The contribution of lay rescuers in out-of-hospital cardiac arrest
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CHAPTER 6

Summary and future directions
6.1 SUMMARY

Out-of-hospital cardiac arrest is still a major cause of death in industrialized countries. Early defibrillation is one of the major determinants of survival in patients suffering from an out-of-hospital cardiac arrest. To achieve earlier cardiopulmonary resuscitation (CPR) and defibrillation, first responder and public access defibrillation programs have been widely introduced.1-7 Such programs have successfully proven to increase survival after out-of-hospital cardiac arrest. However, they rarely reach cardiac patients in residential areas, where the great majority of out-of-hospital cardiac arrests occur. In this thesis I describe the contribution of lay rescuers in addressing the need for early defibrillation in the Netherlands. In the first part of this chapter, I summarize the data presented in this thesis entitled ‘The contribution of lay rescuers in out-of-hospital cardiac arrest’ and I end with a conclusion.

Chapter 2

To address the need for early defibrillation in the Netherlands, a dispatcher driven alert system has been implemented that uses text messages to direct trained lay rescuers (text message responders) with automated external defibrillators (AEDs) to cardiac arrest patients. When the dispatcher suspects a cardiac arrest, he/she will also activate this text message alert system. A maximum of 30 local text message responders, trained in basic life support and AED use, are dispatched to the cardiac arrest patient.

Chapter 2 describes a study in which the functioning of the text message alert system is analyzed, with the focus on response times in relation to other types of responders. Our study shows that the dispatcher activated the text message alert system in 58% of all out-of-hospital cardiac arrests. In more than half of all cardiac arrests an AED was connected prior to arrival of the ambulance. In 23%, the connected AED was provided by a text message responder and was mainly used in a residential area. In 12% of all patients with a shockable initial rhythm, a text message responder AED was used to provide the first shock. Compared to first shock delivery by ambulance personnel, text message responders provided the first shock 2 minutes and 39 seconds earlier. We conclude that the text message alert system contributes to earlier defibrillation in out-of-hospital cardiac arrest patients, particularly in residential areas.

Chapter 3

Between July 2009 and March 2013, the dispatch center of our study area North-Holland North introduced the text message alert system stepwise in 21 clusters of independent municipalities. From March 2013 onwards, 100% of the population of the study region was covered by the text message alert system. In Chapter 3, we
present a study in which we assessed if the text message alert system improved survival of out-of-hospital cardiac arrest patients found in a shockable rhythm in residential areas of North-Holland North. We compared the proportion of cardiac arrest patients with a shockable initial rhythm that survived to hospital discharge, before and after introduction of the text message alert system. We found that survival of patients with an initial shockable rhythm who collapsed in a residential area significantly increased, from 25% in the pre-introduction period to 38% in the post-introduction period. We also found an increase in the proportion of bystander CPR prior to ambulance arrival, from 77% pre-introduction to 91% post-introduction. After introduction of the text message alert system, the median time to the first shock significantly decreased by 2.5 minutes. In public areas, we found no significant difference in survival and in the proportion of bystander CPR between the two periods. In public areas, the time to the first shock also decreased (from 9.3 to 8.1 minutes) but less than in residential areas due to increased onsite AED use. We believe that the text message alert system increases bystander CPR and earlier defibrillation, thereby improving survival of out-of-hospital cardiac arrest patients in residential areas.

Chapter 4
Resuscitation attempts are stressful events and may lead to severe stress including post-traumatic stress disorder (PTSD). Since the introduction of the text message alert system, lay rescuers are more often exposed to this type of stressful events. In chapter 4, we present a study where we investigated the short-term psychological impact and PTSD-related symptoms in text message responders. We also assessed which factors are associated with a higher level of PTSD-related symptoms. After a text message alert, rescuers were asked to fill out an online questionnaire (phase 1). This questionnaire included questions regarding the rescuer’s response and, if applicable, their perceived level of short-term psychological impact. Based on the questionnaires, we interviewed all first arriving text message responders who provided CPR and/or used an AED (phase 2). The aim of the interview was to obtain more detailed information about the (impact of) the resuscitation. To assess the psychological impact of the resuscitation, the Impact of Event Scale (IES) was send to all rescuers four to six weeks after the resuscitation (phase 3). Twenty-five percent of all alerted text message responders completed the online questionnaire. In total, 203 rescuers were interviewed and 189 also completed the IES. Of these, 41% perceived no/mild short-term impact, 46% perceived bearable impact and 13% perceived severe impact. On the IES, 81% of the rescuers had a score that indicates ‘no stress’ and 19% had a score that indicates ‘mild stress’. No rescuer had a score above the threshold that indicates that the rescuer has PTSD-related symptoms. Since approximately one-fifth of the rescuers had an IES score indicating ‘mild stress’, we searched for factors
with an independent association with ‘mild stress’. We identified three factors that had an independent impact on mild stress level, namely: no AED connected by lay rescuer, severe short-term impact and no (very) positive experience. We conclude that lay rescuers alerted by text messages do not show PTSD-related symptoms four to six weeks after performing bystander CPR, even if they perceived severe short-term psychological impact.

Chapter 5

Between 2006 and 2012, the percentage of connected AEDs in out-of-hospital cardiac arrest patients almost tripled in the Netherlands, from 21% to 59%. With increasing use of AEDs, incidental reports of AED failure also increased. In most cases it is however unclear whether there is a specific relation to an operator error or a device failure. In chapter 5, we describe to what extent AEDs were failing and whether this had a device-related cause or an operated-related cause, or a combination of both. We analyzed 1114 AED recordings with 3310 analysis periods from 12 different AED brands. Only 12% of the AEDs were fully automatic; the AED delivers the shock without the requirement of a rescuer action. We found that all studied AED brands comply with the accepted diagnostic rhythm performance standards. Sensitivity for coarse ventricular fibrillation and fine ventricular fibrillation was 99% and 88%, respectively. Specificity for non-shockable rhythm detection was 98%. The AED gave an incorrect shock advice in 4% (44/1091) of all shock advices, due to device-related errors (n=15) and operator-related errors (n=28). In one case, we could not find the cause of the error. One percent (26/2219) of all no-shock advices was incorrect due to device-related errors (n=20) and operator-related errors (n=6). A commonly observed operator-related error was the continuation of chest compressions during an AED’s analysis period, ignoring the voice prompt to stop compressions. In 5% (59/1091) of all cases in which the AED gave the instruction to provide a shock, the operator did not deliver the shock to the patient. In most cases, the rescuer did not respond to the audible/visual prompts of the AED or the AED was disconnected before ambulance personnel arrived on scene. In a few cases, the operator pushed the off button instead of the shock button. The great majority of these errors were caused by an operator that used an semi-automatic AED. We conclude that errors associated with AED use are rare and if they do occur, are mainly related to the operator and circumstances of use. Fully automatic AEDs may prevent the majority of these errors.

Conclusion

The outcomes of the studies described in this thesis show that a text message alert system including both local lay rescuers and nearby AEDs contributes to earlier defibrillation, a higher percentage of bystander CPR and improves survival rates in
out-of-hospital cardiac arrest patients in residential areas. When involved in an out-of-hospital cardiac arrest, the great majority of lay rescuers use an AED correctly and deliver shocks when indicated. After the resuscitation, lay rescuers do not show any clinically relevant stress symptoms.

### 6.2 FUTURE DIRECTIONS

The studies in this thesis show that (technological) improvements are needed to further enhance the system. In the second part of this chapter, I present suggestions that may increase the efficiency of the text message alert system and that may facilitate the correct use of AEDs. I end with an overview of success indicators that can be of importance to other regions that are interested in implementing a volunteer-based alert system to increase out-of-hospital cardiac arrest survival rates.

**More advanced mobile phone technologies**

During the study periods included in this thesis, text message responders were alerted based on predefined locations. During registration for the text message alert system, text message responders could enter a maximum of five addresses and they were alerted based on their entered availability for these locations. A disadvantage of this system is that it is uncertain whether the alerted text message responders were located at the predefined location, whether they responded to the alert and if they arrived on scene. Consequently, a great amount of text message responders needs to be alerted.

Since October 2015, the text message alert system alerts text message responders by means of a more advanced telecommunication technology, namely a mobile application alert (app-alert). A great advantage of using this technology is that text message responders are alerted based on their actual location instead of on a predefined location. In this way, the system will only select text message responders that are actual nearby the cardiac arrest site. Another advantage is that the mobile application immediately provides a map with the shortest route to the AED and to the cardiac arrest patient. As a result, text message responders do not have to spend valuable time in searching for the address of the cardiac arrest. In theory, this novel approach could increase response rates of nearby text message responders, and decrease the time to the first arrival of a text message responder, thereby decreasing the time to the first shock. In Sweden, a mobile phone application that alerts volunteers to perform CPR has already been developed and studied. Ringh et al.\textsuperscript{11} analyzed this system and showed that the rate of bystander CPR was significantly higher in cases in which lay volunteers were activated by a mobile-phone positioning system than in cases in which lay volunteers were not activated.
However, is this study there was no integration with AED registries. In another study from Caputo et al., activation of traditional first responders and/or lay responders via a text message was compared with the activation of responders via a mobile app-alert. This study showed a 30% reduction in time to arrival on scene when responders were alerted by an app-alert compared to a text message alert. The earlier arrival of a first responder or of a lay responder contributed to a higher survival rate.

Currently we are planning a randomized controlled trial to analyze whether alerting text message responders through an app-alert results in earlier defibrillation compared to alerting text message responders by a text message alert only.

**Use of standardized protocols by dispatch centers**

In this thesis we showed that in more than 40% of the out-of-hospital cardiac arrests the dispatcher did not activate the system. In the majority of cases, the need for resuscitation was not recognized by the dispatcher from the emergency call. Berdowski et al. found that in 29% of the cardiac arrests, the dispatcher did not recognize the cardiac arrest. The most important reason for missing a cardiac arrest diagnosis was insufficient questioning about the patient’s breathing status. The use of standardized protocols by dispatch centers, including questions about unconsciousness and the absence of normal breathing, can contribute to earlier recognition of out-of-hospital cardiac arrests but could also result in higher false-positive dispatch rates. During the course of the studies described in this thesis, standardized protocols for dispatchers were in the process of being implemented. Future studies should reveal whether the use of such protocols contributes to earlier and better recognition of out-of-hospital cardiac arrests.

**Increasing the density of AEDs and text message responders**

Increasing the density of AEDs and text message responders in the system may further improve the efficiency of the system. Preliminary data from the ARREST study show that there is a relationship between higher AED and lay rescuer density and a shorter time to the first shock. A density of two AEDs and 10–20 text message responders available per km², seems to result in the shortest time to defibrillation.

The question remains: how many text message responders are needed? According to the Dutch Heart Foundation, 1% of the Dutch population needs be registered as a text message responder to comply with the 6-minute zone principle. Since October 2017, the Netherlands has >170.000 text message responders. However, the distribution of registered text message responders is still not optimal: some regions have more than 2% coverage while others have <0.5% coverage. Active recruitment and encouragement of people to participate in the text message alert system remains therefore necessary.

(62% vs. 48%).
Increasing the availability of AEDs

Part of the registered AEDs in our text message alert system was only limited accessible. Automated external defibrillators located in, for example, supermarkets are only accessible during opening hours. A study from Denmark showed that only 9% of the AEDs was 24/7 accessible. Almost all AEDs were highly accessible during the daytime on weekdays, but considerably inaccessible during the evening, night time and weekends, which was when most cardiac arrests occurred. AED owners should be encouraged to make their AED 24/7 accessible. In the majority of cases this means that they need to move their AED to the outside of a building and place them in a protective box.

Optimal AED placement

In the current text message alert system, AED placement was mostly dependent on the willingness of AED owners to make their AEDs available for the system. Some municipalities bought AEDs and placed them at strategic places in the community, such as on the outside wall of a church or (primary) school. By using mathematical modelling techniques based on historical cardiac arrests, AEDs could be placed even more strategically. Also, previous research has shown that a combination of demographic characteristics can identify areas with a high cardiac arrest incidence. By taking into account historical cardiac arrests and demographic characteristics, AEDs could be placed more optimally and can increase cardiac arrest coverage and decrease the distance to the closest AED.

Drone-delivered AEDs

The deployment of AEDs by drones to an out-of-hospital cardiac arrest has been proposed as a novel method of reducing time to defibrillation. Drones can be activated by a dispatcher and sent to an address provided by the emergency caller. The drone can carry an AED to the location of an out-of-hospital cardiac arrest so that a bystander can detach and use it. Boutilier et al. investigated the theoretical benefit of drone-delivered AEDs using a mathematical model. They found that drones can not only improve the median time to defibrillator arrival on scene but also reduce the entire response time distribution. A preliminary study in a municipality north of Stockholm, characterized by long ambulance response times, showed that it is possible to autonomously transport and deliver an AED using a drone. All drones arrived in less time than the ambulance in all simulated cases of out-of-hospital cardiac arrest.

By 2018, the Dutch Ministry of Infrastructure and Environment wants to perform a pilot project in the Dutch Wadden area with drones who may also fly outside the pilot’s sight. The current Dutch law states that a pilot must always keep his drone in sight. If the pilot project succeeds, drones may also be used to transport AED devices to the Wadden area.
Increasing correct AED use

Many errors that are related to the AED operator can be prevented, such as movement of the patient due to the provision of chest compressions during the analysis process of an AED. Such movements can lead to an inappropriate shock advice or not recognizing the rhythm as shockable. Paying strict attention to the AED voice prompts should be emphasized during basic life support training. This can be enhanced by reducing the voice prompts to only key messages, make voice prompts louder and use prominent visual prompts, such as a flashing shock button. To prevent ignoring a correct shock advice or prevent rescuers from pushing the off button instead of the shock button, fully automatic AEDs may be helpful. Finally, AED software that can analyze the rhythm during the provision of chest compressions may avoid false positive shock advices or disruption of the analysis process.

Success indicators

The studies described in this thesis show that the addition of a volunteer-based text message alert system contributes to improved survival of out-of-hospital cardiac arrest patients in residential areas of two Dutch regions. Recently, researchers from the Dutch province of Limburg reported that the involvement of text message responders substantially increased survival in out-of-hospital cardiac arrest patients. In a subsequent study, the researchers demonstrated that the contribution of the text message alert system to survival is most substantial in cases of witnessed arrest, in a residential area, at slightly delayed arrival of the first ambulance and during the evening/night.

The aforementioned studies demonstrate that the success of a volunteer-based text message rescuer system depends on a variety of factors such as the location of the cardiac arrest, the availability and response times of other responders, the availability of a substantial number of trained volunteers that are willing to participate in the system, and the availability of sufficient registered AEDs that are 24/7 accessible.

In addition, part of the success of the Dutch text message alert system can be explained by the high rate of bystander CPR. Due to the involvement of e.g. the Dutch Heart Foundation, CPR training programs for lay rescuers have been successful for many years. Consequently, AEDs for public use were already well accepted prior to the introduction of the text message alert system. In addition, the willingness of municipal authorities to invest in AEDs for residential use may also have contributed to the observed success. However, in countries where basic life support and/or AED use is less extensively developed, a volunteer-based alert system will probably not be the best way to improve survival rates of cardiac arrest patients. Nevertheless, this thesis may inspire others in setting up a system to increase survival of out-of-hospital cardiac arrest patients.
REFERENCES


