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**AUTOMATED EXTERNAL DEFIBRILLATORS ON BOARD  
MERCHANT VESSELS ? PRELIMINARY REPORT  
ARTICLE FOR DISCUSSION**

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**ABSTRACT**

**Objectives** – Acute heart diseases are the most frequent causes for fatalities on merchant vessels. Presently there is no sufficient therapy available to treat ventricular fibrillation. The aim of this study was to test whether common automated external defibrillators [AED] may be appropriate for the use aboard merchant vessels.

**Methods** – In 2005, nine seafarers were introduced to four common models of AED (HeartStartFR2+, Lifepak500, AEDplus, FREDeasy) using standard video or DVD presentations. AED handling by the subjects was tested in standardized simulated emergency scenarios. After training, they subjectively rated each AED on 24 factors involved in the introduction and handling of the device. An actual ECG was then obtained with each AED at a site located beside the ship's main engine to test under

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maximum vibration. The ECG data were extracted and sent as an e-mail attachment via satellite to the German Telemedical Maritime Assistance Service [TMAS] in Cuxhaven.

**Results and conclusions** – All subjects handled the AED correctly. The AED received a total amount of points in the range between 2125 to 2241 (of 2400 possible). The subjects preferred AED with coloured as well as light marked buttons which gave a feedback (e.g. audible tones) when they were pressed. All AED were able to register an ECG in the vibrating ambient. Due to interface problems it was only possible to extract three ECG files, and only two files (data < 300 kB) could be sent as e-mail attachment via satellite to the German TMAS. In noisy areas the AED must guide the user, e.g. by screen messages and/or pictograms. Displays should provide additional data to help assess resuscitation effectiveness. A special procedure is necessary to ensure that ships and TMAS own the same software to read the transmitted ECG files, which are not allowed to exceed a size of 300 kB.

**Keywords:** automated external defibrillator, seamen, merchant vessel, cardiac arrest

## INTRODUCTION

Previous studies reveal that ischemic heart diseases are the most frequent causes of death on board merchant vessels (1, 2, 3, 4, 5, 6). Aboard German vessels an average of five acute severe cardiac cases are reported per year (7). Two major sources are responsible for cardiac arrest on ships: cardiac infarction and electrical shock subsequent to technical failure of electrical equipment. Presently no appropriate therapy is available to give sufficient first aid for cardiac arrest on board civilian ships.

There is consensus that inexperienced lay people are able to perform early defibrillation with automated external defibrillators [AED] (8, 9). All crew members of German ships are trained in first aid before employment; nautical officers additionally undergo repetitive advanced medical training (10, 11, 12). Due to this level of training, we assumed seafarers may be able to use a common AED correctly.

If AEDs are employed on merchant vessels, in addition to appropriate therapy for cardiac arrests, diagnostic opportunities concerning dysrhythmia, tachy arrhythmia and brady cardia (e. g. subsequent to hypothermia) are improved. Also the diagnosis of exitus letalis may be based upon objective data.

Using a common AED register, saved ECG-data can be transferred to a personal computer (PC) and sent via E-mail, e. g. to the national Telemedical Maritime Assistance Service [TMAS]. Based upon ECG-data, medical recommendations concerning further procedures may improve dramatically.

This study attempted to identify technical requirements for an AED intended to be used aboard merchant vessels. Further, we wanted to determine whether it is possible to register an actual one-channel ECG (rhythm and amplitude) and send this data by standard communications devices to TMS Germany, Cuxhaven.

## MATERIALS AND METHODS

### Automated External Defibrillators (AED)

Four common AEDs were included: HeartStart FR2+ (Laerdal/ Philips Medical Systems), Lifepak 500 (Medtronic Physio-Control Corp.), AEDplus (Zoll Medical Corporation), FREDeasy (Schiller AG, Baar). All AEDs met requirements established by the German See-Berufsgenossenschaft: semi-automatic configuration (the AED analyses the heart rhythm in amplitude and frequency and recommends a shock, the user decides whether to deliver the shock, and a manual shock release is technically impossible), user display, ECG display, and storage of ECG data. All AEDs guided the user by voice prompts as well as screen messages.

### Subjects

Nine German seamen, divided into four teams, participated. Subjects were a convenience sample aboard a single merchant vessel. All subjects had completed basic training in cardio-respiratory resuscitation [CPR] (see table 1).

Table 1.

German seafarers participating in the study conducted aboard a merchant vessel in 2005

Subject	Sex	Age	at sea for yrs.	last medical training	Position on board
NB	Male	49	29	before 3 yrs.	Technical engineer
GS	Male	44	17	before 5 yrs.	Technical engineer
RL	male	47	30	before 3 yrs.	Nautical officer
EL	female	18	0	this year	Apprentice
SE	male	29	18	before 3 yrs.	Nautical officer
RU	male	45	28	before 10 yrs.	Ordinary seamen
NH	male	18	1	this year	Apprentice
TR	male	55	25	before 7 yrs.	Ordinary seamen
DK	male	54	35	before 2 yrs.	Nautical officer
<b>Mean values</b>		<b>40</b>	<b>19</b>	before 4 yrs.	

### AED testing

In a four day period sixteen tests were performed in a cross-over design to ensure each AED was tested as the first, second, third and last device (see table 2).

Table 2:

Testing schedule of equipment used in the study

Team	Number of subjects	1st test	2nd test	3 rd test	4 th test
1	2	FREDeasy	AEDplus	Heartstart FR2+	Lifepak 500
2	2	Lifepak 500	FREDeasy	AEDplus	Heartstart FR2+
3	2	Heartstart FR2+	Lifepak 500	FREDeasy	AEDplus
4	3	AEDplus	Heartstart FR2+	Lifepak 500	FREDeasy

The teams were introduced to the AED using the manufacturer's standard video or DVD presentation. After the introduction, the subjects used the AED in a standard simulated emergency scene (see emergency scene). Subjective ratings of the manufacturer's introduction and the technical handling of the AEDs were collected using a questionnaire (see questionnaire). Ratings were entered on a 100 mm long analogue-scale: 100 mm for the best and 0 mm the worst rating. The maximum possible value for 24 questions was 2400 mm.

Directly after the introduction the subjects rated the quality of comprehension (questions 1 – 2). After the practical test, the technical aspects of the AED were rated (questions 3 – 21), and, based on the practical experience, introduction quality was assessed a second time (questions 22 – 23). The subjects were free to give additional comments concerning the AED.

#### Questionnaire

The analogue-scales of the 24 questions ranged between two extreme statements, representing the best (=100 mm and the worst vote (0 mm).

AED introduction:

Did you understand the whole text of the introduction (=100 mm), or was the introduction completely

unintelligible (=0 mm)? 2) In the introduction no scientific terms were used (=100 mm), or were there too many scientific terms used (=0 mm)?

AED: 3) Was the readiness status of the AED clear (=100 mm), or was no information concerning the readiness status visible (0 mm)? 4) Was it possible to open the AED without any difficulties (=100 mm), or was it impossible to open it (0 mm)? 5) Was it possible to switch the AED on without any difficulties, or was their meaning not clear? 6) Was the meaning of the AED buttons completely clear, or was their meaning not clear?

Voice prompts:

7) Was it possible to understand all voice prompts with respect to the rescue procedure, or were the voice prompts not helpful? 8) Was it possible to understand all voice prompts concerning warnings, or were they completely unclear? 9) Was the meaning of the voice prompt completely clear, or were the meanings completely unclear?

Electrodes:

10) It was very easy to unpack the electrodes, or was it too complicated to unpack them? 11) It was very easy to connect the electrodes with the AED, or was it too complicated to connect them? 12) It was very easy to fix the electrodes on the manikin, or was it too complicated to fix them? 13) It was easy to place the electrodes at the correct anatomical position, or was the correct anatomical position not clear?

Shock delivering:

14) It was easy to recognize the shock button, or it was not clear which button is for the shock delivering? 15) The handling of the button was very easy, or it was too complicated? 16) The warnings just before the shock were easy to understand, or the warnings were completely unclear? 17) It was easy to recognize the end of the defibrillation procedure, or was the end of the procedure completely unclear ?

Display:

18) The screen messages were very helpful for the CPR-defibrillation procedure, or the screen messages were not helpful? 19) The warnings given in the display were easy to follow, or the warnings were completely unclear? 20) The meaning of the screen messages were completely clear, or they were completely unclear ?

21) The additional information in the display was easy to understand, or it was not helpful?

Video/DVD introduction: 22) The AED description was very precise, or the description was of poor quality?

23) The description of the procedure was very precise, or it was of poor quality? 24) The description of the AED handling was very precise, or it was of poor quality?

### AED introduction

The Lifepak 500 was accompanied by an 18 minute training video on handling and AED set up. The AEDplus used a 9.4 minute training video and a 16.5 minute DVD with an introduction concerning set up and AED maintenance. FREDeasy used a 20 minute interactive training DVD. For the HeartstartFR2+ no video or DVD introduction was available. The basic introduction was made by a standardized oral presentation based upon the manufacturer's manual (13).

### Simulated emergency scene

The subjects tested AED handling in standard simulated emergencies. In a room with low noise exposure each team gave first aid to an unconscious person who had no pulse and no spontaneous breathing, simulated by an Ambu MultiMan manikin.

To ensure a standard scenario for all subjects, the AEDs were configured in the same training mode. If available, the AEDs' training mode, or alternatively a remote control ECG-simulator, generated ventricular fibrillations. In two cases training AEDs were used (see table 3). The training configuration ensured each AED followed a pre-established protocol including the steps: install/connect electrodes; stand clear – analysing now; shock advised; check for pulse; CPR advised. The duration of each emergency scenario averaged four to five minutes.

During the emergency scenario, training electrodes similar to the original therapy - electrodes were used. To ensure subjects were not guided by the pre-installed tapes for the AEDplus training electrodes on the ZOLL training torso, the ZOLL training torso was only used after the subjects had placed the electrodes on the MultiMan manikin.

Table 3:

Emergency scene

VF = ventricular fibrillation detected, shock advised, N = check for pulse and/or spontaneous breathing, CPR advised, SR = sinus rhythm

AED	Scenario	Protocol
HeartStart FR2+ together with training- and management set M3864A	VF VF (CPR) VF N	Script 2 (14)
Lifepak 500: Lifepak 500 T AED Training System	VF VF N (CPR) VF VF N (SR)	Shock protocol Fixed 4
AEDplus together with remote control AEDplus Simulator	VF VF VF N (CPR) VF SR	
FREDeasy: FREDeasy Trainer	VF VF (CPR) VF N (SR)	Scenario 6

### ECG data

Each AED obtained ECG data from a male subject (40 years, 184 cm height, 70 kg bodyweight) (see table 4). The subject lay on the deck directly in front of the main engine, the site with the maximum vibration on board (96 Hz main engine vibration, normal hull movement, and vibration caused by generators, pumps, and the ship's propeller).

The ECG data was transmitted to the ship's communication PC and subsequently read with the manufacture's software (see table 4). The ECG data files were sent as an e-mail-attachment via satellite to the German TMAS MEDICO.

Table 4:  
Data management

AED	data storage in the AED	data transfer to the ship's communication-PC	Required software
HeartStart FR2+	Flash card	via card	HeartStart Event Review
Lifepak 500	digital file in the AED	PC-cable between AED and PC	Quick-View 500 or CODE-STAT
AEDplus	digital file in the AED	infrared interface	Zoll DATA Review
FREDeasy	Flash card	via card	SEAD Reader

## RESULTS

### AED introduction, handling

In the emergency scenario all subjects were able to use the AED correctly. The AED received a total amount of points in the range between 2125 to 2241 (of 2400 possible). The subjective technical evaluation ranged between 1675 and 1778 points (theoretical maximum 1900).

The usual procedure suggested the AEDs remain in their soft cases; opening the case gives immediate access to the AED buttons and electrode connections. However, in the scenarios all subjects unpacked all AEDs except the FREDeasy. Before switching on the AED all subjects connected the electrodes first to the manikin as well as to the AED.

Before the test the subjects expressed fear of delivering electrical shocks accidentally. In eighteen cases the subjects made statements concerning the technical characteristics of the tested AEDs (e.g. buttons, display, voice prompts, battery status, electrodes, opening mechanism).

The subjects preferred easy to reach, large buttons, especially those marked by colour or coloured lights. They suggested the AEDs should indicate when they received an order by pushing any button by tactile information or tones (see table 5, evaluation of questions 5 and 15). Concerning instructions and resuscitation procedure results the subjects preferred large displays with only limited additional information. They recommended that voice prompts and/or screen messages should assist in remembering the recommended CPR algorithm (e. g. 2 x artificial respirations, 15 x thorax compressions). During the emergency scenario all subjects performed sufficient thorax compressions in depth. However, none of the subjects spontaneously performed the thorax compression with the recommended frequency of 100 compressions per minute. The subjects found feedback information concerning CPR quality (thorax compression depth and frequency) very helpful.

The subjects preferred electrode connectors on the top of the AED. Plugs on the sides of the AED were reported to be uncomfortable.

#### **AED in vibrating ambient**

All four AEDs were able to obtain ECG-data in a vibrating environment. In all cases the AED displays showed a normal ECG and the analyses of the AEDs neglected any cardiac dysfunction e. g. fibrillation or asystole. The ECG-files of AEDplus and Heartstart FR2+ showed ECG curves without noteworthy vibration induced artifacts.

#### **Data management, data transmission**

The FREDeasy, Heartstart FR2+, and AEDplus ECG files could be extracted. Data transfer from the Lifepak 500 to the ship's communication PC was impossible due to hardware problems.

The data obtained by the FREDeasy could not be read by the installed software. Due to the large file (~ 14 MB, compressed 8599.5 kbits) it was impractical to send the data via satellite.

The data files of the Heartstart FR2+ (74.6 kB) and AEDplus (registered ECG duration: 6:29 minutes; 210.7 kB; compressed: 74.5 kB) could be read and evaluated (see tab. 4 Data management). Due to the small data volume of both ECG-files (<300 kB), they could be sent as e-mail attachments directly via satellite to Cuxhaven.

At TMAS Germany both files could be read and evaluated with the standard software. Both files included additional information documenting the steps in the protocol.



## DISCUSSION

Besides severe accidents, acute heart diseases are the most frequent sources of seafarer fatalities (1, 2, 3, 5, 6). Epidemiological data suggested that an insufficient cardiac function is most likely at an age between 45 and 75 years, occurring in the normal population in 1 to 2 cases per 1000 persons per year (15). Presently the mean age of German seafarers is within this range. Aboard German merchant vessels presently there is no sufficient therapy available to cope with ventricular fibrillation subsequent to ischemic heart disease or electrical shock. The common AED, which had been designed for laypeople, may offer a sufficient therapy option to treat successfully ventricular fibrillation (16).

In a study conducted in summer of 2005 all sixteen scenarios the AEDs were correctly handled. This suggests that seafarers are also able to use medical devices designed for lay people.

All subjects connected the electrodes first to the AED and the manikin before switching on the AED, deviating from the recommendations of all the manufacturers. This behavior appears to mirror the daily routine of the seafarer when employing electric devices. To keep the set up time of the AED and its equipment as short as possible, an AED with pre-connected electrodes should be preferred.

Practical handling revealed several aspects for criticism: the subjects favoured easy to reach, large buttons. They preferred buttons that indicate signal reception after they had been pushed, e. g. audible signals or tactile feedback. The defibrillation procedure was simple when the AED has clearly marked buttons using colour and/or lamps or diodes.

All subjects found voice prompts with the current CPR algorithm helpful. As these algorithms may change, an AED should allow configuration changes in prompts and screen messages.

All subjects performed thorax compressions at too slow a frequency. Because CPR success is directly related to appropriate compression frequency and depth, the AEDplus's indications of thorax compression quality were helpful.

The epidemiological data concerning ventricular fibrillation suggests the use of an AED on merchant vessels seldom takes place. This low use rate requires both a permanent training routine to maintain crew proficiency and clear guidance by the AED in an emergency.

On vessels there are a great number of noisy areas ( $>> 85 \text{ dB[A]}$ ). In one such noisy area, the main engine room, and during repair work at electrical installations, an electrical accident with subsequent ventricular fibrillation may be likely. However, it is

impossible to guide an AED user in noisy areas by voice prompts. Alternative ways to guide the user are essential, for example, screen messages or pictograms. Additionally, the ECG curve on the display may provide important information for assessment of the patient's status as well as an indication of the success of the defibrillation therapy.

To improve therapy recommendations by the TMAS in severe acute heart disease cases, actual ECG data has to be transmitted from the vessel to TMAS. As early as 1978 the transmission of ECG files from ship via broadcast to TMAS Germany was demonstrated (7). To ensure data transfer ashore usual and stable communication methods must be employed. In the daily routine, e-mails including attachments as well as telefacsimile are used in the communication between ship and shore. ECG files may be sent as e-mail-attachment or as telefacsimile. The technical problems which hindered the data transfer from two of the tested AEDs may illustrate the vulnerability of the great number of interfaces (AED – communication PC – satellite etc.). Based upon these interface problems the AED's screen messages may play a unconventional role concerning data transfer. In principle it is possible to take a photo with a digital camera of the ECG given on the AED's display. So it may be possible to save suspect ECG-curves as digital picture file and send it via e-mail ashore.

All ECG-files generated by the AED require special software at the TMAS for the medical staff to read the data. In future, shipping companies which use AEDs on their vessels must integrate their national TMAS into their software update program. The companies also must ensure that all changes in AED hardware are also mirrored at the TMAS; otherwise transferred files may not be able to be opened due to different software standards.

## CONCLUSIONS

Seafarers are able to use common AEDs. To avoid misuse only automated defibrillators should be employed on vessels without medical staff.

To reduce set up time and errors, only AEDs with preconnected electrodes should be used.

To clarify button functions, buttons should be differently coloured and have coloured lamps or diodes. When buttons are pressed, audible or tactile signals should acknowledge the order.

The AED user should be guided through the CPR procedure by voice prompts and screen messages, especially the standard one rescuer CPR algorithm. To accommodate

changes in therapy procedures the AED should allow changes in voice prompts and screen messages.

For use in noisy areas, the AED should guide users in additional ways, such as screen messages or pictograms. The ECG display should give additional information on the success of the therapy.

The national TMAS must be integrated into shipping company maintenance programs for AED hardware and software updates to ensure TMAS's ability to read received ECG-files.

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