

## Original Article

# Characterization of available automated external defibrillators in the market based on the product manuals in 2014

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**BACKGROUND:** To popularize the wide-spread use of automated external defibrillator (AED) to save life in sudden cardiac arrest, we compared the strength and weakness of different types of AEDs to enable a sound selection based on regional requirement.

**METHODS:** This was a retrospective descriptive study. Different types of AEDs were compared according to the information of AEDs from manuals and brochures provided by the manufacturers. Fifteen types of AEDs were divided into 3 groups, basic, intermediate and advanced.

**RESULTS:** Lifeline™ AUTO AED had the best performance in price, portability and user-friendly among AEDs of basic level. It required less time for shock charging. Samaritan PAD defibrillator was superior in price, portability, durability and characteristic among AEDs of intermediate level. It had the longest warranty and highest protection against water and dust. Lifeline™ PRO AED had the best performance in most of the criteria among AEDs of advanced level and offered CPR video and manual mode for laypersons and clinicians respectively.

**CONCLUSION:** Lifeline™ AUTO AED, Samaritan PAD defibrillator, Lifeline™ PRO AED are superior in AEDs of basic, intermediate and advanced levels, respectively. A feasible AED may be chosen by users according to the regional requirement and the current information about the best available products.

**KEY WORDS:** Automated external defibrillator; Electrodes; Pads; Cardiac arrest

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## INTRODUCTION

Heart attack is one of the top 3 killer diseases which kill 6 200 victims per year in Hong Kong.<sup>[1]</sup> Out of hospital cardiac arrests (OHCA) are mostly unexpected and may occur within an hour of the onset of acute symptoms. Within 4 minutes of collapse, around 53% were in ventricular fibrillation/tachycardia.<sup>[2]</sup> Many studies<sup>[3–7]</sup> have already showed that rapid defibrillation with automated external defibrillator (AED) by non-paramedics can improve survival of patients. For every minute that passes prior to receiving a defibrillation shock, a victim's chances of survival decline by between 7%–10%. After more than 12 minutes of ventricular defibrillation, the survival rate is less than 5%.<sup>[8]</sup> It revealed the significance of AED on basic life support.

However, according to a survey conducted by Hong Kong Inter-Hospital Network of Pacing and Cardiac Electrophysiology (HK-in-Pace) in 2014, there are only 5 084 automated external defibrillators territory-wide. Just 57% of malls and half of primary and secondary schools have AED.<sup>[9]</sup> Moreover, referring to another medical journal, the rate of public access defibrillation was only 0.168% between 2010 and 2013.<sup>[10]</sup> This is why AEDs should be installed in places such as public transports, shopping malls, schools, offices and other public places to popularize the usage of AEDs, in order to enhance victims' survival chances.

To make a good choice on various types of AEDs, this article would aim at comparing the characteristics of

different types of AED from 7 brands (Philips, Cardiac Science, Physio Control, Zoll®, Defibtech, Heartsine®, CU Medical Systems) which are common to be sold in the markets of the United States of America.

The brief details of the brands of AEDs are shown below.

Philips, founded in Holland at 1891, introduced the first AED (ForeRunner Series) in 1996.<sup>[11]</sup> HeartStart Onsite, HeartStart FRx and HeartStart FR3 are sold on the AED online market in the USA.

Cardiac Science, founded in USA at 1913, produced the first AED (First Save Survivalink 9200-series) in 2001.<sup>[12]</sup> Powerheart® G3 Plus and Powerheart® G3 Pro are sold on the AED online market in the USA.

Physio Control, founded in the USA at 1955, introduced the first AED (LIFEPAK®500) in 1997.<sup>[13]</sup> LIFEPAK EXPRESS®, LIFEPAK CR®Plus and LIFEPAK®1000 are sold on the AED online market in the USA.

Zoll®, founded in the USA at 1980, designed the first AED (Zoll AED Plus®) in 2001.<sup>[14]</sup> Zoll® AED Plus® and Zoll® AED Pro® are sold on the AED online market in the USA.

Defibtech, founded in the USA at 1999, shipped its first AED in 2002.<sup>[15]</sup> Lifeline™ AED,<sup>[15]</sup> Lifeline™ AUTO AED, Lifeline™ VIEW AED\* and Lifeline™ PRO AED are sold on the AED online market in the USA.

CU Medical Systems, founded in Korea at 2001, introduced its first brand-new AED in 2002.<sup>[16]</sup> i-PAD AED is sold on the AED online market in the USA.
















Heartsine®, founded in the USA at 1998, developed the first Samaritan AED in 2001.<sup>[17]</sup> Samaritan PAD defibrillator is sold on the AED online market in the USA.

HeartStart FRx, HeartStart FR3, Powerheart® G3 Plus, Powerheart® G3 Pro, LIFEPAK CR®Plus, LIFEPAK®1000, Lifeline™ AED, Lifeline™ AUTO AED, Lifeline™ VIEW AED, and Lifeline™ PRO AED are sold in Hong Kong as well.

## METHODS

Fifteen types of AED of 7 brands which are commonly available in the United States were compared. They were divided into three groups (basic, intermediate, and advanced) according to their difference (Table 1). ECG display was included in AEDs of advanced level but not in AEDs of basic level and intermediate level. The major difference between basic level and intermediate level was the mode of shock delivery. AEDs in basic level were fully automatic while AEDs in intermediate level were semi-automatic. The comparison was based

**Table 1.** AEDs in the basic, intermediate, and advanced groups

Basic	Intermediate	Advanced
Powerheart® G3 Plus (Cardiac Science)	HeartStart Onsite (Philips)	HeartStart FR3 (Philips)
		
LIFEPAK CR®Plus (Physio Control)	HeartStart FRx (Philips)	Powerheart® G3 Pro (Cardiac Science)
		
Zoll® AED Plus® (Zoll®)	LIFEPAK EXPRESS® (Physio Control)	LIFEPAK®1000 (Physio Control)
		
Lifeline™ AUTO AED (Defibtech)	Lifeline™ VIEW AED (Defibtech)	Zoll® AED Pro® (Zoll®)
		
	i-PAD AED (CU Medical Systems)	Lifeline™ PRO AED (Defibtech)
		
	Samaritan PAD defibrillator (Heartsine®)	
		

\*: Philips HeartStart FR3 and Physio Control LIFEPAK®1000 can be installed with ECG display as optional.

on the information of AED from manuals and brochures provided by the companies.

In each group, specifications and features including price, portability, battery and pads, durability, user-friendly, characteristics were compared.

## RESULTS

### AEDs of basic level

In AEDs of basic level, Powerheart® G3 Plus, LIFEPAK CR®Plus, Zoll® AED Plus®, Lifeline™ AUTO AED were compared (Tables 2 and 3).

### AEDs of intermediate level





In AEDs of intermediate level, HeartStart Onsite, HeartStart FRx, LIFEPAK EXPRESS®, Lifeline™ VIEW

**Table 2.** Comparison of Powerheart® G3 Plus, LIFEPAK CR®Plus, Zoll® AED Plus®, Lifeline™ AUTO AED

Variables	Powerheart® G3 Plus (Cardiac Science)	LIFEPAK CR®Plus (Physio Control)	Zoll® AED Plus® (Zoll®)	Lifeline™ AUTO AED (Defibtech)
Price* (1/7/2014)	~\$12 000 (★)	~\$13 000	~\$13 000	~\$10 000 (★★)
Portability		★		★★
Weight (kg)	3.1	2.0	3.1	2.0
Size (cm)	8×31×27	10.7×20.3×24.1	13.3×24.1×29.2	22×30×7
Maintenance			★★	★
Battery price* (1/7/2014)	~\$3 000	~\$700 (adult pads included)	~\$300	~\$1 500
Standby life of battery	4-years	2-years	5-years	7-years
Types of battery	LiSO <sub>2</sub>	LiSO <sub>2</sub> Cl <sub>2</sub>	LiMnO <sub>2</sub>	LiMnO <sub>2</sub>
Capacity	290 shocks; 12 hours of operating time	30 shocks; 3 hours 30 minutes of operating time	300 shocks; 13 hours operating time	300 shocks; 16 hours operating time
Price* (adult+pediatric pads)	~\$400+\$800	~\$900 (pediatric pads)	~\$1 300+\$700	~\$300+\$800
Standby life of pads	2-years	2-years	5-years	2.5-years
Cost per year (battery and pads)	~\$1 300	~\$800	~\$500	~\$600
Durability			★★	★
Dust protection** (IP ratings***)	2	/	5	5
Water protection** (IP ratings***)	4	4	5	4
User-friendly		★		★★
Shock charge time (seconds)	10	<9	<10	<6
Shock delivery mode	Fully Auto optional	Fully Auto optional	Fully Auto optional	Fully Auto optional
Characteristics	★★	★	★★	★
CPR support	Metronome	Metronome	CPR Feedback	Metronome
Data storage	60 minutes	20 minutes	50 minutes	100 minutes
Training use	Yes	Yes	Yes	Yes
Warranty	7-years	8-years	5-years	5-years
Supporting synchronized shock	Yes	None	None	None

\*: The price is quoted from AED online markets in the USA (AED brands® and AED Superstore®) and then converted to HK dollars directly. Therefore, they are not the real price of AEDs in Hong Kong. \*\*: Dust protection: 2=protected against object >12 mm; 5=dust protected. Water protection: 4=against splashing water; 5=against water jet. \*\*\*: IP ratings, a worldwide standard has been established by the International Electrotechnical Commission (IEC) for comparing the ability of electronic devices to withstand exposure to dust particles and water.

**Table 3.** Summary of AEDs of basic level

Variables	Powerheart® G3 Plus (Cardiac Science)	LIFEPAK CR®Plus (Physio Control)	Zoll® AED Plus® (Zoll®)	Lifeline™ AUTO AED (Defibtech)
				
Price	★			★★
Portability		★		★★
Maintenance			★★	★
Durability			★★	★
User-friendly		★		★★
Characteristics	★★	★	★★	★

AED, i-PAD AED and Samaritan PAD defibrillator were compared (Tables 4 and 5).

**AEDs of advanced level**

In AEDs of advanced level, HeartStart FR3, Powerheart® G3 Pro, LIFEPAK® 1000, Zoll® AED Pro®, Lifeline™ Pro AED were compared (Tables 6 and 7).

**DISCUSSION**

Prompt delivery of public access defibrillation (PAD) to OHCA patients with shockable rhythms certainly can improve the outcome. The factors of a successful PAD delivery include adequate number of AED in the community, close proximity of AED to the site of

OHCA, bystanders have knowledge in using AED, and bystanders are willing to use AED.<sup>[10]</sup> The features we compared in this study can have certain role in a successful PAD delivery. An ideal AED should be low cost, light and small, durable, with short charge to shock time, and able to be used by laypersons even without any basic life support (BLS) training before. Other characteristics like data storage and CPR support are also useful in clinical practice.

**AED of basic level**

In AEDs of basic level, Powerheart® G3 Plus, LIFEPAK CR®Plus, Zoll® AED Plus®, Lifeline™ AUTO AED are compared.

Lifeline™ AUTO AED is the cheapest AED in the

group. According to the AED online market in the USA, the price of Lifeline™ AUTO AED is the lowest, which offers an economic incentive owing to the fact that it is a new brand comparing with others. In traditional brands of AEDs, Powerheart® G3 Plus is less expensive than LIFEPAK CR® Plus and Zoll® AED Plus®.

One barrier for the installation of AED is the cost. According to AHA recommendation, AED should be placed where there is likely one cardiac arrest within 100 m in 5 years,<sup>[18]</sup> i.e. if there were more than 0.2 OHCA per AED per year within 100 m, the AED installation was regarded as cost effective. Lower price certainly can

improve the cost effectiveness. Furthermore, if the price and maintenance cost are lower, more institutions will consider installation of AED so the total number of AED in the community will be increased.







The portability of Lifeline™ AUTO AED is the best. The weight of LIFEPAK CR® Plus and Lifeline™ AUTO AED are lighter than others, which are both 2.0 kg; however, Powerheart® G3 Plus and Zoll® AED Plus® are 1.1 kg heavier than those of them. Moreover, Lifeline™ AUTO AED is the smallest AED, 22 cm×30 cm×7 cm in dimension, in this group. Portability is also important for early delivery of PAD. A small, lighter AED certainly

**Table 4.** Comparison of AEDs of intermediate level

Variables	HeartStart Onsite (Philips)	HeartStart FRx (Philips)	LIFEPAK EXPRESS® (Physio Control)	Lifeline™ VIEW AED (Defibtech)	i-PAD AED (CU Medical Systems)	Samaritan PAD defibrillator (Heartsine)
Price* (1/7/2014)	~\$9 000 (★★)	~\$12 000	~\$10 000 (★)	~\$12 000	~\$10 000(★)	~\$9 000 (★★)
Portability	★	★		★		★★
Weight (kg)	1.5	1.5	2	1.4	2.2	1.1
Size (cm)	7×21×19	6×18×22	10.7×20.3×24.1	18.5×24 ×5.8	22×28.1 ×8.2	20×18.4×4.8
Maintenance		★		★★	★★	★
Battery price* (1/7/2014)	~\$1 300	~\$1 300	~\$700** (adult pads included)	~\$1 300	~\$1 000	/***
Standby life of battery	4-years	4-years	2-years	4-years	5-years	4-years
Types of battery	LiMnO <sub>2</sub>	LiMnO <sub>2</sub>	LiSO <sub>2</sub> Cl <sub>2</sub>	LiMnO <sub>2</sub>	LiMnO <sub>2</sub>	LiMnO <sub>2</sub>
Capacity	>90 shocks; 3 hours of operating time	>200 shocks; 4 hours of operating time	20 shocks; 2 hours 20 minutes of operating time	125 shocks; 8 hours of operating time	>200 shocks; 10 hours of operating time	>60 shocks; 6 hours of operating time
Price* (adult+pediatric pads)	~\$500+\$800	~\$400**** (adult pads)	~\$900 (pediatric pads)	~\$500+\$800	~\$300+\$300	~\$1 200+\$1 600 (battery included)
Standby life of pads	2-years	2-years	2-years	2-years	3-years	4-years
Cost per year (battery and pads)	~\$1 000	~\$500	~\$800	~\$900	~\$400	~\$700
Durability		★		★		★★
Dust Protection (IP ratings)	2	5	/	5	5	5
Water Protection (IP ratings)	1	5	4	5	4	6
Operation temperature (°C)	0–50	0–50	0–50	0–50	0–40	0–50
User-friendly		★	★	★★		
Shock charge time (seconds)	<20	8	<9	<4	<10	<12
Shock delivery mode	Semi-automatic	Semi-automatic	Semi-automatic	Semi-automatic	Semi-automatic	Semi-automatic
Characteristics	★	★★		★★	★	★★
CPR support	None	None	None	CPR Video	Metronome	Metronome
Data storage	15 minutes	15 minutes	20 minutes	12 hours	40 minutes	90 minutes
AED Trainer	Yes	Yes	No	No	No	Yes
Warranty	8-years	8-years	5-years	5-years	5-years	10-years
Pediatric key	No	Yes	No	No	No	No

\*: The price is quoted from AED online markets in the USA (AED brands® and AED Superstore®) and then converted to HK dollars directly. Therefore, they are not the real price of AEDs in Hong Kong. \*\*: The price of adult pads of LIFEPAK EXPRESS® is included in the price of battery. \*\*\*: The price of battery of Samaritan PAD defibrillator is included in the price of pads. \*\*\*\*: No pediatric pads is required in HeartStart FRx. (Pediatric key is provided).

**Table 5.** Summary of AEDs of intermediate level

Variables	HeartStart Onsite (Philips)	HeartStart FRx (Philips)	LIFEPAK EXPRESS® (Physio Control)	Lifeline™ VIEW AED (Defibtech)	i-PAD AED (CU Medical Systems)	Samaritan PAD defibrillator (Heartsine)
						
Price	★★		★		★	★★
Portability	★	★		★		★★
Maintenance		★			★★	★
Durability		★		★		★★
User-friendly		★	★	★★		
Characteristics	★	★★		★★	★	★★

can encourage a layperson to use it. It also can shorten the travel time of layperson and earlier defibrillation can be delivered. Zoll® AED Plus® has the best performance in maintenance. The battery of this model is the cheapest; despite the fact that battery of Lifeline™ AUTO AED involves a longest standby life of 7 years. The battery of Lifeline™ AUTO AED and Zoll® AED Plus® provides likewise 300 shocks but 16 hours and 13 hours of operation time respectively. Furthermore, only pediatric






pads are measured in LIFEPAK CR® Plus because the adult pads are included with battery. Excluding LIFEPAK CR® Plus, the total price of adult pads and pediatric pads is the lowest in Lifeline™ AUTO AED but the pads of Zoll® AED Plus® have a standby life of 5 years. After the calculation, the operation cost of Zoll® AED Plus® per year is the cheapest. If the standby life of battery and pads is longer, the chance of replacement can be reduced. Again, the lower operation cost can give an incentive to

**Table 6.** Comparison of AEDs of advanced level

Variables	HeartStart FR3 (Philips)	Powerheart® G3 Pro (Cardiac Science)	LIFEPAK® 1000 (Physio Control)	Zoll® AED Pro® (Zoll®)	Lifeline™ Pro AED (Defibtech)
Price*(1/7/2014)	~\$20 000 (★)	~\$20 000 (★)	~\$19 000 (★★)	~\$22 000	~\$17 000 (★★)
Portability	★★			★	★★
Weight (kg)	1.6	3.2	3.2	2.7	1.4
Size (cm)	6.9×13.5×22.1	8×31×27	8.7×23.4×27.7	7.6×23.5×23.9	18.5×24×5.8
Maintenance	★		★	★★	★
Battery price*(1/7/2014)	~\$2 100	~\$3 100	~\$2 600	~\$1 200	~\$1 300
Standby life of battery	3-years	4-years	5-years	5-years	4-years
Types of battery	LiMnO <sub>2</sub>	LiSO <sub>2</sub>	LiMnO <sub>2</sub>	LiMnO <sub>2</sub>	LiMnO <sub>2</sub>
Capacity	300 shocks; 12 hours of operating time	290 shocks; 12 hours of operating time	440 shocks; 17 hours of operating time	300 shocks; 15 hours of operating time	125 shocks; 8 hours of operating time
Rechargeable battery	None	None	Optional	Optional	None
Price*(adult+pediatric pads)	~\$400** (adult pads)	~\$400+\$800	~\$300+\$900	~\$1 300+\$700	~\$500+\$800
Standby life of pads	2-years	2-years	2-years	5-years	2.5-years
Cost per year	~\$900	~\$1 300	~\$1 100	~\$700	~\$800
Durability	★★		★★	★★	★★
Dust protection*(IP ratings**)	5	2	5	5	5
Water protection*(IP ratings*)	5	4	5	5	5
User-friendly	★		★	★	★★
Shock charge time (seconds)	<8	10	<7	<10	<4
Shock delivery mode	Semi-automatic	Semi-automatic	Semi-automatic	Semi-automatic	Semi-automatic
Manual mode (energy selection)	None	None	None	Yes (50, 70, 85, 120, 150, 200 Joules)	Yes (25, 50, 70, 100, 150, 200 Joules)
Characteristics	★	★		★★	★★
ECG display	Optional	Yes	Optional	Yes	Yes
CPR support	None	None	None	CPR Feedback	CPR Video
Data storage	8 hours	60 minutes	40 minutes	5.8 hours	1 hour
Pediatric key	Yes	None	None	None	None
Supporting synchronized shock	None	Yes	None	None	None
AED trainer	Yes	Yes	Yes	None	None
Display	LCD color display	TFT color display	LCD with backlight	LCD display	TFT color LCD with backlight
Warranty	5-years	7-years	8-years	5-years	5-years

\*: The price is quoted from AED online markets in the USA (AED brands® and AED Superstore®) and then converted to HK dollars directly. Therefore, they are not the real price of AEDs in Hong Kong. \*\*: No pediatric pad is required in HeartStart FR3. (Pediatric key is provided).

**Table 7.** Summary of AEDs of advanced level

Variables	HeartStart FR3 (Philips) 	Powerheart® G3 Pro (Cardiac Science) 	LIFEPAK® 1000 (Physio Control) 	Zoll® AED Pro® (Zoll®) 	Lifeline™ Pro AED (Defibtech) 
Price	★	★	★★		★★
Portability	★★			★	★★
Maintenance	★		★	★★	★
Durability	★★		★★	★★	★★
User-friendly	★		★	★	★★
Characteristic	★	★		★★	★★

consumer in long-term consideration. Zoll® AED Plus® also has a high durability. The durability is measured by the IP ratings test in dust and water protection of AED. The IP ratings test, a worldwide standard, has been established by the International Electrotechnical Commission (IEC) for comparing the ability of electronic devices to withstand exposure to dust particles and water. Higher score means stronger protection against foreign objects and moisture. Zoll® AED Plus® has a score of 5 in the dust protection and water protection of IP ratings, which means the AED is dust protected and against water jet respectively. Lifeline™ AUTO AED has a score of 5 in dust protection but only 4 in water protection, which means the AED is against splashing water. Powerheart® G3 Plus is protected against object which is larger than 12 mm only; therefore, it might be unavailable to be used in beaches. The higher durability allows the application of AED in different environment, especially in outdoor facilities such as beaches and swimming pools.

Lifeline™ AUTO AED is the most user-friendly AED owing to the fact that the shock charge time is less than 6 seconds. The shock charge time of LIFEPAK CR® Plus is less than 9 seconds. The less time required for charging, higher chance to save victims' lives immediately. Although most of the shock charge time of AED in this study only differs a few seconds, every second is crucial for cardiac arrest patient.

Zoll® AED Plus® and Powerheart® G3 Plus include more characteristics than other AEDs. Zoll® AED Plus® offers the CPR feedback while LIFEPAK CR® Plus and Lifeline™ AUTO AED offer metronome only. The technology of CPR feedback gives the user, especially for laymen, real-time depth and rate feedback under cardiopulmonary resuscitation (CPR), providing guidance that can improve CPR quality. Metronome means that AED beats time, leading the user follow the frequency of CPR compression. Powerheart® G3 Plus is the only one supporting the synchronized shock which allows the pads putting in inverse position without any negative effect. To specify others' specialties, the warranty of LIFEPAK CR® Plus and Powerheart® G3 Plus are 8 years and 7 years respectively while the other AEDs are 5 years. Longer warranty ensures a longer standby life of AED and the lower operation cost for maintenance. Lifeline™ AUTO AED has 100 minutes data storage, which is the longest. The data record of cardiac arrest of victims is vital to doctor for analysis after victims being sent to hospital. It provides valuable information for the subsequent patient management such as implantation of implantable cardioverter defibrillator

(ICD). The data record can also be used for clinical audit and research purpose. Longer data storage is optional with higher price. All of them have the AED trainer for training use. Public can learn to use AED through the AED trainer from AED courses.

Lack of confidence is another barrier for PAD. A survey conducted in a shopping mall with AED in the USA in 2001 found that the most common concern of using community AED was 'fear of using the machine correctly'. The second most common concern was 'fear of legal liability'.<sup>[19]</sup> The CPR feedback and AED trainer can certainly boost the confidence and willingness of layperson of using AED.

In AEDs of basic level, Lifeline™ AUTO AED has the best performance in most of the criteria, especially the price, portability, user-friendly. It is the cheapest, the lightest, the smallest AED in the group. The longest standby life of battery in Lifeline™ AUTO AED provides the highest number of shocks and longest operation time. Therefore, it reduces the chance in replacement of battery. Lifeline™ AUTO AED requires the shortest time for shock charging in order to save life immediately.

### **AEDs of intermediate level**

In AEDs of intermediate level, HeartStart Onsite, HeartStart FRx, LIFEPAK EXPRESS®, Lifeline™ VIEW AED, Samaritan PAD defibrillator and i-PAD AED are compared.

HeartStart Onsite and Samaritan PAD defibrillator are the cheapest AED in the group. Referring to the price listed in AED online market in the USA, their price is the lowest, which offers an economic incentive. LIFEPAK EXPRESS® and i-PAD AED are less expensive than HeartStart FRx and Lifeline™ VIEW AED.

Samaritan PAD defibrillator is the most portable AED in the group. It is the lightest AED which is 1.1 kg while I4 is 1.4 kg. Besides, Samaritan PAD defibrillator is the smallest AED, 20 cm×18.4 cm×4.8 cm in dimension, in the group. Both HeartStart Onsite and HeartStart FRx are smaller than other AEDs in size.

i-PAD AED has the best performance in maintenance. The battery of LIFEPAK EXPRESS® is the cheapest but the standby life of battery in i-PAD AED is the longest (5 years). The battery of i-PAD AED provides more than 200 shocks and 10 hours of operating time. Furthermore, no battery price is marked in Samaritan PAD defibrillator because the battery is included with adult pads. The price of pads in HeartStart FRx is the cheapest due to the fact that only adult pads are required. The pediatric key replaces the function of pediatric pads. However, the

standby life of pads in Samaritan PAD defibrillator is the longest, 4 years. Under calculation, the total operation cost per year in i-PAD AED is the lowest.

Samaritan PAD defibrillator is the most durable AED in the group. In IP ratings, higher score means stronger protection against foreign objects and moisture. Samaritan PAD defibrillator, HeartStart FRx, Lifeline™ VIEW AED and i-PAD AED have the score of 5, dust protected, from dust protection in IP ratings. Samaritan PAD defibrillator also has the score of 6, against heavy sea, from water protection in IP ratings. However, HeartStart Onsite can only protect against object which is larger than 12mm and against dripping water, indicating that it is not available to be used in beaches, swimming pools and some wet place. The operation temperature of i-PAD AED is 0–40 °C, hence it could not be used in hot place.

Lifeline™ VIEW AED is the most user-friendly AED in the group. It requires less than 4 seconds for shock charging. The shock charge time of HeartStart FRx and LIFEPAK EXPRESS® is less than 9 seconds. The less time required for charging, the higher chance to save victims' lives immediately.

Lifeline™ VIEW AED and HeartStart FRx involve more characteristics than other AEDs. Lifeline™ VIEW AED offers CPR video while i-PAD AED and Samaritan PAD defibrillator offer metronome only. Lifeline™ VIEW AED shows step-by-step videos for performing CPR, rescue breathing and external defibrillation, especially for laypersons to use. Studies<sup>[20,21]</sup> have shown that laypersons can perform CPR more effectively with aid of video clip. The video is also particular useful when under noisy environment or the laypersons have language barrier. Laypersons without any BLS training before may also be able to perform CPR by watching the video. Samaritan PAD defibrillator has a warranty of 10 years, which is the longest. Longer warranty ensures a longer standby life of AED and the lower operation cost for maintenance. Lifeline™ VIEW AED also has 12-hour data storage. The data record of cardiac arrest is vital for analysis after victims being sent to the hospital. Furthermore, HeartStart FRx provides a pediatric key which replaces the function of pediatric pads. It lowers the operation cost in buying pediatric pads. HeartStart Onsite, HeartStart FRx and Samaritan PAD defibrillator have the AED trainer for training use.

In AEDs of intermediate level, Samaritan PAD defibrillator has the best performance in most of the criteria, particularly the price, portability, durability, and characteristics. It is the cheapest, lightest, and smallest

AED in the group. It has the highest score in dust protection and water protection, indicating that the AED is dust protected and could combat heavy sea, shown by the IP ratings test. The longest warranty allows Samaritan PAD defibrillator for long-term use.

### AEDs of advanced level

In AEDs of advanced level, HeartStart FR3, Powerheart® G3 Pro, LIFEPAK®1000, Zoll® AED Pro® and Lifeline™ PRO AED are compared.

The price of LIFEPAK®1000 and Lifeline™ PRO AED are the lowest in the group. The lower price provides an economic incentive. HeartStart FR3 and Powerheart® G3 Pro are less expensive than Zoll® AED Pro®.

HeartStart FR3 and Lifeline™ PRO AED are the most portable AED in the group. Lifeline™ PRO AED is the lightest, 1.4 kg. HeartStart FR3 is the smallest AED, 6.9 cm×13.5 cm×22.1 cm in dimension, in the group.

Zoll® AED Pro® has the best performance in maintenance. The price of battery of Zoll® AED Pro® is the lowest. The standby life of battery of LIFEPAK®1000 and Zoll® AED Pro® is 5 years. The battery of LIFEPAK®1000 allows 440 shocks and 17 hours of operating time. The price of pads in HeartStart FR3 is the lowest owing to the fact that no pediatric pads are needed. The pediatric key replaces the function of pediatric pads completely. However, the standby life of pads in Zoll® AED Pro® is 5 years. Therefore, the total operation cost per year in Zoll® AED Pro® is the lowest.

HeartStart FR3, LIFEPAK®1000, Zoll® AED Pro® and Lifeline™ PRO AED are more durable in the group. They have a score of 5 in dust protection, water protection, and combating water jet according to the IP ratings test. They have stronger protection against foreign objects and moisture. On the contrary, Powerheart® G3 Pro can protect against object larger than 12 mm only, showing that it might be unable to be used in beach.

Lifeline™ PRO AED is the most user-friendly in the group. It requires less than 4 seconds for shock charging. Both Zoll® AED Pro® and Lifeline™ PRO AED offer manual mode, which allows the user to choose the shocking range from 50, 70, 85, 120, 150, 200 joules and 25, 50, 70, 100, 150, 200 joules respectively. It allows people with medical background, doctors in particular, to choose appropriate energy for shocking. Even without pediatric pads, the AED can provide smaller energy for shocking.

Zoll® AED Pro® includes more characteristics than other AEDs in the group. Zoll® AED Pro® and

Lifeline™ PRO AED offer CPR feedback and CPR video respectively. HeartStart FR3 has 8-hour data storage, which is the longest. HeartStart FR3 also has the pediatric key to replace the function of pediatric pads. Powerheart® G3 Pro is the only one which can deliver synchronized shock. It provides additional benefit to patients with unstable tachyarrhythmia. HeartStart FR3, Powerheart® G3 Pro and LIFEPAK® 1000 have the AED trainer for training use. Furthermore, Powerheart® G3 Pro and Lifeline™ PRO AED have the TFT color display which provides high quality of image. The technology of TFT can improve the quality of image. The warranty of LIFEPAK® 1000 is 8 years, ensures a long standby life, and avoids high operation cost.

In AEDs of advanced level, Lifeline™ PRO AED has the best performance in most of the criteria, especially the price, portability, durability, user-friendly and other characteristics. It is the cheapest and smallest AED in the group. Lifeline™ PRO AED is dust protected while combating water jet according to the IP ratings test. It requires less than 4 seconds for shock charging. Furthermore, it offers manual mode, which allows the professional user to choose the shocking range from 25, 50, 70, 100, 150, and 200 joules. Besides, the CPR video allows laypersons following the steps of CPR. The TFT color LCD Display also provides a high quality image for ECG.

In conclusion, within the limits of this retrospective study, Lifeline™ AUTO AED, Samaritan PAD defibrillator, and Lifeline™ PRO AED are found to have better performance in basic level, intermediate level and advanced level, respectively. All of them come from the two new brands of AEDs (Defibtech, Heartsine®), which might learn from the old brands to enhance the strength and minimize the weakness. Despite the fact that the performance of other AEDs is not as good as them, all of the AEDs have their own features, strength and weakness. A suitable AED can be chosen by users according to their regional requirement and the current best available information.

### Limitations

The information of AEDs is only obtained from the product manuals and brochures by their companies. The functions of AEDs are not examined by testing real AEDs.

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**Conflicts of interest:** We certify that there is no conflict of interest with any financial organization regarding the AEDs discussed in this study.

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