanceverpleegkundigen de inzet van het MMT nog steeds zinvol. Mogelijk komt dit door andere competenties, zoals diagnostiek en besluitvorming.



Appendices

ABOUT THE AUTHOR

Hans (Johannes Lambertus) van Schuppen was born on October 20th 1982 and grew up in Veenendaal with his parents, two sisters and brother. His passion for emergency anesthesia started during high school, when he joined the Dutch Red Cross where he followed several first aid courses and joined the regional disaster response team. He studied Medicine at Maastricht University, beginning in 2001. During his medical training he remained active in emergency care, by becoming a Basic Life Support instructor and following internships at the ambulance service of Amsterdam and prehospital physician services of Leuven and Aachen. In the final phase of his training, Hans began his first study on prehospital physicians during an internship at the VU medical center in Amsterdam, mentored by prof. Joost Bierens.

After his graduation in 2007, Hans worked as ward doctor in the department of Cardiology of Meander medical center in Amersfoort. In 2008 he started his residency in Anesthesiology at the University Medical Center Utrecht, under the supervision of prof. Hans Knape and later on of prof. Reinier Hoff. Next to his clinical work, Hans worked at AmbuCare, covering shifts as ambulance nurse at several Dutch ambulance services. This resulted in a position as EMS Medical Director at AmbuCare and member of the Dutch Association of EMS Medical Directors (NVMMA). During the Venticare conference in 2012, the resuscitation team of the UMC Utrecht, with Hans as team leader, won the national resuscitation competition. At the end of his residency, Hans followed a rotation in prehospital emergency medicine at London's Air Ambulance. After his residency, he finished the fellowship in Intensive Care at the UMC Utrecht, under the supervision of prof. Jozef Kesecioglu and mentored by prof. Dirk Donker. Since 2018, Hans works as anesthesiologist at the Amsterdam UMC, focusing on resuscitation and prehospital care. In 2021, he joined the Mobile Medical Team (MMT) of Amsterdam as HEMS physician.

Throughout his medical career, Hans was increasingly active in resuscitation education. Following his role as Basic Life Support Instructor, he became an Instructor-Trainer. After some years as an active Advanced Life Support Full Instructor, Hans became a Course Director. He succeeded the Educator Masterclass of the European Resuscitation Council (ERC) in 2018, resulting in a role as ERC Educator and Course Educator for the European Trauma Course (ETC).

Next to his educational activities, Hans stimulated collaboration, knowledge dissemination and quality improvement through various activities like being part of the founding organizing committee of the multidisciplinary ResusNL conference, member of the expert group on national ambulance guidelines on resuscitation, member of the jury of the Venticare Resuscitation Competition and writing several book chapters on resuscitation. As a member of the Dutch Resuscitation Council, he co-authored the national resuscitation guidelines, and helped to develop and implement a nationwide standard operating procedure for the handover of out-of-hospital cardiac arrest patients. Currently, Hans is the chair of the Medical Committee and board member of the Dutch Resuscitation Council.

Eager to learn, his research on prehospital physicians evolved into a formal PhD research with the Amsterdam Resuscitation Studies (ARREST) group and the department of Anesthesiology, supervised by prof. Markus Hollmann, prof. Benedikt Preckel and dr. Rudy Koster. During his PhD project, he received a grant from the Zoll Foundation and AMC Foundation. In the final phase of his PhD, Hans was honored and grateful to take over the position from dr. Rudy Koster as director of resuscitation science of the ARREST group. He continues to study ways to optimize airway management and ventilation during prehospital life support, and envisions a close collaboration between clinical care, education, research and innovation in resuscitation.

Hans lives in Soest, together with his wife Jolanda and their four children Joëlle, Eliza, Lukas and Job. He loves to spend time with his family, have long walks and drinks with Jolanda, and - as can be expected from an anesthesiologist - loves coffee. Hans volunteers together with Jolanda at their local church and at the 4th Musketeer (4M) movement.

PORTFOLIO

Name PhD student:	J.L. van Schuppen
PhD period:	2017 - 2023 Part-time besides work as consultant in anesthesiology
PhD supervisors:	prof. dr. dr. M.W. Hollmann prof. dr. B. Preckel
PhD co-supervisor:	dr. R.W. Koster

PHD TRAINING

	Year	ECTS
General courses		
CRM training	2021	1
Resuscitology course, Resuscitology group	2019	1
Specific courses		
Prehospital Paediatric Life Support (PHPLS)	2021	1
Scherpschutters Training	2020	1
Clinical Data Management, Graduate School AMC	2018	0.5
Reanimate 5, ED ECMO San Diego	2018	1
Evidence Based Guideline Development	2018	1
European Trauma Course (ETC), ERC/ESA/EuSEM/ESTAS	2017	2
PubMed Basics, Graduate School AMC	2017	0.5
Searching for a CAT, Graduate School AMC	2017	1
Searching for Evidence, Graduate School AMC	2017	0.5
Searching for a Systematic Review, Graduate School AMC	2017	1
Embase/Medline via Ovid, Graduate School AMC	2017	1
EndNote, Graduate School AMC	2017	0.5
Scientific Writing for Publication, Graduate School AMC	2017	1
Basics course for Regulation and Organisation for Clinical Researchers (BROK) , Graduate School AMC	2017	1
Practical Biostatistics, Graduate School AMC	2017	1
Clinical Epidemiology: Systematic Reviews, Graduate School AMC	2017	2
Seminars, workshops and master classes		
The ResusTEE workshop, the Resuscitative TEE Project	2019	1
Educator Masterclass, European Resuscitation Council	2018	2
Resuscitation Academy, Seattle Medic One	2018	2
Presentations		
The prehospital physician controversy. Notfallmedizin 2018, Graz.	2018	0.5
Don't forget the flow – blood flow. Ventilation during cardiopulmonary resuscitation. Notfallmedizin 2018, Graz.	2018	0.5
Controversies during Advanced Life Support: airway and ventilation. Dutch Resuscitation Council Congress.	2018	0.5
E-poster presentation "The prehospital physician controversy" at Social Media And Critical Care (SMACC) Dublin	2016	0.5
(Inter)national conferences		
London Cardiac Arrest Symposium	2022	0.5
London Prehospital Care Symposium	2022	0.5
The Big Sick	2020	0.5
Cofounder and member organizing committee ResusNL conference, first and second edition	2019, 2022	6
State-of-the-future of Resuscitation Conference	2018, 2019, 2020	3
Member of the organization and jury of the Dutch Resuscitation Competition	2017 - now	4
Dutch Resuscitation Council Conference	2017, 2018, 2022	3
European Resuscitation Council Congress	2017, 2022	1
SMACC 2017,	2019	2
London Performance Psychology Symposium	2017	0.5
Advanced Resuscitation Symposium, Nottingham	2017	0.5
Other activities		
Writing group of the Dutch Resuscitation Guidelines. The Dutch Resuscitation Council, scientific board.	2021	3
Expertgroup of national EMS protocols on resuscitation. National EMS Organization (Ambulance Care in The Netherlands, AZN)	2021	3
Member of the guideline committee of the guideline: "Transfer of the OHCA patient, from prehospital to hospital." Dutch Resuscitation Council.	2020 - 2022	5
Member of the project group of the innovation project: Improvement of Handover and Information transfer for Good Hospital treatment in critical patients with video connection using 5G (HIGH5). Amsterdam UMC, Ambulance Amsterdam, KPN.	2019 - now	5
Member of Platform Research in Ambulance Care.	2016 - now	2
Weekly science meeting. ARREST study group.	2017 - now	5

TEACHING

	Year	ECTS
Lecturing		
Improving the chain of survival. Regional education meeting Emergency Medicine.	2023	0.2
Teamwork makes the difference. Triennial Conference of the International Orthopaedic Trauma Association (IOTA).	2022	0.2
Resuscitation in the Netherlands. RACS, SFMU.	2022	0.2
Ventilation during basic life support. Dutch Heart Foundation conference.	2022	0.2
Updates on the new resuscitation guidelines. Venticare Live conference.	2021	0.2
BVM ventilations during CPR using the two-hands technique. Dutch Resuscitation Council Congress.	2021	0.2
There is FOAM in the gap of EMS education! Webinar on Innovative EMS	2020	0.2
Trainings by the Italian Resuscitation Council.	2020	0.2
Citizen Response in Cardiac Arrest. The Big Sick conference.	2020	0.2

Optimizing Resuscitation Strategies in the Netherlands. State-of-the-future of Resuscitation Conference, EMS World Expo.	2020	0.2
Training lay persons in BLS. State-of-the-future of Resuscitation Conference, Paris.	2019	0.2
CPR – current developments. SpoedZorgNet symposium on ECPR.	2019	0.2
Airway management and ventilation during CPR. NvAM Masterclass.	2019	0.2
Ventilation during BLS. Dutch Resuscitation Council Congress.	2019	0.2
CPR. EMS Masterclass.	2018	0.2
Community response in out-of-hospital cardiac arrest in the Netherlands. State-of-the-future of Resuscitation Conference. Oakland (CA).	2018	0.2
Ultrasound during CPR. Dutch Resuscitation Council Congress.	2018	0.2
Ventilation during BLS. Dutch Resuscitation Council	2018	0.2
What can we learn from London HEMS? TraumaNetAMC evening on 'Scoop and run'.	2017	0.2
High Performance Resuscitation. Dutch Resuscitation Congress (NVSHA	2017	0.2

Tutoring, Mentoring

Mentor of masterstudents (interns)	2015-2017	1
Mentor of anesthesiology resident	2015-2020	0.5
Trainer for anesthesia secondment for ambulance nurses	2016-2019	2

Supervising

Full instructor and Course Educator European Trauma Course (ETC) ERC	2018 - now	4
Full instructor and Course Director Advanced Life Support ERC	2017 - now	6
ERC Educator for Generic Instructor Course	2019 - now	2
Instructor-trainer Basic Life Support ERC	2015 - now	1

Other

Faculty of Workshop Airway Management, SMACC preconference workshop	2017-2019	0.2
Faculty of Workshop Airway Management, The Big Sick	2020	0.2

PARAMETERS OF ESTEEM

Grants

	Year
TKI-PPP grant 'HEART-SAFE'(co-applicant)	2022
Stryker Emergency Care (main applicant)	2022
Zoll Foundation (main applicant)	2019
AMC Innovation grant (co-applicant)	2019
AMC Foundation (main applicant)	2018

PUBLICATIONS

Peer reviewed

	Year
Vianen NJ, Maissan IM, den Hartog D, Stolker RJ, Houmes RJ, Gommers DAMPJ, Van Meeteren NLU, Hoeks SE, Van Lieshout EMM, Verhofstad MHJ, Van Vledder MG; **Dutch Opportunities & Barriers in EMS research group.** Opportunities and barriers for prehospital emergency medical services research in the Netherlands; results of a mixed-methods consensus study. Eur J Trauma Emerg Surg. 2023. Online ahead of print.	2023
Smits RLA, Sødergren STF, **van Schuppen H**, Folke F, Ringh M, Jonsson M, Motazedi E, van Valkengoed IGM, Tan HL. Termination of resuscitation in out-of-hospital cardiac arrest in women and men: An ESCAPE-NET project. *Resuscitation. 2023;185:109721.*	2023
Schober P, van den Beuken WMF, Nideröst B, Kooy TA, Thijssen S, Bulte CSE, Huisman BAA, Tuinman PR, Nap A, Tan HL, Loer SA, Franschman G, Lettinga RG, Demirtas D, Eberl S, **van Schuppen H**, Schwarte LA. Smartwatch based automatic detection of out-of-hospital cardiac arrest: Study rationale and protocol of the HEART-SAFE project. *Resusc Plus.2022;12:100324.*	2022
van Schuppen H, Doeleman LC, Hollmann MW, Koster RW. Manual chest compression pause duration for ventilations during prehospital advanced life support - An observational study to explore optimal ventilation pause duration for mechanical chest compression devices. *Resuscitation.2022;180:24-30.*	2022
van Schuppen H, Wojciechowicz K, Hollmann MW, Preckel B. Tracheal Intubation during Advanced Life Support Using Direct Laryngoscopy versus Glidescope® Videolaryngoscopy by Clinicians with Limited Intubation Experience: A Systematic Review and Meta-Analysis. *J Clin Med. 2022;11(21):6291.*	2022
Schober **P, van Schuppen H,** Schwarte LA. A mnemonic for high quality basic life support: The RACERS acronym. *Resuscitation. 2022;176:24-26.*	2022
Sinnige JS, Kooij FO, **van Schuppen H**, Hollmann MW, Sperna Weiland NH. Protection of healthcare workers during aerosol-generating procedures with local exhaust ventilation. *Br J Anaesth. 2021;126(6):e220-e222.*	2021
van Schuppen H, Boomars R, Kooij FO, den Tex P, Koster RW, Hollmann MW. Optimizing airway management and ventilation during prehospital advanced life support in out-of-hospital cardiac arrest: A narrative review. *Best Pract Res Clin Anaesthesiol. 2021;35(1):67-82.*	2021
Dijkstra FS, Renden PG, Meeter M, Schoonmade LJ, Krage R, **van Schuppen H**, de la Croix A. Learning about stress from building, drilling and flying: a scoping review on team performance and stress in non-medical fields. *Scand J Trauma Resusc Emerg Med. 2021;29(1):52.*	2021

Druwé P, Monsieurs KG, Gagg J, Nakahara S, Cocchi MN, Éló G, **van Schuppen H**, Alpert EA, Truhlár A, Huybrechts SA, Mpotos N, Paal P, BjØrshol C, Xanthos T, Joly LM, Roessler M, Deasy C, Svavarsdóttir H, Nurmi J, Owczuk R, Salmeron PP, Cimpoesu D, Fuenzalida PA, Raffay V, Steen J, Decruyenaere J, De Paepe P, Piers R, Benoit DD; REAPPROPRIATE study group. Impact of perceived inappropriate cardiopulmonary resuscitation on emergency clinicians' intention to leave the job: Results from a cross-sectional survey in 288 centres across 24 countries. *Resuscitation. 2021;158:41-48.* 2021

Druwé P, Benoit DD, Monsieurs KG, Gagg J, Nakahara S, Alpert EA, **van Schuppen H**, Éló G, Huybrechts SA, Mpotos N, Joly LM, Xanthos T, Roessler M, Paal P, Cocchi MN, Bjørshol C, Nurmi J, Salmeron PP, Owczuk R, Svavarsdóttir H, Cimpoesu D, Raffay V, Pachys G, De Paepe P, Piers R; REAPPROPRIATE study group. Cardiopulmonary Resuscitation in Adults Over 80: Outcome and the Perception of Appropriateness by Clinicians. *J Am Geriatr Soc. 2020;68:39-45.* 2020

Pepe, Paul E. MD, MPH, MCCM; Aufderheide, Tom P. MD, MS; Lamhaut, Lionel MD, PhD; Davis, Daniel P. MD; Lick, Charles J. MD; Polderman, Kees H. MD; Scheppke, Kenneth A. MD; Deakin, Charles D. MD; O'Neil, Brian J. MD; **van Schuppen, Hans MD**; Levy, Michael K. MD; Wayne, Marvin A. MD; Youngquist, Scott T. MD, MS; Moore, Johanna C. MD, MS; Lurie, Keith G. MD; Bartos, Jason A. MD, PhD; Bachista, Kerry M. MD, EMT-P; Jacobs, Michael J. EMT-P; Rojas-Salvador, Carolina MD; Grayson, Sean T. MS, EMT-P; Manning, James E. MD; Kurz, Michael C. MD; Debaty, Guillaume MD, PhD; Segal, Nicolas MD, PhD; Antevy, Peter M. MD; Miramontes, David A. MD; Cheskes, Sheldon MD; Holley, Joseph E. MD; Frascone, Ralph J. MD; Fowler, Raymond L. MD; Yannopoulos, Demetris MD; on behalf of fellow International Resuscitation Collaborative Members. Rationale and Strategies for Development of an Optimal Bundle of Management for Cardiac Arrest. *Critical Care Explorations. 2020;2(10):e0214.* 2020

Druwé P, Monsieurs KG, Piers R, Gagg J, Nakahara S, Alpert EA, **van Schuppen H**, Éló G,Truhlár A, Huybrechts SA, Mpotos N, Joly LM, Xanthos T, Roessler M, Paal P, Cocchi MN, BjØrshol C, Pauliková M, Nurmi J, Salmeron PP, Owczuk R, Svavarsdóttir H, Deasy C, Cimpoesu D, Ioannides M, Fuenzalida PA, Kurland L, Raffay V, Pachys G, Gadeyne B, Steen J, Vansteelandt S, De Paepe P, Benoit DD. Perception of inappropriate cardiopulmonary resuscitation by clinicians working in emergency departments and ambulance services: the REAPPROPRIATE international, multi-centre, cross sectional survey. *Resuscitation. 2018;132:112-119.* 2018

Koers L, **van Schuppen JL**, Viersen VA, Kooij FO, Goslings JC, Hollmann MW. Resuscitation after trauma: better survival chances thanks to goal-oriented treatment. *[article in Dutch] Ned Tijdschr Geneeskd. 2017;161(0):D1174.* 2017

van Schuppen H, Bierens J. Understanding the prehospital physician controversy. Step 2: analysis of on-scene treatment by ambulance nurses and helicopter emergency medical service physicians. *Eur J Emerg Med. 2015;22(6):384-90.* 2015

van Schuppen H, Bierens J. Understanding the prehospital physician controversy. Step 1: comparing competencies of ambulance nurses and prehospital physicians. *Eur J Emerg Med. 2011;18(6):322-7.* 2011

Other

Chapter: Advanced Life Support. In: *Leerboek Acute Geneeskunde.* 2023

Chapter: Niet-technische vaardigheden. In: *Leerboek Acute Geneeskunde.* 2023

Hans van Schuppen. Community Response to Cardiac Arrest in the Netherlands. Journal of Emergency Medical Services (JEMS). *Editorial Supplement to JEMS March 2019: The Future of Resuscitation.* 2019

B. Geraedts; M. Visscher; **J.L. van Schuppen**, J. Hermanides, M.W. Hollmann, B. Preckel. Dial 2222 as a standard Cardiac Arrest call telephone number in European hospitals: current status in The Netherlands. Poster at Euroanaesthesia 2019. *Eur J Anaesth 2019;e-Suppl 57 (36):327.* 2019

M.H.T.M. Haerkens, E.C.T.H. Tan, **J.L. van Schuppen.** "Non-technical skills in emergency care" [Dutch], in *Leerboek Acute Geneeskunde (BSL), 2018.* 2018

van Schuppen H. Why you should always debrief your resuscitation. *ICU Management & Practice. 2017;17(2):99.* 2017

2013 **J.L. van Schuppen** - A: Airway. Chapter 8 in Handbook Emergency Medicine - Th.W. Wulterkens, R.G. van Kesteren, R.A.M. Verbeek. Bohn Stafleu & Van Loghum, 2013. 2013

LIST OF PUBLICATIONS AND AUTHOR CONTRIBUTIONS

Chapter 2: van Schuppen H, Boomars R, Kooij FO, den Tex P, Koster RW, Hollmann MW. Optimizing airway management and ventilation during prehospital advanced life support in out-of-hospital cardiac arrest: A narrative review. Best Pract Res Clin Anaesthesiol. 2021 May;35(1):67-82.

H.v.S.: Conceptualization, methodology, software, validation, formal analysis, investigation, resources, writing-original draft, writing-review and editing, visualization. R.B.: Investigation, validation, formal analysis, writing—original draft, writing—review and editing, visualization. F.O.K.: Resources, validation, writing—review and editing. P.d.T.: Conceptualization, methodology, software, formal analysis, investigation, writing—original draft. R.W.K.: Conceptualization, methodology, validation, writing—review and editing, supervision, project administration. M.W.H.: Conceptualization, methodology, validation, writing—original draft, writing—review and editing, supervision, project administration.

Chapter 3: van Schuppen H*, Wojciechowicz K*, Hollmann MW, Preckel B. Tracheal intubation during Advanced Life Support using direct laryngoscopy versus Glidescope® videolaryngoscopy by providers with limited intubation experience: A systematic review and meta-analysis. Journal of Clinical Medicine 2022;11:6291.

H.v.S., K.W.: Conceptualization, methodology, software, validation, formal analysis, investigation, resources, writing-original draft, writing-review and editing, visualization. M.W.H.: validation, writing-review and editing, supervision, project administration. B.P.: conceptualization, methodology, validation, writing=original draft, writing-review and editing, supervision, project administration.

Chapter 4: Berendsen M*, van Schuppen H*, de Boer HH, Ridderikhof ML, Hollmann MW. Comparing the QuickTrach® and Ventrain® in a Simulated 'Can't Intubate, Can't Oxygenate' Scenario – a Randomized Controlled Trial. Submitted.

H.v.S., M.B.: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Writing - original draft, Writing - review & editing, Visualization. H.d.B.: Methodology, Formal analysis, Writing - original draft, Writing - review & editing. M.W.H., M.L.R.: Methodology, Validation, Writing - Review & Editing, Supervision, Project administration.

Chapter 5: van Schuppen H, Doeleman LC, Hollmann MW, Koster RW. Manual chest compression pause duration for ventilations during prehospital advanced life support - an observational study to explore optimal ventilation pause duration for mechanical chest compression devices. Resuscitation 2022;180:24-30.

H.v.S.: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Writing – original draft, Writing – review & editing, Visualization. L.C.D.: Software, Validation, Formal analysis, Investigation, Resources, Writing – original draft, Writing – review & editing, Visualization. M.W.H.: Validation, Writing – review & editing, Supervision, Project administration. R.W.K.: Conceptualization, Methodology, Validation, Writing – original draft, Writing – review & editing, Supervision, Project administration, Funding acquisition.

Chapter 6: van Schuppen H, Bierens J. Understanding the prehospital physician controversy. Step 1: comparing competencies of ambulance nurses and prehospital physicians. Eur J Emerg Med. 2011 Dec;18(6):322-7.

H.v.S.: Conceptualization, methodology, software, investigation, resources, data curation, writing - original draft, visualization. J.B.: Conceptualization, methodology, writing - original draft, writing - review & editing, supervision, project administration.

Chapter 7: van Schuppen H, Bierens J. Understanding the prehospital physician controversy. Step 2: analysis of on-scene treatment by ambulance nurses and helicopter emergency medical service physicians. Eur J Emerg Med. 2015 Dec;22(6):384-90.

H.v.S.: Conceptualization, methodology, software, formal analysis, investigation, resources, data curation, writing - original draft, visualization. J.B.: Conceptualization, methodology, writing - original draft, writing - review & editing, supervision, project administration.

**) These authors contributed equally to this work.*

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Promotieteam

Ruud: er zijn weinig mensen die zich zo hebben toegewijd aan de reanimatiegeneeskunde als jij. Het was een enorme eer om door jou begeleid te worden tijdens dit promotietraject. Onze gesprekken, je brede blik op reanimatie, gedrevenheid en persoonlijke aandacht hebben mij enorm geïnspireerd. Dank ook voor je geduld bij de trage voortgang van mijn onderzoek als ik weer eens (te veel) met andere activiteiten bezig was. Het is een hele grote eer om de leiding over het reanimatieonderzoek met ARREST van je te hebben mogen overnemen. Ik zal me blijven inzetten om met ARREST de kans op goede overleving na reanimatie te blijven doen toenemen.

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Promotiecommissie

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Paranimfen

Dank aan Fabian en Lotte voor het vervullen van de rol als paranimf. Fabian: we delen de drive om de urgentiegeneeskunde te beoefenen op het hoogste niveau. Je inhoudelijke kennis en vaardigheden zijn voor mij een voorbeeld en ik vind het geweldig om samen te bouwen aan ons subspecialisme, zowel binnen de zorg als het onderwijs. Veel dank voor je hulp als collega, accountability partner en COVID buddy. Super om je nu ook als 'chief doctor' te hebben bij het MMT. Lotte: veel dank voor je hulp bij dit onderzoek en geweldig om verder samen op te trekken in de zoektocht naar de beste manier om te beademen tijdens de specialistische reanimatie. Ik kijk er naar uit dat ook jouw boekje klaar is en heb daar het volste vertrouwen in.

Begin van mijn onderzoek en loopbaan

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Afdeling anesthesiologie

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ARREST

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Reanimatiecommissie en acute zorg regiop

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Nederlandse Reanimatie Raad, Venticare, ResusNL

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Persoonlijk

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Prehospital Advanced Life Support, including airway management and ventilation, is vital in critical patients. The setting, time pressure and limited exposure to these patients can make resuscitation very challenging.

Hans van Schuppen is an anesthesiologist and Mobile Medical Team physician at the Amsterdam UMC, with a special interest in resuscitation, prehospital care and human factors. He is committed to integrate clinical care, education, science and innovation to keep improving the quality of prehospital care.

This PhD thesis presents research on possible strategies to optimize prehospital advanced life support, by using innovative equipment, improving the design and use of devices and dispatching mobile medical teams with a specialized physician.