SUMMARY OF SAFETY AND EFFECTIVENESS DATA (SSED)

I. GENERAL INFORMATION

Device Generic Name: Automated External Defibrillator (AED)

Device Trade Names: Lifeline/ReviveR DDU-100, Lifeline/ReviveR AUTO DDU-120, Lifeline/ReviveR VIEW DDU-2300, Lifeline/ReviveR VIEW AUTO DDU-2200, Lifeline/ReviveR ECG DDU-2450, and Lifeline/ReviveR ECG+ DDU-2475 Automated External Defibrillators

Device Procode: MKJ

Applicant's Name and Address: Defibtech, LLC.
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Date(s) of Panel Recommendation: None

Premarket Approval Application (PMA) Number: P160032

Date of FDA Notice of Approval: February 1, 2018

Defibtech AEDs have been on the market in the US since 2003 when the first Defibtech AED 510(k) was cleared (K013896, Sentry was the name for the product, now marketed as the DDU-100), with the most recent AED cleared in 2014 for the DDU-1000 AED (K131525), and four (4) other AED clearances in between these submissions. Defibtech AEDs are marketed in the US under the tradename Lifeline and are also privately-labeled and sold under the tradename ReviveR, while outside the US, they are also privately-labeled under the LifeForce name in addition to the Defibtech branding.

P160032 has been submitted in response to the *Final Order* issued January 29, 2015, in the Federal Register Volume 80 Number 19, Docket No. FDA-2013-N-0234 and republished February 3, 2015, in the Federal Register Volume 80 Number 22, Docket No. FDA-2013-N-0234. This Final Order required premarket approval of marketed pre-amendment Class III Automated External Defibrillators (AEDs), product code MKJ. Products affected by this Order are the Lifeline/ReviveR DDU-100, Lifeline/ReviveR AUTO DDU-120, Lifeline/ ReviveR VIEW DDU-2300, Lifeline/Reviver VIEW AUTO DDU-2200, Lifeline/ ReviveR ECG DDU-2450, and Lifeline/ReviveR ECG+ DDU-2475 Automated External Defibrillators. A combination of relevant literature, clinical data, and in-vitro bench testing has been reviewed to demonstrate a reasonable assurance of safety and effectiveness for the Lifeline/ReviveR DDU-100, Lifeline/ReviveR AUTO DDU-120, Lifeline/ ReviveR VIEW DDU-2300, Lifeline/Reviver VIEW AUTO DDU-

2200, Lifeline/ ReviveR ECG DDU-2450, and Lifeline/ReviveR ECG+ DDU-2475 Automated External Defibrillators.

II. INDICATIONS FOR USE

The Lifeline/ReviveR DDU-100 series Automated External Defibrillator (AED) is indicated for use on victims of sudden cardiac arrest (SCA) who are:

- Unconscious and unresponsive; and
- Not breathing or not breathing normally.

Lifeline/ReviveR DDU-100 series AEDs may be used with Defibtech adult defibrillation pads (model number DDP-100). For patients under 8 years old, or weighing less than 55 lbs (25 kg), use Defibtech child/infant defibrillation pads (model number DDP-200P), if available.

The Lifeline/ReviveR DDU-2000 series Automated External Defibrillator (AED) is indicated for use on victims of sudden cardiac arrest (SCA) who are:

- Unconscious and unresponsive; and
- Not breathing or not breathing normally.

Lifeline/ReviveR DDU-2000 series AEDs may be used with Defibtech adult defibrillation pads (model number DDP-2001). For patients under 8 years old, or weighing less than 55 lbs (25 kg), use Defibtech child/infant defibrillation pads (model number DDP-2002), if available.

III. CONTRAINDICATIONS

Should not be used if the patient is responsive or conscious.

IV. WARNINGS AND PRECAUTIONS

The warnings and precautions can be found in the Lifeline/ReviveR DDU-100, Lifeline/ReviveR AUTO DDU-120, Lifeline/ReviveR VIEW DDU-2300, Lifeline/Reviver VIEW AUTO DDU-2200, Lifeline/ReviveR ECG DDU-2450, and Lifeline/ReviveR ECG+ DDU-2475 Automated External Defibrillator's labeling.

V. DEVICE DESCRIPTION

Defibtech's AEDs are public access AEDs. Defibtech's DDU-100 series AED product line consists of two (2) Automated External Defibrillator models and their related accessories. The two (2) defibrillators that comprise the DDU-100 series product line are the DDU-100 and the DDU-120.

The DDU-100 is a Semi-Automatic External Defibrillator ("AED") designed for ease of use and portability. It is battery pack powered and has only two (2) user controls: ON/OFF and SHOCK buttons. Voice prompts and visual indicators provide a simple interface to guide the user. The DDU-100 AED can record event information including electrocardiogram (ECG), audio data (optional), and SHOCK/NO-SHOCK recommendations. The AED also provides verbal guidance on performing cardiopulmonary resuscitation (CPR), including when to stop and start compressions and frequency of compressions. Similarly, the DDU-120 is an Automatic External Defibrillator (a fully automated AED) designed for ease of use and portability. It is battery pack powered and has only one user control, which is an ON/OFF button, and will automatically deliver a shock without any user intervention. Voice prompts and visual indicators provide a simple interface to the user. The DDU-120 AED can record event information including ECG, audio data (optional), and SHOCK/NO-SHOCK recommendations. The AED also provides verbal guidance on performing CPR, including when to stop and start compressions, and frequency of compressions.

The defibrillation waveform in both AED models is an impedance compensating, biphasic, truncated exponential waveform. Both AEDs perform automatic self-testing, including daily, weekly, monthly, and quarterly tests, with the results of the self-testing communicated both audibily and visually via an Active Status Indicator (ASI). See Figure 1.

Figure 1. DDU-100 Series AEDs front view.
Left: DDU-100 Semi-Automatic. Right: DDU-120 Fully-Automatic.

DDU-2000 Series:

The DDU-2000 series AEDs includes model numbers DDU-2200, DDU-2300, DDU-2450, and DDU-2475, and are summarized in Table 1 below:

Table 1. The DDU-2000 series AED family models.

Model Number	Brand Names	Description
DDU-2200	Lifeline/ReviveR VIEW AUTO	Fully-Automatic AED with video display/ instruction
DDU-2300	Lifeline/ReviveR VIEW	Semi-Automatic AED with video display/ instruction
DDU-2450	Lifeline/ReviveR ECG	Semi-Automatic AED with video display/ instruction with optional non-diagnostic quality ECG display
DDU-2475	Lifeline/ReviveR ECG+	Semi-Automatic AED with video display/ instruction with optional non-diagnostic quality ECG display, and additional configurable features

The DDU-2000 series AEDs guide the user through a Rescue Protocol by analyzing rescue conditions (e.g., pads connections, heart rhythm) and providing loud, clear voice and visual (via full motion, LCD display) prompts that instruct the user through the rescue sequence. The semi-automatic AEDs (DDU-2300, DDU-2450, and DDU-2475) have two (2) primary push-button controls: an ON/OFF button that turns the device on and off and a SHOCK button that delivers defibrillation therapy when a shock is recommended and a user pushes the SHOCK button. The fully-automatic type (DDU-2200) has only one primary control: ON/OFF button and will automatically deliver a shock without user intervention.

For all DDU-2000 series AED models, three (3) context sensitive soft key buttons, located next to the liquid crystal display (LCD) , are used to enable enhanced features such as user help, dual language, ECG display (DDU-2450/2475) or factory set, customizable, non-therapeutic parameters, such as battery status, heart rate, rescue timer, and shock delivery counter shown on the display (DDU-2475 only). These softkeys are also used to navigate the menu screens in maintenance mode. Optionally, for the DDU-2450 and DDU-2475, the LCD display can be enabled to show the patient's ECG waveform. The display is also used in maintenance mode to display unit/battery pack/pads status.

The DDU-2000 series AEDs perform daily, weekly, monthly, and quarterly self-tests to help ensure readiness for use. An Active Status Indicator (ASI) is used to indicate the readiness of the AED when the unit is in standby mode: a green blinking light indicates that the unit is ready for use. See Figure 2 below.

Figure 2. DDU-2000 series AEDs.
Shown left to right, DDU-2450 (marketed under the name ECG), DDU-2300 (marketed under the name VIEW), DDU-2300 (marketed under the name VIEW) with dual language.

The rescue protocol defines a series of steps and actions to direct AED operation according to standard American Heart Association(AHA)/European Resuscitation Council (ERC) CPR guidelines. It instructs the user when to leave the patient alone so the AED can analyze and then provides time to perform CPR with audible and visual CPR coaching. CPR coaching can be configured to include rescue breathing prompts, per the selected protocol, by default. The user can also enable or disable rescue breathing prompts during the CPR period using a soft key.

Battery Packs

The DDU-100 series AEDs use a user-replaceable (non-rechargeable) battery pack to power the AED during operation, supply the defibrillation shock energy, and maintain the unit during standby. Battery packs are available in standard capacity (DBP-1400) and high-capacity (DBP- 2800), using five (5) or ten (10) 0.3V lithium manganese dioxide cells, respectively. An additional 9V lithium battery provides power to the Active Status Indicator and is inserted into a compartment in the battery pack. The DBP-1400 has a 5-year standby life or can supply 125 shocks. The DBP-2800 has a 7-year standby life or can supply 300 shocks. The battery pack is labeled with an expiration date.

The DDU-2000 series AEDs uses a user-replaceable (non-rechargeable) battery pack to provide power for the AED during operation, supply the defibrillation shock energy, and maintain the unit during standby. The DBP-2003/2013 battery pack contains eight (8) 3V lithium manganese dioxide cells, and has a 4-year standby life or can supply 125 defibrillation shocks. The DBP-2013 is a TSO-142a authorized battery pack. An

optional rechargeable battery, DBP-2009, is also available. The DBP-2009 battery pack uses three (3) 3.7 V lithium ion cells, has a 3-month shelf life and can deliver a minimum of 250 shocks. The battery pack must be removed from the AED to be recharged in a separate charging stand and its associated wall charger.

Each battery pack contains an internal memory to store battery related parameters, such as battery capacity, ratings, type, and expiration date. These parameters are used in conjunction with the AED's automatic self-testing to alert the user when the battery pack is near the end of its life. Additionally, all battery packs are marked with an expiration date.

Defibrillation Pads

Both adult and pediatric pads are available for use with the DDU-100 series AEDs and the DDU-2000 series AEDs. The defibrillation pads (adult: DDP-100 for use with the DDU-100 series AEDs and the DDP-2001 for use with the DDU-2000 series AEDs; pediatric: DDP-200 for use with the DDU-100 series AEDs and the DDP-2002 for use with the DDU-2000 series AEDs) act as a conductive interface between the AED and the patient's skin.

The defibrillation pads consist of two (2) self-adhesive defibrillation/monitoring pads used to capture ECG signals and, if advised, to deliver defibrillation energy to the patient. These pads (also sometimes called electrodes) are single use and non-sterile, and are provided as a packaged, disposable assembly. The defibrillation pads assembly (pads, cable, and pads connector) is provided as a pre-assembled item, designed to minimize the number of operational steps during a rescue. The DDU-100 series and DDU-2000 series AEDs determine proper pad-to-patient contact by assessing the impedance between the two (2) pads.

Audio and visual prompts inform the user of possible problems with patient contact and instruct for proper application.

The pediatric pads have an integrated attenuator that automatically reduces the default 150J (nominal) energy level to 50J (nominal). The pads package is labeled with an expiration date.

VI. ALTERNATIVE PRACTICES AND PROCEDURES

Defibrillation is the only currently available treatment for termination of ventricular fibrillation (VF) or pulseless ventricular tachycardia. Public access defibrillation is designed to provide potentially lifesaving treatment prior to the arrival of emergency personnel.

VII. MARKETING HISTORY

Defibtech first commercialized its AEDs in 2003 with an introduction to the US market of the DDU-100 (initially called the Sentry, cleared via K013896 on June 19, 2002). The DDU-100 is an AED with two (2) user controls: an on/off button and a shock button,

with voice and visual indicators, and requires the user to press the shock button when a shock is advised (i.e., a semi-automated AED). Additional AED products have been added to Defibtech's product offerings, mainly differentiated by the user interface, DDU-2000 series (K081259 cleared on June 15, 2009, and K121853 cleared on December 14, 2012) and the DDU-120, which is a fully automated version of the DDU-100, cleared via K113787 on January 4, 2013. Pediatric pads are also available for use with all Defibtech AEDs, with the initial clearance via K033896 on June 16, 2004. In addition to the Defibtech branding, Defibtech privately-labels its AEDs in the US, under the ReviveR tradename, as well as privately labeling other tradenames for AED models sold exclusively outside the US. Defibtech has grown to offer its AEDs in over 30 languages (including dual-language combinations), and Defibtech's AEDs have been sold in more than 70 different countries, including the European Union, European Economic Area, Canada, Australia, Israel, Korea, Malaysia, South Africa, and United Arab Emirates.

VIII. PROBABLE ADVERSE EFFECTS OF THE DEVICE ON HEALTH

The probable adverse effects (e.g., complications) associated with use of an automated external defibrillator include, but are not limited to, the following:

- Failure to identify shockable arrhythmia;
- Failure to deliver a defibrillation shock in the presence of ventricular fibrillaton (VF) or pulseless ventricular tachycardia (VT,) which may result in death or permanent injury;
- Inappropriate energy, which could cause failed defibrillation or post-shock dysfunction;
- Myocardial damage;
- Fire hazard in the presence of high oxygen concentration or flammable anesthetic agents;
- Incorrectly shocking a pulse sustaining rhythm and inducing VF or cardiac arrest;
- Bystander shock from patient contact during defibrillation shock;
- Interaction with pacemakers;
- Skin burns around the defibrillation pads placement area;
- Allergic dermatitis due to sensitivity to the materials used in the defibrillation pads construction; and
- Minor skin rash.

IX. SUMMARY OF NONCLINICAL STUDIES

The DDU-100, DDU-120, DDU-2300, DDU-2200, DDU-2450, and DDU-2475 AEDs for Public Access Defibrillation and their accessories (battery packs and defibrillation pads as a matter of completeness although not part of this PMA submission*) underwent bench evaluation, as well as software verification and validation appropriate for major level of concern devices. The testing was conducted on key device subassemblies and the complete systems.

*Note: As allowed by the AED Systems Final Order preamble, the battery packs and defibrillation pads are not included in this PMA, but will be the subject of a future PMA submission. However, as a matter of completeness, certain information was provided in this submission.

As a key data point for the PMA, a Defibrillation Waveform Comparison Report was generated that demonstrates the DDU-100 series and DDU-2000 series AEDs waveforms are almost the same as the Heartstream/Hewlett-Packard/Agilent/Philips waveform at all adult and child/infant impedances and energy levels.

There are no performance standards required by FDA for AED systems.

Defibtech uses standards in its design and development process since the same AED models are sold worldwide, including Europe, where compliance to standards are mandatory. As a result, Defibtech completed FDA Form 3654 "Standards Data report for 510(k)s" as part of the PMA submission for relevant standards associated with its AEDs, including:

- IEC 60601-1, General requirements for basic safety and essential performance;
- IEC 60601-1-2, General requirements for basic safety and essential performance - electromagnetic compatibility;
- IEC 60601-1-6, General requirements for basic safety and essential performance – usability;
- IEC 60601-2-4, General requirements for basic safety and essential performance of cardiac defibrillators; and
- IEC 62366, Application of usability engineering to medical device.

Summary of Non Clinical Testing

Table 2 below summarizes the bench testing conducted to demonstrate proper performance of all Defibtech AED models, including conformance with applicable consensus performance standards.

Table 2. Bench Testing

	Test Report and Conformance Standard (as applicable)	Results
1.	Medical Electrical Equipment Safety (IEC 60601-1 3rd edition)	Pass
2.	Particular Requirements for the Basic Safety and Essential Performance of Cardiac Defibrillators (IEC 60601-2-4)	Pass
3.	Arrhythmia Algorithm Detection	Pass
4.	Defibrillation Shock Waveform	Pass
5.	Defibrillation Waveform Comparison with Other Defibrillation Waveforms	Pass
6.	Mechanical Hardware Verification and Validation	Pass
7.	Environmental: Ingress (IEC 60529), Temperature Extremes, Humidity and Altitude	Pass
8.	Vibration: Air (RTCA DO-160) & Ground (MIL-STD-810)	Pass
9.	Shock (MIL-STD-810)	Pass

	Test Report and Conformance Standard (as applicable)	Results
10.	Electromagnetic Compatibility (RTCA DO-160, IEC 60601-1-2) with additional Home Use environment requirements	Pass
11.	Particular requirements for the basic safety and essential performance of electrocardiographic monitoring equipment (IEC 60601-2-27)	Pass
12.	Electronic Hardware Verification and Validation	Pass
13.	AED Software Verification and Validation	Pass
14.	Battery Pack Verification and Validation[3]	Pass
15.	Rechargeable Battery Pack (IEC 62133)[3]	Pass
16.	Defibrillation Pads Shelf Life[3]	Pass
17.	Defibrillation Pad Biocompatibility (ISO 10993)[3]	Pass
18.	Packaging (UN, IATA DGR)	Pass

The ECG arrhythmia analysis algorithm performance has been evaluated by using several databases of real-life ECG recordings, including the AHA, Massachusetts Institute of Technology (MIT) – National Standards of Technology (NST), and Creighton University databases. The devices meet the recommendations of the AHA for performance goals of arrhythmias analysis algorithms.

Biocompatibility Testing

The only patient contacting portions of the Defibtech AED system are the defibrillation pads (model number DDP-100, DDP-2001 for adults and model number DDP-200P or DDP-2002 for pediatrics) and, as allowed by the Final Order,* the defibrillation pads are not the subject of this application. As a matter of completeness, these accessories were tested in accordance with ISO 10993 for cytotoxicity, irritation, and sensitization testing, and passed all testing to adequately demonstrate biocompatibility.

Software Documentation and Validation

The DDU-100, DDU-120, DDU-2300, DDU-2200, DDU-2450, and DDU-2475 AEDs software was documented and validated according to the FDA guidance document "Guidance for the Content of Premarket Submissions for Software Contained in Medical Devices" for a major level of concern device. Software documentation included level of concern, software description, device hazard analysis, software requirements specification, software architecture diagrams, software design specifications, software module design specifications, requirements traceability matrix, software development environment description, verification and validation documentation, revision level history, unresolved anomaly report, results of tools implemented to detect run-time errors, and cybersecurity documentation.

Software verification and validation testing conducted on each model included: unit, integration, and system-level protocols and test reports with pre-defined pass/fail criteria, algorithm testing, source code inspections for all software modules and algorithms, integrated system testing, software compatibility testing, and software summary

validation testing. This testing demonstrated that the DDU-100, DDU-120, DDU-2300, DDU-2200, DDU-2450 and DDU-2475 AEDs and software perform as intended.

Shelf Life Testing

As the applicant is not sterilizing the AED and the defibrillation pads, a sterility review is not necessary. The cleaning instructions provided for the AED unit are acceptable as they do not make any claims of the sterility of the device before/after cleaning. The cleaning informs the user to minimize exposure of the device with fluid and to check the device after cleaning. The cleaning does not use abrasive or strong solvents that could compromise the device. The defibrillation pads are single use, so no cleaning is necessary.

X. SUMMARY OF PRIMARY CLINICAL STUDIES

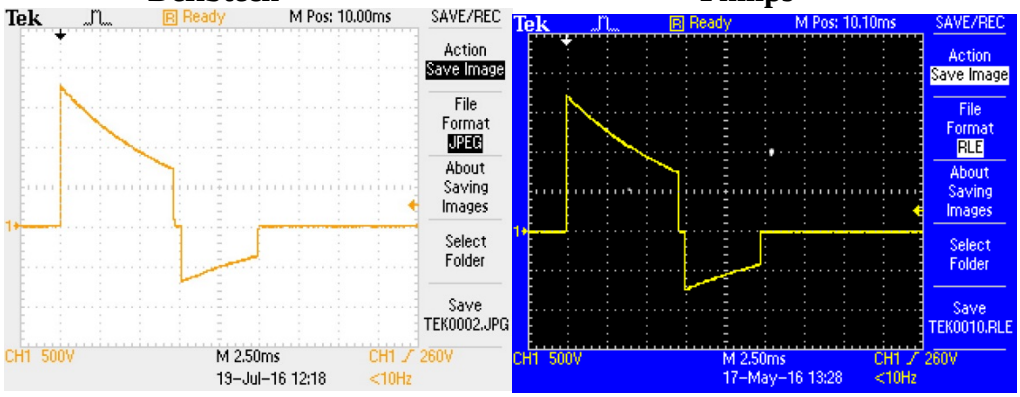
The final order, Effective Date of Requirement for Premarket Approval for Automated External Defibrillator Systems, published on January 29, 2015 and republished on February 3, 2015, states that clinical study information can be leveraged for AEDs from both published studies and clinical data previously submitted to FDA under the 510(k) process. Defibtech, LLC submitted a comparison of the Defibtech adult and pediatric defibrillation waveforms for the DDU-100 and DDU-2000 series AEDs and the Philips defibrillation waveforms that were also used for the original clearance of the Defibtech AEDs. The waveform delivered by the Defibtech and Philip AEDs is a biphasic truncated, impedance-compensating exponential waveform. The comparison consisted of oscilloscope captures of the defibrillation waveforms, as shown in the examples below. The waveforms were collected from 25 ohms to 200 ohms in 25 ohms steps. The following electrical parameter measurements and calculations were also included:

- Peak voltage of the leading edge of the first phase
- Peak voltage of the trailing edge of the first phase
- Peak voltage of the trailing edge of second phase
- Peak current of the leading edge of the first phase
- Peak current of the trailing edge of the first phase
- Phase 1 duration
- Phase 2 duration

Examples: Adult Waveform at 75 omhs. See Figure 3 below.

Figure 3. Adult Waveforms at 75 ohms.

Defibtech **Philips**



The waveform data provided by Defibtech demonstrates that the waveforms from Defibtech and Philips are almost identical. Consequently, the clinical data included in this submission was leveraged from published clinical data[1,3] for adult and pediatric uses of the Philips waveforms.

A. Published Clinical Data

The published clinical data is mainly derived from an out-of-hospital clinical study from a prospective, multicenter, out-of-hospital clinical study published by Schneider et al.[1] for adult defibrillation. Pediatric defibrillation was supported by an animal study performed on swine for defibrillation success and safety[2] and by a clinical study published by Atkins et al.[3]

Adult Waveform

The objective of the Schneider et al.[1] study was to compare AEDs that delivered 150J biphasic shocks with AEDs that delivered high-energy (200 to 360J) monophasic shocks. AEDs were prospectively randomized according to defibrillation waveform on a daily basis in four (4) EMS systems. First responders used either the 150J biphasic waveform delivered by the Philips AEDs or 200 to 360J monophasic waveform AEDs on victims where defibrillation was indicated. As noted above, the data provided by Defibtech demonstrates that the waveforms from Philips and Defibtech are almost identical. Therefore, the clinical data for adult defibrillation included in the Schneider publication was leveraged to support the safety and effectiveness of the Defibtech waveform.

A sequence of up to three (3) defibrillation shocks was delivered: 150J-150J-150J for the biphasic units and 200J-200J-360J for the monophasic units. Defibrillation was defined as termination of VF for five (5) seconds without regard to hemodynamic factors. Of 338 patients with an out-of-hospital cardiac arrest, 115 had a cardiac etiology, presented with VF, and were shocked with one of the randomized AEDs. There were no statistical differences between the monophasic and biphasic groups in terms of age, sex, weight,

primary structural heart diseases, cause or location of arrest, bystanders who witnessed the arrest, or type of responder. A summary of the results is presented in Table 3 below.

Table 3. Biphasic vs. Monophasic waveform

	Biphasic Patients Number (%)	Monophasic Patients Number (%)	P Value
Defibrillation Efficacy			
1 shock	52/54 (96%)	36/61 (59%)	< 0.0001
≤ 2 shocks	52/54 (96%)	39/61 (64%)	< 0.0001
≤ 3 shocks	53/54 (98%)	42/61 (69%)	< 0.0001
Patients defibrillated	54/54 (100%)	49/58 (84%)	0.003
ROSC	41/54 (76%)	33/61 (54%)	0.01
Survival to Hospital Admission	33/54 (61%)	31/61 (51%)	0.27
Survival to Hospital Discharge	15/54 (28%)	19/61 (31%)	0.69

More patients were defibrillated with an initial biphasic shock than monophasic shock and ultimately the biphasic waveform defibrillated at higher rates than the monophasic waveform. A higher percentage of patients achieved return of spontaneous circulation (ROSC) after biphasic shocks. Rates of survival to hospital admission and discharge did not statistically differ between the two (2) waveforms.

The Schneider study was performed exclusively in Europe, and the following summarizes why that study is applicable to the US population**.** The American Heart Association (AHA)[12] and European Resuscitation Council (ERC) guidelines[5, 6, 7] published when the studies were conducted recommended similar basic life support (BLS) and advanced life support (ALS) steps for treating sudden cardiac arrest. The sudden cardiac arrest chain of survival is consistent between the AHA and ERC, recommending delivering a shock as quickly as possible for VF and pulseless ventricular tachycardia, performing CPR and ensuring access to advanced medical care for post resuscitation care. In addition, these recommendations by AHA and ERC are still applicable to today's resuscitation procedures and practices.[8, 9, 10] Therefore, the study applies to the US population since the most significant factors influencing sudden cardiac arrest outcomes are based on the specifics of the victim and the circumstances around the event,[11] none of which are dependent on a US or European designation.

Pediatric Waveform

Defibtech's pediatric defibrillation is supported by publications by Tang et al.[2] and by Atkins et al.[3] As with the adult Defibtech defibrillation waveform, the data provided by Defibtech demonstrates that the pediatric waveforms from Philips and Defibtech are almost identical. The Tang animal study tested the defibrillation waveform used for defibrillation success and safety on a pediatric model (swine). The Atkins clinical study was published in 2005 and evaluated the same waveform in a post-market study.

The prospective, randomized animal study included piglets weighing 3.5 ± 0.5 kg, 7 ± 1 kg, 14 ± 1 kg, and 25 ± 1 kg. The study was divided into two (2) phases: In phase 1, 20 experiments were completed in four (4) groups of piglets weighing 3.8 kg, 7.5 kg, 15 kg, and 25 kg (average). After ventricular fibrillation (VF) was induced and maintained for 7 minutes, a 50J biphasic truncated exponential shock was delivered (up to 3 shocks) by a manual defibrillator.

In phase 2, nine (9) experiments were completed on piglets weighing 3.7 kg, 13.5 kg, and 24.2 kg (average). The same VF duration was treated with the AED waveform using a 150J biphasic waveform attenuated to deliver a 50J shock.

All animals in both groups were successfully defibrillated with return of spontaneous circulation. No differences were observed in hemodynamic and myocardial measurements before cardiac arrest and after successful resuscitation. No myocardial injury was observed during the autopsy in any of the animals. The study demonstrated that this 150J adult defibrillation waveform attenuated to a 50J shock, successfully defibrillated and restored spontaneous circulation without post shock dysfunction in this pediatric model.

Atkins et al. is an observational study on pediatric patients intended to evaluate reported uses of pediatric pads that reduced energy delivered by the Philips AEDs such that they could be used with pediatric patients. Pediatric pads are designed for use on children 0 - 8 years old or up to 25 kg kg (55 lbs) that reduces the energy delivered by the AED waveform from 150J (for adults) to 50J. Users of pediatric pads were asked to report to the original equipment manufacturer for any use of the pads, even if no shock was delivered and to provide details about the event, caregiver and patient. Electrocardiograms (ECGs) and information from the AED's internal memory (when available) were reviewed and confirmed by the principle investigator. All submitted information was also periodically reviewed by a Data Monitoring and Safety Board. From May 2001 to November 2004, 30 cases were reported, and three (3) cases were later excluded as being false reports and not included in the remaining analysis. Nineteen (19) cases were from the US and the remaining eight (8) from outside the US. Ventricular fibrillation was reported in eight (8) cases, ages 4.5 months to 10 years. An average of 1.9 shocks were delivered. All patients had termination of VF and were admitted to the hospital. Five (5) patients survived to hospital discharge. Until the attenuated pediatric pads for use with an AED were first introduced in 2001, shock delivery to pediatric patients did not occur until a manual defibrillator arrived. These reports indicate that the biphasic AED waveform performed appropriately since in all cases where VF was the presenting rhythm, the VF was terminated via the AED, and five (5) survived to hospital discharge.

ECG Algorithm

The ECG arrhythmia analysis performance has been evaluated by using several databases of real-life ECG recordings, including MIT-BIH A (Massachusetts Institute of

Technology-Beth Israel Hospital, Arrhythmia), MIT-BIH MVA (Massachusetts Institute of Technology-Beth Israel Hospital, Malignant Ventricular Arrhythmia), MIT-BIH SVA (Massachusetts Institute of Technology-Beth Israel Hospital, Supraventricular Arrhythmia), CU VT (Creighton University, Ventricular Tachyarrhythmia), AHA (American Heart Association, Ventricular Arrhythmia), and Defibtech's internal library of real-life and electronically-manipulated ECG recordings. The Defibtech AEDs meet the recommendations of the AHA[12] and IEC 60601-2-4 for performance goals of arrhythmia analysis algorithms. The performance of the arrhythmia analysis algorithm is summarized in Table 4 below. Note that the same ECG arrhythmia analysis algorithm is used in all Defibtech AEDs.

Table 4. Defibtech AED Patient Analysis System Performance (typical).

Rhythm Class	ECG Test Sample* Size	Specification[12]	Algoithm Performance*	
			Performance[12]	90% Lower Confidence Limit[12]
Shockable Rhythms				
Ventricular Fibrillation	227	> 90% sensitivity	> 97% sensitivity	> 95%
Ventricular Tachycardia	101	> 75% sensitivity	> 98% sensitivity	> 95%
Non-shockable Rhythms				
Normal Sinus Rhythm	213	> 99% specificity	100% specificity	100%
Asystole	113	> 95% specificity	100% specificity	100%
Atrial fibrillation (AF), Atrial flutter (AFL), Heart Block (HB), Premature Ventricular Contractions (PVCs), Sinus Braycardia (SB), Supra-ventricular Tachycardia (SVT) & Idioventricular rhythms	248	> 95% specificity	> 99% specificity	> 98%
Intermediate Rhythms				
Fine Ventricular Fibrillation	31	Report only	> 90%	NA
Other Ventricular Tachycardia Sinusoidal	17	Report only	> 40%	NA
Other Ventricular Tachycardia Horizontal	9	Report only	> 65%	NA

*From Defibtech ECG Rhythm Databases.

B. Usability Studies

Human factors data was collected and analyzed in Defibtech's various usability studies and report (for the DDU-2200) which support the conclusions that the user interfaces for

the various AED models, when used by untrained lay users, are safe and effective. The studies and total number of participants are listed below:

A. DDU-2300 Usability Study – 31 subjects
B. DDU-120 Usability Study – 15 subjects
C. DDU-100 Usability Study – 17 subjects
D. DDU-2450 / 2475 Usability Study – 19 subjects

The usability studies focused on three (3) aspects of usability: 1) Time to shock, 2) Safety to users and bystanders, and 3) Ease and clarity of use of the user interface. These three (3) aspects of usability are essential to the safety and effectiveness of an AED. Average time to shock for all Defibtech's usability studies ranged from 69 seconds to 102 seconds, well within the target timeframe of 3 minutes for time to shock for untrained lay users[18]. There were no instances of users touching the manikin during shock delivery, demonstrating safety to users.

There were four (4) total instances from all the usability studies (total n = 82, 5%) related to pads placement (either failure to apply the pads properly to the manikin's skin or pads were placed in potentially ineffective positions). The 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations[14], attempts to assess the variations seen with pad placement; however, recommendations conclude that there are no studies in patients with VF/pulseless VT directly comparing the effects of various positions of paddle/pad placement on defibrillation success and ROSC. Therefore, it is difficult to accurately gauge the effect (if any) the various pad positions observed in these studies would have on actual clinical defibrillation success and ROSC. Pad placement difficulties has been documented for lay responders and those with advanced training[15,16,17] Heames et al. tested the ability of doctors to position paddles correctly on a manikin and found 35% of the sternal and 78% of the apical paddle placements to be incorrect.[15]

In addition, the rate of users who improperly placed the pads on the simulated victim in all of Defibtech's usability studies combined compare favorably to the rates presented in the usability study results for four AEDs from other manufacturers in the Andre et al. study[13]. Note that the shock delivery success rates for all Defibtech's usability studies ranged from 86.7% to 96.8%, well above other lay-user AED usability study success rates.[18]

There was one user that was observed touching the manikin during ECG analysis even though the AED prompts the user to "do not touch the patient." In an actual clinical setting, the AED has motion detection capabilities (that are not available during usability testing) that instruct the user with voice prompts to "stop motion" and "do not touch patient," and as this event involved the DDU-100 series AED, the LED labeled "do not touch the patient" on the user interface flashes red during these messages.

The results of these studies demonstrate that the Defibtech AEDs achieve high usability as untrained subjects were able to safely deploy the AED and deliver an effective

defibrillation shock, without any safety risk, and any failures encountered do not result in an unacceptable occurrence rate nor introduce any previously unknown risks.

C. **Complaint Analysis**

To further demonstrate the safety and effectiveness of the Defibtech AEDs in clinical use, relevant complaint data for Defibtech AEDs were analyzed since the AEDs were first launched for marketing in 2002.

A medical device reporting (MDR) analysis was conducted and results identified 17 deaths, four (4) serious injuries, and 22 malfunctions associated with Defibtech AEDs, including model numbers DDU-100, DDU-120, and DDU-2300. Model numbers DDU-2200, DDU-2450, and DDU-2475 had no MDR reports. The analysis covers January 1, 2014 through August 24, 2016. Results indicated that of the 17 death reports identified, 12 were related to the following use errors: inability to properly maintain the device battery (5), inability to properly apply pads to patient (2), inability to operate the AED correctly (1), inability to assure proper connection between the pads and the AED (2), no battery pack in the AED during the rescue attempt (1), and performing compressions during ECG rhythm analysis (1). The remaining five (5) were the result of unknown electrical interference or AED service codes occurring during use. For the four (4) serious injury MDRs reported, one event was attributed to use error in which pediatric pads were applied to an adult patient (although the patient survived), and the remaining reports were a delay of therapy caused interference from an unknown source (1), and no fault in the device identified (2).

For the malfunctions, the reported root cause for each report as determined by Defibtech's analysis (regardless if the product was returned or not) and quantity of each cause are listed below. As this information shows, most malfunctions are associated with improper battery pack maintenance activities or other use behaviors that resulted in a delay in therapy.

1. Device maintenance issues: (11) resulting in shock aborted, no shock delivered, unit shut down, unit damaged, or unattended service codes.
    - Did not maintain battery pack (6)
    - Device powered off accidentally by user (2)
    - Inadvertent battery ejection from AED by user during use (1)
    - AED physically damaged by use (1)
    - Pads not properly connected to AED. Did not occur during patient use (1)

2. Power issues: (1)
    - Short in active status indicator (ASI) lead to a depleted main AED battery pack

3. Labeling issues: (3)
    - Distributor's label concealed defibrillation pads' expiration date (2)

- Unconfirmed report of both defibrillation pads graphics displayed same apical image for patient placement (1)

4. Unit would not power on, shock delivery error, AED stopped working, or shock abort. (7)
    - Indeterminate root cause as AED functioned properly or inconclusive root cause due to device, although requested, was not returned.

D. **Pediatric Extapolation**

In this premarket application, the applicant provided pediatric waveform analysis from pediatric patients (Atkin et al[3]). In addition, the applicant also provided supporting animal data (Tang et al[2]) to further support the use of the pediatric waveform. As with the adult Defibtech defibrillation waveform, the data provided by Defibtech demonstrates that the pediatric waveforms from Philips and Defibtech (as described above) are almost identical.

E. **Financial Disclosure**

The Financial Disclosure by Clinical Investigators regulation (21 CFR 54) requires applicants who submit a marketing application to include certain information concerning the compensation to, and financial interests and arrangement of, any clinical investigator conducting clinical studies covered by the regulation. There were four (4) clinical studies to support safety and effectiveness, none of which were sponsored by the applicant, and included in total five (5) clinical investigators (as identified in the published studies) and 32 study authors, none of which were full-time or part-time employees of the applicant and none had disclosable financial interests/arrangements with the applicant as defined in 21 CFR 54.2(a), (b), (c) and (f). This information provided does not raise any questions about the reliability of the data.

Additionally, Defibtech had five (5) physicians, none of who were full time or part time employees, that classified the ECG rhythms used in Defibtech's ECG database. Of the five (5) physicians three (3) were independent, board-certified electrophysiologists (EPs) who categorized each of the adult or pediatric ECG segments by rhythm and identified each of the segments as shockable, non-shockable, or intermediate. One (1) EP physician was an equity investor, meaning that they had stock in Defibtech and, hence, had disclosable financial interest/arrangement, while the other two (2) EP physicians did not hold equity in the company that could be affected by the outcome of the review. The potential bias in this physician's review who holds equity was minimized via the following steps:

1. The ECG test samples were reviewed by three (3) EPs independently. Only samples where all three (3) EPs came to an agreement on class and/or category were accepted into the test sample database.

2. Specific criteria were defined by a test sample review protocol. The EP physicians were given a protocol that defined objective criteria for sample classification, thus reducing the chance that personal bias would significantly affect the outcome of the review.

3. An analysis was performed to assess whether the physician who held equity biased the algorithm validation results. The ECG database classifications were reviewed, and the algorithm reassessed excluding this physician's rhythm classifications. The performance of the arrhythmia detection algorithm was not impacted, demonstrating that the physician did not bias the results of the arrhythmia detection algorithm. The AHA minimum requirements for sensitivity of all shockable rhythms, the specificity of non-shockable rhythms, as well as Defibtech's sensitivity and specificity performance specifications, were not impacted.

The applicant has adequately disclosed the financial interest/arrangements with clinical investigators and physicians. Statistical analyses were conducted by FDA to determine whether the financial interests/arrangements had any impact on the clinical study outcome. The information provided does not raise any questions about the reliability of the data.

XI. PANEL MEETING RECOMMENDATION AND FDA'S POST-PANEL ACTION

In accordance with the provisions of section 515(c)(3) of the act as amended by the Safe Medical Devices Act of 1990, this PMA was not referred to the Cardiovascular Device Panel, an FDA advisory committee, for review and recommendation because the information in the PMA substantially duplicates information previously reviewed by this panel on January 25, 2011 as part of the 515(i) process. The majority of the panel recommended that AEDs be regulated as Class III PMAs to have better oversight of device manufacturing and post-market performance.

XII. CONCLUSIONS DRAWN FROM PRECLINICAL AND CLINICAL STUDIES

A. Effectiveness Conclusions

The effectiveness analysis was based on bench testing of the arrhythmia analysis algorithm, the comparison of the defibrillation waveform, and data collected from the published literature. The bench testing demonstrates that the arrhythmia analysis algorithm meets and/or exceeds the AHA recommendations and IEC defibrillator standard for sensitivity and specificity for detecting shockable and non-shockable rhythms.

The waveform data provided by Defibtech demonstrates that the adult and pediatric waveforms from Defibtech and Philips are almost identical. Consequently, the clinical data included in this submission was leveraged from published clinical data[1,3] for adult and pediatric use of the Philips waveform.

The Schneider et al. study shows that more adult patients were defibrillated with the same biphasic waveform as the Defibtech biphasic waveform than a monophasic waveform and a higher percentage of patients achieved ROSC after biphasic shocks.

Pediatric defibrillation was supported by an animal study by Tang et al[2] performed on swine for defibrillation success and safety and by a study published by Atkins et al[3]. The Tang study demonstrated that the 150 J adult defibrillation waveform attenuated to a 50 J shock, successfully defibrillated and restored spontaneous circulation without postshock dysfunction in this pediatric model. The Atkins et al. study showed that the Philips waveform, which is almost identical to Defibtech's waveform, defibrillated all pediatric patients in sudden cardiac arrest where VF was the presenting rhythm, and five (5) victims survived to hospital discharge.

B. Safety Conclusions

The risks of the device are based on non-clinical testing and data collected from the published literature. The results from the non-clinical testing performed on the AEDs demonstrated appropriate electrical safety, electromagnetic compatibility, environmental conditions, biocompatibility, mechanical performance, transportation, and overall performance. The clinical data, including published clinical studies, usability/human factors reports, and complaint analysis, further demonstrate the safety of the device. The results of the usability studies demonstrate that the Defibtech AEDs achieve high usability as untrained subjects were able to safely deploy the AED and deliver an effective defibrillation shock, without any safety risk, and any failures encountered do not result in an unacceptable occurrence rate nor introduce any previously unknown risks.

C. Risk-Benefit Determination

The probable benefits of the Defibtech AEDs are based on published literature and post market data published by Atkins et al,[22] collected after the device initially received 510(k) clearance, as described above. The benefit of early defibrillation therapy is survival of patients in cardiac arrest. AEDs are life-saving devices used in emergency situations. They have shown to have a high benefit for patients with underlying diseases that remain undetected until sudden cardiac arrest occurs. The benefit of early defibrillation is providing the sudden cardiac arrest victim a chance at surviving the arrest since the chances of surviving a sudden cardiac arrest decreases by 7-10% for each minute without defibrillation[19]. Sudden cardiac arrest is a leading cause of out of hospital death in the US, claiming approximately 326,000 lives each year, with only about a 10% survival rate[20]. Sudden cardiac arrest is the unexpected loss of the heart's ability to effectively pump blood to the body and the victim is unconscious and unresponsive. The most common rhythm of adult sudden cardiac arrest resulting in ventricular fibrillation[21] whereas for infants and children sudden cardiac arrest related to breathing is more common, although the importance of rapid AED deployment remains.[22] The role early defibrillation plays in adult and pediatric sudden cardiac arrest has been extensively

documented[23] and access to an AED provides a sudden cardiac arrest victim a chance of surviving the event.

The magnitude of this benefit is either life or death. The published clinical studies mentioned before[1,3] have no ability to predict which patients will experience a benefit or determine probability of benefit because of the differing pathophysiology of underlying cardiac arrest. The subpopulations have a high degree of heterogeneity of etiologies of cardiac arrest therefore variation in public health benefit cannot be determined. Likewise, the duration of effect is dependent on underlying etiology and, though valuable to the patient, is highly dependent on subsequent treatment of the underlying disease. Duration of effect of the treatment is not related to the device.

Patients put a high value on this treatment because it has the potential to save their lives. Patients are, therefore, willing to accept the risks of this treatment to achieve the benefit. If the treatment provides timely successful defibrillation, the patient may survive a life threatening cardiac arrest situation and will be able to seek further treatment.

The general population would place a high value on AEDs since they have the potential to help save a life. Most sudden cardiac arrest victims have no prior symptoms of heart disease. The only effective treatment for ventricular fibrillation is defibrillation. A sudden cardiac arrest victim cannot use an AED on themselves, so other people, for these public access AEDs, have to be willing to apply it to someone they may or may not know.

1. Patient Perspecties: This submission did not include any specific information on patient perspectives.

In conclusion, the data described above supports, that for sudden cardiac arrest victims who are unresponsive and not breathing (or not breathing normally) and most likely will die without defibrillation, the probable benefit of having access to an AED outweighs the probable risks.

D. **Overall Conclusions**

The data in this application support the reasonable assurance of safety and effectiveness of this device when used in accordance with the indications for use.

XIII. CDRH DECISION

CDRH issued an approval order on February 1, 2018. FDA has developed unique conditions of approval to pursue real world information and in response to panel comments from the 515i Panel discussed in Section XI above. The final conditions of approval cited in the approval order are described below.

The applicant will provide the following non-clinincal information as part of the annual report, which may be followed by a PMA supplement, where applicable:

1. The number of devices returned to the applicant for cause from domestic sources, with a breakdown into:
    a. Those returned for normal end-of-life; and
    b. Those returned with any alleged failures or malfunctions, including a summary of root causes and the frequency of occurrence for each identified root cause.

2. The number of replacement defibrillation pads and replacement batteries issued to customers domestically for all causes.

3. A summary of information available to you related to individual domestic uses of your device that may include, but is not limited to:
    a. Defibrillation success and the number of shocks required for success; and
    b. Identification of any error codes or malfunctions during use and their related MDR number.

4. A listing of any safety alerts, technical service bulletins, user communications, or recalls for devices under this PMA.

The applicant's manufacturing facilities have been inspected and found to be in compliance with the device Quality System (QS) regulation (21 CFR 820).

XIV. APPROVAL SPECIFICATIONS

Directions for use: See device labeling.

Hazards to Health from Use of the Device: See Indications, Contraindications, Dangers, Warnings, Cautions, and Adverse Events in the device labeling.

Post-approval Requirements and Restrictions: See approval order.

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