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Moderate sea states do not influence the application of an AED in rigid inflatable boats☆

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Summary
Purpose: This study was to determine if the AED can be operated correctly on board rigid inflatable rescue boats (RIBs), and if downloading of data later for quality control is possible.
Methods: Six AEDs were tested for their reliability, robustness and stability. Data were collected on three different types of RIBs, in a harbour and at sea. Each AED was connected to a volunteer and a manikin simulating VF. Data from the AED were continuously collected.
Results: At one of the RIBs each AED became wet; no AED had a technical problem. When connected to the volunteer, the ECGs delivered by the AEDs showed a regular sinus rhythm. When connected to a manikin in VF, each AED was able to recognise VF and to provide a shock. There were differences in the time between first analysis and the shock. The voice prompt of the Zoll AED Plus was 'understandable', while the other AEDs were 'difficult to understand'.

We had a problem with the infrared connection, which means that evaluation and quality control afterwards may be difficult.
Conclusion: The use of AEDs on RIBs during patient transport over calm water is possible and effective. The AED should have a screen and better features to download data. However, AEDs are only worthwhile when they fit well in the Chain of Survival (fast arrival, immediately availability of an AED, trained provider and advanced life support).

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Introduction

The automated external defibrillator (AED) is the single most important device to increase survival from out hospital cardiac arrest.[1–3] For this reason AEDs are increasingly deployed at all kind of locations. Research shows an improvement in survival when AEDs are applied for patients in VF in public places such as casinos[4] and airplanes.[5] It is suggested that the availability of AEDs can improve survival at sporting venues[6,7] and in shopping malls.[7]

The crews of rescue boats can also be confronted with a patient in cardiac arrest during their rescue duty, and during transport of patients. An AED could be of great help in this situation. The possibility of delivering BLS in the water,[8,9] on a RIB[10] or the use of an AED in a wet environment[11] has been investigated earlier. We investigated the technical reliability of an AED on board rigid inflatable boats (RIB). The RIB is the most common type of fast boat used for search and rescue (SAR) and other activities by rescuers as coastguard, lifeguard, police, or fire fighters. The following aspects were studied: is the AED reliable, solid and stable enough to be used on a RIB, will the AED operate correctly on a RIB and is downloading of data, for quality control, possible?

Materials and methods

Six distributors of AEDs in the Netherlands were invited to provide an AED to assess the application of an AED on RIBs. The distributors were asked to supply the AED, the software to download the electronically registered data of the AED and the necessary connecting parts. They were aware that the results of the study were intended for publication.

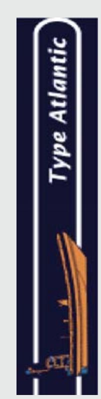
The AED were the standard versions and no special protective features were used during the study.

The Zoll has a hallmark IPX5, ''protected against water in jets from any direction.'' The Laerdal HS 1 has an IPX1 rating, ''protected from vertically dripping water.'' All other AEDs have a hallmark IPX4, ''protected against water splashed against the component from any direction.''

Data were collected on three different types of RIBs, as offered by the Royal Netherlands Sea Rescue Institution KNRM: 'Johannes Frederik', 'Valentijn' and 'Atlantic. Technical aspects of these boats are summarized in Table 1.

During the first phase of the study we assessed reliability, solidity and stability of the AED. A standard protocol was used for each AED. The AED was connected to a volunteer, using standard electrodes. Once connected the volunteer was put into

Table 1 Technical aspects of the three types of RIBs used during the AED test

RIB		Length (m)	Width (m)	Capacity (hp)	Marine speed (km/h)	Crew (number)	Maximum victims on board (number)
Type 1		14.40	5.40	2 × 680	63	4	75
Type 2		10.60	4.10	2 × 430	63	4	50
Type 3		6.45	2.25	2 × 70	56	3	12

a survival suit for reasons of safety and comfort. This volunteer was then transported with each of the three RIBs. The volunteer was instructed to simulate an unconscious state. Data of the performance of the AED were collected continuously during 2 min in the harbour and during 2 min at sea (salt water).

At sea the RIBs followed several tracks: parallel with the waves and crossing the waves for 180°, 90°, and 45°. EMS health care providers on board collected data concerning voice-prompts, time and kind of events, through-the-water speed, wind force and direction.

Data of the electrocardiogram (ECG), given voice-prompts, time and kind of events (power-on, connected electrodes, analysing, shock-indication, etc.) were downloaded from the AED on land after the transport.

We asked the EMS health care providers on board to give a score for the quality of the voice prompt in this situation. Scores that could be given were: not understandable, difficult to understand, understandable, easy to understand.

During the second phase of the study we assessed the operation of the AED in a VF situation. The following protocol was used: each AED was connected to a Resusci® Anne CPR-D manikin (Laerdal Medical AS, Stavanger, Norway), which, at a certain moment, was prompted to simulate VF. The standard electrodes of an AED were attached to the skin of the manikin. When the AED prompted to press to shock, one of the assessors pushed the button immediately. During the second phase of the study, the RIB crossed the waves for 45°, because this is the most 'bumpy' course and has the largest impact on irregular artefacts. Time between first analysis after connection and shock at sea were measured. To validate the time, video analysis was performed (Panasonic NV-DS60EG).

Pictures were taken of the chest of the simulation patients before and afterwards to assess the position of the electrodes (Canon PowerShot S45 and Canon PowerShot S50).

The interval between first analysis of the heart rhythm and the delivery of the shock was measured.

After the trip at sea, data of the AED were downloaded on land and checked for artefacts due to the vibration from the engine of the boat and the movement by the sea.

For collecting the AED-data afterwards on land, we used two laptop computers and the software delivered by the manufacturers.

One of the distributors was a subcontractor of the AccessAED. Shortly after our study started, the Access AED was no longer for sale, as it was not longer considered to be a reliable defibrillator. The device might have failure of the shock delivery circuit and the ON/OFF button of the device might become inoperative after the device was turned on inadvertently.[12] Because all data had been collected already, the data from this AED remained within the study.

We could not download the ECG and event data from the Zoll Plus AED, because we did not receive the software.

We did not receive software for the Zoll Plus and the Laerdal Heartstart HS1. The data for the Zoll Plus was downloaded and provided as screen prints by ZOLL Europe Region Office. The Laerdal Heartstart HS1 was not able to deliver data to the computer and no output was available. Data were collected by assessing the video.

AED-data, videotapes and pictures were analysed by the researchers, using data sheets and SPSS 12.0.1 for Windows (SPSS Inc., Chicago, USA). Time intervals were expressed as medians (range).

Results

Six manufacturers agreed to deliver without restriction one or two types of AED for the study, with software and parts (Table 2).

The weather conditions during the day of the study were stable. The height of the waves on sea was between 70—100 cm. Wind force was average 12 m/s (range 9—15 m/s) (strong breeze). Wind direction 220° (South West). It was a cloudy day without rain. The average temperature was 14 °C (range 11—17 °C). All studies were performed during high tide (receeding).

Reliability, solidity and stability

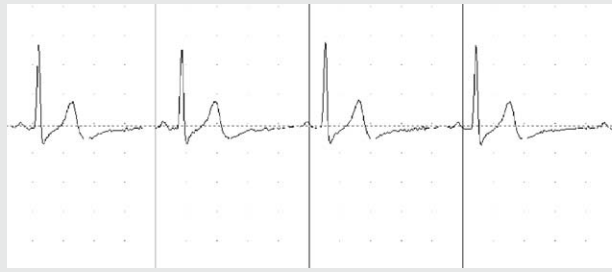
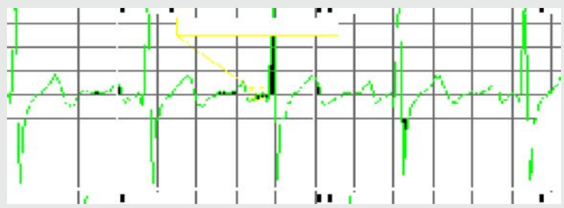
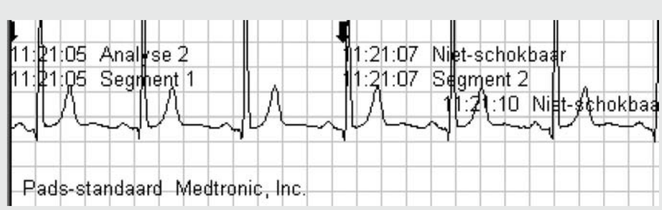
During use in the 'Atlantic' RIB all AEDs became wet (Figure 1). In spite of a wet outer surface, none had any technical problems in this environment. In the two other RIBs the AED was used in shelter of the wheelhouse and therefore remained dry during the study period.

When the AEDs were connected to the volunteer in the RIB, each ECG showed a regular sinus rhythm (examples in Table 2). None of the six AEDs had problems with analysing and registering the heart rhythm. So each of the six AEDs performed well in each type of boat.

Effectiveness

All AED were able to recognise VF and to provide an electric shock. The time from first analysis to shock to the CPR-D manikin is recorded in Table 2.

Table 2 Examples of ECGs and time to first shock

	Brand name	Type (software)	Examples of ECGs downloads during analyse time when connected to a simulation patient in a boat at sea[a]	The time from first analyse to shock when connected to the BLS-D manikin(s)
1	Access	AccessAED		23
2	Cardiac Science	Powerheart G3		13
3	Laerdal	Heartstart FR2		24
4	Laerdal	HeartStart HS1	[b]	36[c]
5	Defibtech	Lifeline (DefibView 1.303)		17
6	Zoll	AED Plus (Zoll Data Review)	[d]	43[c]
7	Medtronic	LifePak 500 DPS (CODE-STAT Reviewer 5.0)		17
8	Medtronic	LifePak CR-plus (CODE-STAT Reviewer 5.0)		22

[a] All ECGs were all right
[b] No output available. Only video tape as source.
[c] No output available due a technical problem.
[d] No software available during research.

Figure 1 All AEDs became wet on the Atlantic type at normal sea conditions. Notice the limited space in which the AED had to be used.

The voice prompt of the Zoll AED Plus was 'understandable'. The other AEDs were 'difficult to understand' because the voice prompts were hard to hear even when the highest volume was turned on.

Download data

We already had a problem with the infrared (IR) connection prior to the test. Both laptops had a standard IR-sensor and both had proven to be able to connect with mobile phones and other personal computers. However both laptops could not detect the information transferred from the AED with the IR-sensor. Connection of an additional IR-sensor with Universal Serial Bus (USB) connection and with serial port connection did not work as well.

For reasons of US legalisation the Zoll AED Plus and the Cardiac Science Powerheart G3 only retain information from one person and the Medtronic AEDs retains information from two persons. The other four AEDs had a secure digital (SD) memory card to collect the required information. The information on the SD-card of these four AEDs was all easily downloadable.

Discussion

This study investigated if the AED is sufficiently robust to work in the challenging environmental conditions on a RIB, and if the AED is able to monitor the heart rhythm and to defibrillate in case of VF in spite of artefacts. We also wished to see if downloading data for quality control is possible. Download data for quality control is necessary because volunteer crews of rescue boats work within a formal organisation which is responsible for their activities.

To study the performance in challenging environment conditions we used a setting that was similar to the normal situation of patient transport or medical assistance at sea (Figure 2). We did not simulate situations with storm and extremely high waves, because under these situations crewmembers have no time, space or opportunity to use an AED. The possibility of providing proper CPR is doubtful in these circumstances. Our study demonstrated that all the AEDs involved are robust enough to be used on RIBs; none of them gave problems with monitoring or defibrillation, but that there are some points of improvement regarding the possibilities of downloading data.

All AEDs were solid to be used under the circumstances. None of the AEDs failed when the external surface of the AED got wet.

All electrodes were able to acquire an ECG signal, on a human as well as on a manikin, when applied to a dry chest. However, the AED can be used on wet victims as long as the chest is made dry before connecting the electrodes.

Figure 2 In bad weather crew has neither time nor space to use an AED.

Table 3 Patients with a circulatory problem at sea during action of KNRM RIB

Year	Total numbers of action (number of persons rescued)	Rescued persons (% of total persons rescued)	Medical evacuation and transport (no submersion) (% of total persons rescued)[a]
2002 (second half)	741 (1497)	2 (0.1)	3 (0.2)
2003	1517 (2699)	2 (0.1)	0 (0)
2004	1611 (3483)	4 (0.1)	6 (0.2)
2005 (first half)	[b]	2	0

[a] The KNRM also has a task in transport patients from boats to shore and from the Dutch isles to shore.
[b] Total figures not available at this moment.

Also, all AEDs were effective in analysing heart rhythm and in delivering a shock in spite of the motion on the RIB. There are however differences between the AEDs in the time to shock. This is already known from training devices,[13,14] but we used 'real' AEDs. The interval between first analysis of the heart rhythm and the delivery of the shock was measured, because the time to attach the electrodes is a dependent variable, depending on the experience and skills of the assessor.

A practical relevant observation during this study was that it was difficult to hear the voice-prompts.

For quality control it is necessary that the medical supervisor of the rescue organization is able to download the data collected by the AED. In this study the memory card, cable-connection or serial port were most reliable. The infrared connection was less reliable.

Some other limitations should be addressed to appreciate the results of this study. The assessment by observation may lead to missing information. However, the reliability of our data is considered good because data were collected from multiple sources and provided in the same format (ECG and critical events recording, pictures and video).

If the AEDs will still work well if they become wet for a long time, their use during stormy weather should be investigated by further research.

What are the conclusions? First, the AED can be used in an aquatic environment if the chest of the victim is dry. Second that a screen to display the commands is recommended. Third, that good quality control needs an effective connection between the AED and computer.

But what are the practical consequences of this study? Concerning the actual discussions of the position of the AED in the Chain of Survival, it is relevant to evaluate the potential of AEDs on RIBs critically. During a recent resuscitation policy conference on the use of AEDs in Europe it was stated that: ''the potential benefit of having AEDs deployed in strategic locations should be based on the assessment of the number expected interventions and the high costs of training and maintenance of these programmes.''[15,16]

AEDs are worthwhile when they fit well in the Chain of Survival, meaning the immediately application of the AED by trained providers and the start of advanced life support shortly after successful defibrillation.

In most cases rescue boats are not on the spot shortly after a cardiac arrest occurs. In the reports of the KNRM cardiac arrest has not occurred during transport during the last three years (Table 3). If AEDs are available on a RIB, this means that at least two persons have to be trained as AED-providers, For the Netherlands this would mean that the organization that provide the rescue boats, the KNRM, would need to train 185 persons and 65 AEDs would have to be bought. The initial cost of this operation would be €150,000, thereafter €15,000 per year. Even than, advanced life support can only be started after arrival on land.

For this reasons it is doubted if an AED is of great practical value and cost-effective.

However, RIBs are used in a diverse range of tasks around the world. Rescue, life-saving, police and fire fighter organisations might consider if it is worthwhile to add an AED to the equipment of a RIB. This study might help in this discussion.

Finally, since most rescue organisations have to find a balance between practical, medical, organisational and financial aspects in the decision if an AED fits well in their organisation, it would be interesting if the International Maritime Organisation (IMO) and the International Life Saving Federation (ILSF) would take action to develop guidelines for the use of AEDs in the aquatic environment.

Conclusion

All AEDs did their job and none gave any problems. The best performance was delivered by the Cardiac Science Powerheart G3, which has the shortest time between first analysis and shock.

When used under aquatic conditions, it can be worth full if the AED has a hallmark for water-resistance or waterproof, has a screen and has the possibility to download data.

The decision as to whether the AED should be standard equipment on board of RIBs depends on the local aspects of the Chain of Survival, the training programme of the crewmembers and the medical quality management system of the organisation.

When the decision is made that the AED will be part of the equipment of the RIB, there will be no major technical obstacles in respect of using the AED effectively.

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