Monophasic and Biphasic Shock for Transthoracic Conversion of Atrial Fibrillation: Systematic Review and Network Meta-analysis

Article (PDF Available) *in* Resuscitation 100 · January 2016 *with* 48 Reads
DOI: 10.1016/j.resuscitation.2015.12.009

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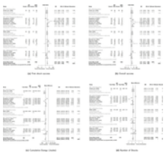
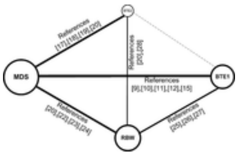
Abstract

Objectives: Conduct a systematic review of the literature to compare the efficacy of different biphasic and monophasic shock waveforms technologies for transthoracic cardioversion of Atrial Fibrillation (AF). Methods: We searched PubMed, EMBASE, The Cochrane Library, LILACS and ClinicalTrials.gov databases for randomized clinical trials comparing two or more defibrillation waveforms when performing elective transthoracic cardioversion of AF. The outcomes assessed were 1st shock success, overall success, cumulative energy and number of shocks to restore Normal Sinus Rhythm. Results: Were included 23 trials involving 3046 patients, 5 biphasic and the monophasic waveform. Direct meta-analysis revealed that Biphasic waveforms have higher chance to achieve cardioversion in the 1(st) shock (OR: 3.2; 95% CI 2.2-4.7) and after a sequence of attempts (OR:2.4; 95% CI 1.5-3.9), requiring 296 less Joules (95% CI 356-237) and 0.74 less shocks (95%CI 1.03-0.44) when compared to Monophasic. Network meta-analysis showed no significant differences between the Biphasic technologies of PhysioControl ADAPTIV, Philips SMART and ZOLL Rectilinear, in any of the four outcomes. Conclusion: The evidences points to a Biphasic waveform superiority over Monophasic to perform AF cardioversion, supporting current guidelines to use less energy when using a Biphasic defibrillator. It is suggested that the Biphasic defibrillators from PhysioControl ADAPTIV, Philips SMART and ZOLL Rectilinear have similar efficacy and the use of any of them may result in similar chances, energy and number of shocks to achieve successful AF cardioversion.

3 Figures

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Resuscitation 100 (2016) 66–75

Contents lists available at ScienceDirect

Resuscitation

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Review article

Monophasic and biphasic shock for transthoracic conversion of atrial fibrillation: Systematic review and network meta-analysis☆

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A R T I C L E I N F O

Article history:
Received 2 October 2015
Received in revised form 4 December 2015
Accepted 18 December 2015

Keywords:
Monophasic defibrillator
Biphasic defibrillator
Cardioversion
Atrial fibrillation
Systematic review, Network meta-analysis

A B S T R A C T

Objectives: Conduct a systematic review of the literature to compare the efficacy of different biphasic a monophasic shock waveforms technologies for transthoracic cardioversion of Atrial Fibrillation (AF).
Methods: We searched PubMed, EMBASE, The Cochrane Library, LILACS and ClinicalTrials.gov databa for randomized clinical trials comparing two or more defibrillation waveforms when performing ele tive transthoracic cardioversion of AF. The outcomes assessed were 1st shock success, overall succe cumulative energy and number of shocks to restore Normal Sinus Rhythm.
Results: Were included 23 trials involving 3046 patients, 5 biphasic and the monophasic waveform. Dir meta-analysis revealed that Biphasic waveforms have higher chance to achieve cardioversion in the shock (OR: 3.2; 95% CI 2.2–4.7) and after a sequence of attempts (OR: 2.4; 95% CI 1.5–3.9), requiring 296 l Joules (95% CI 356–237) and 0.74 less shocks (95% CI 1.03–0.44) when compared to Monophasic. Netwo meta-analysis showed no significant differences between the Biphasic technologies of PhysioCont ADAPTIV, Philips SMART and ZOLL Rectilinear, in any of the four outcomes.
Conclusion: The evidences points to a Biphasic waveform superiority over Monophasic to perform cardioversion, supporting current guidelines to use less energy when using a Biphasic defibrillator. I suggested that the Biphasic defibrillators from PhysioControl ADAPTIV, Philips SMART and ZOLL Rec linear have similar efficacy and the use of any of them may result in similar chances, energy and numb of shocks to achieve successful AF cardioversion.

Introduction

Electrical cardioversion for the treatment of Atrial fibrillation (AF) is classified as a Class I treatment when pursuing rhythm-control strategy (LOE B). Its benefits have been demonstrated when a rapid ventricular response to AF does not respond promptly to pharmacological strategies and contributes to other comorbidities (LOE C) and when it is associated with hemodynamic instability (LOE C).[1] It is also known that biphasic shock wav forms need lower energy than monophasic shock wavefor for transthoracic cardioversion of AF. Recommendations for i tial energy have been set to 120 J for biphasic waveforms, a 200 J for monophasic waveforms.[2] Animal studies suggest t lower energy biphasic shocks decrease the risk of myocard dysfunction.[3]

Overall, in guidelines and literature reviews, Biphasic wav formshocks are treated as equal, and possible differences betw Biphasic waveform technologies have not yet been complete clarified. A recent systematic review of nine studies on t treatment of AF compared monophasic and biphasic techno gies demonstrating better performance of the Biphasic, b no distinction of the biphasic technologies were evaluated reported.[4]

☆ A Spanish translated version of the summary of this article appears as Appendix in the final online version at http://dx.doi.org/10.1016/j.resuscitation.2015.12.009.

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http://dx.doi.org/10.1016/j.resuscitation.2015.12.009
0300-9572/

Two major types of biphasic waveforms are known as Rectilinear Biphasic Waveform (RBW) and Biphasic Truncated Exponential (BTE.) Different BTE manufactures can have different peak voltages, positive and negative cycle's durations and tilts. In both types of biphasic waveforms the defibrillator reads the patient's transthoracic impedance during energy delivery, and adjusts its outputs in order to deliver the selected energy to the patient. However they differ in how they adjust their output to compensate for the patient's impedance. Rectilinear Biphasic Waveform (RBW), developed by Zoll™, has a 200 J limit and adjusts its internal impedance to deliver a constant current. One major Biphasic Transthoracic Exponential waveform is the ADAPTIV™ developed by PhysioControl™. It has a 360 J limit and controls lead-edge voltages and adjusts pulse duration. Another major BTE waveform is the Philips SMART™ Biphasic, it has a 200 J limit, constant edge voltages and it controls pulse tilts and adjusts pulse duration.[5–7] A number of randomized control trials have evaluated the safety and performance of these technologies and others, yet further investigation is needed to better understand these differences. Thus, the aim of this study was to conduct a systematic review and network meta-analysis of randomized control trials to compare the efficacy of different biphasic waveforms and monophasic shock waveforms, applied through the thorax, for the conversion of Atrial fibrillation. The outcomes compared were Cumulative Energy, Number of Shocks, First Shock Success Rate and Overall Success Rate to restore normal sinus rhythm (NSR) in patients with AF undergoing elective cardioversion therapy.

Methods

Protocol and registration

This systematic review is reported in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) statement[8] and is registered in the Prospero database [CRD42014010479].

Eligibility criteria

Participants: Patients diagnosed with AF, persistent or not, undergoing elective cardioversion.

Interventions: Studies where the cardioversion shock therapy delivered through the thorax in attempt to restore NSR was evaluated reporting the number of shocks delivered, the mean energy delivered and success rate to restore NSR.

Comparison: Group receiving any Biphasic shock technology compared to a group receiving Monophasic shock or group receiving one type of Biphasic technology compared to a group receiving other type of Biphasic technology.

Outcomes: The outcomes were Cumulative Energy representing the mean cumulative energy necessary to restore NSR, the number of shocks, representing the mean number of shock necessary to restore NSR, first shock success rate, representing the odds ratio to restore NSR in the first shock attempt and overall success rate to restore NSR representing the odds ratio to restore NSR after all shocks attempt.

Types of Study: Studies designed as a Randomized Clinical Trial (RCT). No language limits were used. Studies with duplicated population and those that did not provide the type of biphasic technology used were excluded.

Information sources

A searched was performed using the following electronic databases: PubMed, EMBASE, Cochrane Central Registry of Controlled Trials, ClinicalTrials.gov, and Lilacs. The search included references of manually included articles and citation analysis of the inc studies was performed using Google Scholar.

Search

The initial search comprised the Mesh terms *Atrial fibril electric countershock, clinical trial* and their related entry term search date was limited between 1/01/2000 and 6/31/201 complete search strategy used for the PubMed database is in Appendix Table 1. The searches were updated on 9/5/20 verify if newer publications were available.

Study selection

Titles and abstracts of the retrieved articles were indepen evaluated by 2 reviewers (JFI and MG). Abstracts that di provide enough information regarding the eligibility criteria kept for full-text evaluation. Reviewers independently eval full-text articles and determined study eligibility. Disagreem were solved by consensus and when a consensus could r reached a third reviewer (AM) was used.

Risk of bias

Risk of bias was evaluated according to the PRISMA state recommendation. Study quality assessment included: select bias items, such as adequate sequence generation, and alloc concealment; performance of bias items, such as blinding of pa pants and personnel, and blinding of outcome assessment; att of bias evaluated through the assessment of incomplete ou data; reporting of bias by the assessment of selective reportin other sources of bias. Two reviewers (JFI and MG) indepen performed quality assessment, and disagreements were solv consensus or by a third reviewer (AM).

Data extraction

Two reviewers (JFI and MG) independently conducted the extraction and disagreements were solved by the third revi (AM). Characteristics such as cumulative energy, number of sh and first shock success to restore normal sinus rhythm retrieved from the included studies. In studies where cro analysis was conducted, the data was collected before the cro was performed. Cumulative success rate and study ups energy protocol were used to calculate the cumulative energ the number of shocks in studies that did not report these outc directly.

Data analysis

Considering that the studies have similar designs, same ou measures and different upscaling energy protocols, we cond direct meta-analysis pooling the results using a random e with mean differences for continuous outcomes such as cumu energy and number of shocks and odd ratios outcomes such shock success and overall success, and calculated 95% confi intervals and two sided *P* values. The Cochran *Q* test was u assess heterogeneity and a value of *P* less than 0.1 was consi statistically significant. The I^2 testing was also used to measu magnitude of the heterogeneity. The possibility of bias across ies was also evaluated using funnel plot of each of the trials size against the standard error (SE).

A network meta-analysis was also used, allowing for in comparison of two trials that have at least one treatment in mon. The Bayesan Markov-chain Monte Carlo method usin statistical software Rstudio and JAGS package was used. The r were expressed with mean differences for cumulative energy and number of shocks and odd ratios for 1st shock success and overall success with 95% credible intervals (CrI).

Results

Study selection

Based on the search strategy, a total of 2651 citations were identified and reviewed. After evaluating those against the predefined eligibility criteria, a total of 23 studies were included in this systematic review involving 3046 patients, 5 different biphasic waveform technologies and 7 types of monophasic waveform. The complete study workflow is shown in Fig. 1.

Studies characteristics

Table 1 summarizes the included studies characteristics. The energy protocol is the predefined upscaling energy protocol of attempts to restore normal sinus rhythm and differences among studies were observed, where the majority had predefined protocols starting with a lower energy and upscaling the energy until the highest energy available was used in the last attempt. In one particularly study the energy dose was defined by the physician individually for each patient and in another study the energy dose was chosen proportionally to the patient weight. Criteria to define successful cardioversion also vary; studies may consider a valid conversion an immediate conversion, a conversion that holds at least a number of consecutive sinus beats or a conversion that sustains at least one to two minutes of normal sinus rhythm. PhysioControl Biphasic (BTE1) is present in 11 studies being applied in 706 patients, Philips SMART Biphasic (BTE2) in 5 studies and 292 patients, WelchAllyn Biphasic (BTE3) in two studies and 93 patients, Nihon-Koden Biphasic (BTE4) in one study and 100 patients and the Zoll Rectlinear Biphasic (RBW) in 9 studies and 655 patients. The Monophasic Damped Sine waveform (MDS) was present in 19 studies and 1200 patients, appearing in seven different forms: PhysioControl Lifepak 9 Monophasic (MDS1), PhysioControl Lifepak 12 Monophasic (MDS2), GE Responder 3000 Monophasic (MDS3), GE CardioServ Monophasic (MDS4), HP CodeMaster XL Monophasic (MDS5), Zoll Monophasic (MDS6) and Chirana BPD 13 Monophasic (MDS7). The use of several pharmacological antiarrhythmic therapies was identified across studies where the patient could be receiving one or more drugs prior to the procedures.

Risk of bias within studies

In relation to selection bias most trials presented unclear descriptions. Eleven studies did not report the method for allocation concealment and 13 failed to report the method for random sequence generation.

For performance bias, because transthoracic elective cardioversion is performed with the patient under sedation, and blinding of the defibrillator is a challenge, single-blinded studies were considered to be of low risk of bias. Only two studies were considered to be of high risk. In relation to detection bias, 13 studies lacked information regarding the blinding of the outcome assessment, and three were considered high risk.

Attrition bias was analyzed by evaluating incomplete outcomes data. Most studies presented low risk of bias (16 trials), three trials were considered to have high risk of bias, and in three trials the risk of bias was unclear. Additionally, among the 23 studies included, 17 had low risk of reporting bias (analyzed by the evaluation of selective reporting) and six had a high risk of reporting bias. T complete risk of bias results is shown in Appendix Table 2.

Qualitative analysis—Individual studies

Of the 23 trials included, 8 compared BTE1 and MDS. Tree stud reported BTE1 as superior for 1st shock success, overall succe cumulative energy and number of shocks to restore NSR.[9–11] O study reported BTE1 as superior to MDS for overall success a cumulative energy but did noate statistical results regarding shock success and number of shocks.[12] One study demonstrat BTE1 as superior for cumulative energy and number of shocks, a no significant difference for overall success. It did not evaluate shock success since the study did not follow a predefined ener protocol; the energy was set at the discretion of the physician In addition, one study showed BTE1 as superior for overall succ and cumulative energy, and reported no significant difference the number of shocks and did not evaluate 1st shock success Also one study had a BTE1 protocol (50–100–150–175 J) using h the energy of the MDS protocol (100–200–300–360 J) presenting significant difference between BTE1 and MDS for 1st shock succe overall success and number of shocks and BTE 1 as superior cumulative energy.[15] Finally, one study reported that the gro that received BTE1 at any point had a significantly higher over success rate.[16]

Four studies were reviewed that compared BTE2 to MDS. (study reported BTE2 as superior to MDS for 1st shock succe cumulative energy and number of shocks, and found no signific difference for overall success.[17] One study showed no signific difference for 1st shock success, overall success or numbe shocks, and found BTE2 to be superior for cumulative energy Another study demonstrated BTE2 as superior to MDS for 1st sho success, and showed no significant difference **for** overall succ but did not evaluate cumulative energy or number of shocks.[19] (study reported BTE2 as significantly superior to MDS for overall s cess and cumulative energy, but did not evaluate 1st shock succ or number of shocks. [20]

Five studies were reviewed comparing RBW to MDS. Two stud reported no significant difference for 1st shock success and ove all success, and reported RBW as superior to MDS for cumulati energy.[21,22] One study found no significant difference for 1st sho success, overall success, or number of shocks and reported RBW superior only for cumulative energy.[23] One study reported RBW superior for overall success and cumulative energy but did not ev uate 1st shock success or number of shocks.[20] One study repor RBW as superior to MDS for 1st shock success and overall succ but did not evaluate cumulative energy or number of shocks.[24]

Three studies were reviewed comparing BTE1 to RBW.[25–27] studies reported no significant difference for 1st shock success overall success. One study reported no significant difference number of shocks and RBW as superior to BTE1 for cumulati energy using the Student's *t* test approach.[27] One study repor no significant difference for number of shocks and BTE1 as su rior to RBW for cumulative energy using the Wilcoxon rank-su test approach. [25]

Two studies were reviewed comparing BTE2 to RBW. Neit study showed significant differences for overall success. One stu had no significant difference for 1st shock success, overall succe cumulative energy or number of shocks.[28] One study reported B1 as superior to RBW for cumulative energy.[20]

Two studies evaluated BTE3 versus MDS. One study repor no significant difference for 1st shock success or overall succ and reported BTE3 as significantly superior to MDS for cumulati energy and number of shocks.[29] One study presented cumulati energy and number of shocks results however no statistical diffe ences were calculated between groups.[30]

Table 1
Summary of characteristics of included studies.

First Author and Year of publication	Study arms	No. of patients	Energy protocol (J)	Successful cardioversion criteria	Mean age± SD (years)	Mean wei or BMI ±S
Deakin 2013[28]	RBW	n = 101	50–100–150–200–200	Converted to sinus rhythm immediately after shock and remained at for 60 s	65.5 (60.0–70.2)[*]	90.2 (80.0–03.
	BTE2	n = 99	50–100–150–200–200		68.0 (61.5–72.0)[*]	88.9 (80.2–98.
Stanaitienė 2008[11]	MDS1	n = 112	100–200–300–360	ECG registered sinus rhythm within 30 s after shock	64.9 ±9.28	89.5 ± 15

First Author and Year of publication	Study arms	No. of patients	Energy protocol (J)	Successful cardioversion criteria	Mean age± SD (years)	Mean wei or BMI ±S
Manegold 2007[21]	MDS4	n = 21	200–300–360–360	Not reported	70.0 ±10.0[†]	27± 4 kg
	RBW	n = 23	100–150–200–200			
Kawabata 2007[15]	MDS5	n = 77	100–200–300–360	Restored sinus rhythm for 1 h after the shock	60.1 ±13.3	26.6 +4.8
	BTE1	n = 77	50–100–150–175		55.1 ±13.5	26.5 +3.8
Ambler 2006[29]	MDS5	n = 68	100–200–300–360–360	Not reported	70 (22–87)[*†]	83 (42–13 kg[*†]
	BTE3	n = 60	70–100–150–200–300			
Skulec 2006[13]	MDS3	n = 70	At discretion of physician	Sinus rhythm restoration persisted >30 s after shock	67.2 ±10.9	27.3 +3.5
	BTE1	n = 71	At discretion of physician		68.6 ±11.7	27.6 +3.0
Alatawi 2005[25]	RBW	n = 71	50–75–100–120–150–200	Conversion to sinus rhythm for at least 1 minute	67.6 ±12.9	31.8 +6.8
	BTE1	n = 70	50–70–100–125–150–200–300–360		65.3 ±14.5	30.2 +6.1
Kosior 2005[14]	MDS4	n = 22	2 J/kg-360–360	Sinus rhythm was maintained for >2 h after the procedure	61.3 ±9.1	Not repor
	BTE1	n = 26	2 J/kg-360–360		62.1 ±10.5	
Kim 2004[26]	RBW	n = 71	50–100–150–200	Restoration of sinus rhythm lasting >5 s after defibrillation	64 ±15.2	84.9 ± 20
	BTE1	n = 74	50–100–150–200–360		65 ±14.8	83.7 ± 19

Table 1 (*Continued*)

First Author and Year of publication	Study arms	No. of patients	Energy protocol (J)	Successful cardioversion criteria	Mean age ± SD (years)	Mean wei or BMI ±S
Siaplaouras 2004[23]	MDS6	n = 108	200–300–360–360	Termination of AF with at least 2 consecutive sinus beats	65 ±10	
	RBW	n = 108	120–150–200–200		66 ±10	
Santomauro 2004[20]	MDS6	n = 18	100–200–300–360–360	Sinus rhythm restoration for at least 30 s	55.4 ±14	
	RBW	n = 22	75–100–150–200–200		55.6 ±7	
	BTE2	n = 24	70–100–150–200–200		54.8 ±9.2	
Koster 2004[9]	MDS2	n = 37	70–100–200–360	Absence of AF after delivered shock, even if short-lived	63.2 ±15.8	80.5 ± 19
	BTE1	n = 35	70–100–200–360		69.6 ±10.9	80.4 ± 15
Page 2002[17]	MDS5	n = 107	100–150–200–360	Two consecutive P waves uninterrupted by AF occurring any time within 30 s of the shock	65 ±13	88± 24 k
	BTE2	n = 96	100–150–200–200		65 ±14	87± 19 k
Marinsek 2003[18]	MDS5	n = 40	100–200–300–360	Atrial P wave was unmistakably identified >30 s after the shock	67 ±8	84± 18 k
	BTE2	n = 43	70–100–150–200		69 ±6	79± 14 k
Neal 2003[27]	RBW	n = 53	50–100–200–200	Presence of P waves, a captured atrial paced rhythm, or junction rhythm for 3 consecutive beats	63.0 ±16.0	93.9 ± 25
	BTE1	n = 48	50–100–200–200		60.0 ±16.0	96.3 ± 28
Scholten 2003[22]	MDS5	n = 109	200–360	Sinus rhythm restored for more than five seconds	59.9 ±14.0	82.5 ± 19
	RBW	n = 118	120–200		59.6 ±12.4	81.9 ± 20

Ricard 2001[19]	MDS5	n = 27	150–360	Sinus rhythm was restored for a period >5 min	66 ± 12	77 ± 17 k
	BTE2	n = 30	150–150		69 ± 10	79 ± 14 k
Mittal 2000[24]	MDS6	n = 77	100–200–300–360	Conversion of AF to sinus rhythm for >30s after the shock	66 ± 12	93 ± 24 k
	RBW	n = 88	70–120–150–170		65 ± 12	89 ± 21 k
Kmec 2006[31]	MDS7	n = 100	200–300–360–360	Conversion of AF to sinus rhythm for >60s after the shock	62.6 ± 7.7	29.6 + 4.8
	BTE4	n = 100	100–120–270–270		63.6 ± 8.5	30.4 + 5.3
Khaykin 2003[16]	MDS2	n = 28	360	At least 5 consecutive beats of atrial origin without evidence of fibrillatory activity during diastole	59.7 ± 10.8	96.9 ± 29
	BTE1	n = 28	150–200–360		58.3 ± 14.6	94.5 ± 27
Neumann 2004[10]	MDS1	n = 57	100–200–360	Conversion of AF to sinus rhythm for at least 30 s after shock delivery	63.5 ± 11	Not repor
	BTE1	n = 61	100–200–360		61.5 ± 11	
Deakin 2006[30]	MDS5	n = 25	100–200–300–360–360	Evaluated the time between the shock and the first P wave	71.0 (45–84)*	82.8 (55–139)
	BTE3	n = 33	70–100–150–200–300		68.5 (50–86)*	83.0 (83–139)
Kirchhof 2005[12]	MDS1	n = 97	50–100–200–300–360	Presence of sinus rhythm immediately after the shock	63 ± 1	27.2 + 0.4
	BTE 1	n = 104	50–100–200–300–360		63 ± 1	27.3 + 0.4

BTE1: PhysioControl Biphasic, BTE2: Philips SMART Biphasic, BTE3: Welch-Allyn Biphasic, BTE4: Nihon-Koden Biphasic, RBW: Zoll Rectilinear Biphasic, MDS1: Physi Monophasic, MDS3: GE Responder 3000 Monophasic, MDS4: GE Cardioserv Monophasic, MDS5: HP Code Master XL Monophasic, MDS6: Zoll Monophasic, MDS7: C Index.

* Variable represented in median (minimum, maximum).

† Reported data not separated by study groups.

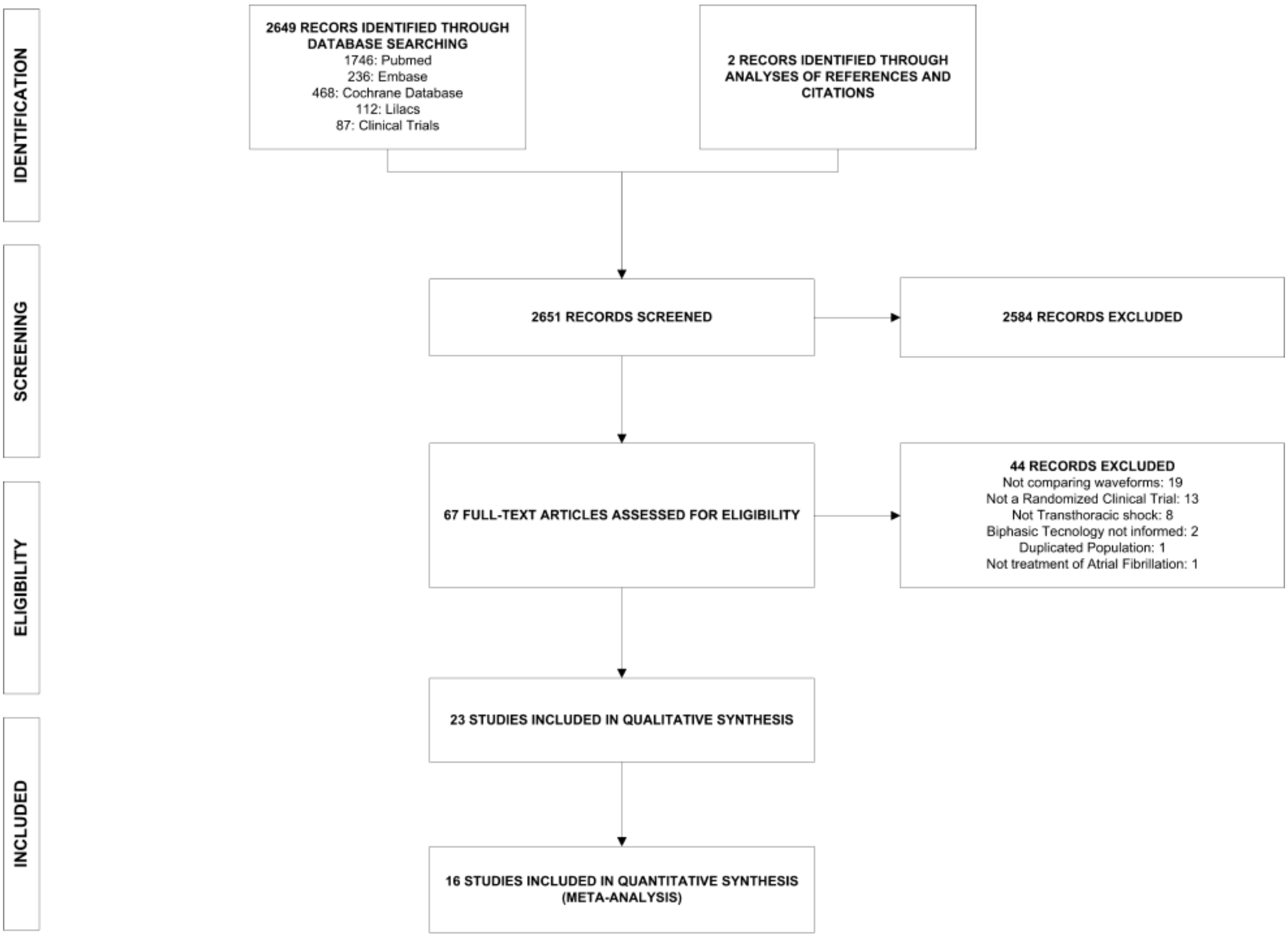

Fig. 1. Study selection workflow diagram.

One study showed BTE4 was significantly superior to MDS for all four outcomes.[31]

Synthesis of results—Direct meta-analysis

Meta-analysis of 15 studies compared MDS to Biphasic, where the Biphasic waveforms were divided into subgroups. Results revealed that Biphasic waveforms have superiority in 1st shock success (OR: 3.2; 95% CI 2.2–4.7) (Fig. 2a), overall success (OR: 2.4; 95% CI 1.5–3.9) (Fig. 2b), achieves cardioversion using 296 less Joules (95% CI 356–237) (Fig. 2c) and using 0.74 less shocks (95% CI 1.03–0.44) (Fig. 2d) when compared to Monophasic.

When considering the subgroups, the PhysioControl has superiority in 1st shock success (OR: 4.1; 95% CI 1.8–9.3) (Fig. 2a) and superiority in overall success (OR: 4.6; 95% CI 1.37–15.8) (Fig. 2b) achieves cardioversion using 256 less Joules (95% CI 336–176) (Fig. 2c) and using 0.89 less shocks (95% CI 1.38–0.39) (Fig. 2d) when directly compared to Monophasic. Philips SMART has superiority in 1st shock success (OR: 4.5; 95% CI 2.8–7.3) (Fig. 2a), achieves cardioversion using 302 less Joules (95% CI 405–198) (Fig. 2c) and using 0.71 less shocks (95% CI 1.35–0.07) (Fig. 2d) when directly compared to Monophasic. ZOLL Rectilinear has superiority in 1st shock success (OR: 2.6; 95% CI 1.05–6.4) (Fig. 2a) and achieves cardioversion using 320 less Joules (95% CI 537–104) (Fig. 2c) when directly compared to Monophasic.

Two meta-analyses compared directly Biphasic waveforms and the results are presented in Table 2. Meta-analysis of 3 studies compared the Biphasic waveforms from PhysioControl Biphasic and Zoll Rectilinear (BTE1 x RBW) and meta-analysis of 2 studies co pared Philips SMART Biphasic versus Zoll Rectilinear (BTE2 × RB and in the pooled results of both meta-analyses no significant d ference in any of the outcomes were revealed, indicating simi efficacy.

Risk of bias across studies

Heterogeneity evidence was found amongst studies comp ing Biphasic with Monophasic (Fig. 2). For first shock succ the I^2 inconsistency was 66%, for overall success 50%, cumu tive energy 84% and number of shocks 90%. When evaluating subgroups homogeneity was found in studies comparing Phil SMART Biphasic with Monophasic for the outcomes first shock s cess (I^2 = 0%) and overall success (I^2 = 0.4%).

For studies comparing Biphasic technologies directly, hon geneity is suggested for all four outcomes (Table 2).

Synthesis of results—Network meta-analysis

In the network analysis, 581 patients received PhysioConti Biphasic shock, 292 received Philips SMART Biphasic, 632 recei ZOLL Rectilinear Biphasic and 866 received Monophasic Damp Sine shock, summing up to a total of 2371 patients. Fig. 3 sho the network of comparisons. The width of the lines is proportio to the number of trials comparing each pair of treatments, and t size of each node is proportional to the number of patients. T dashed line represents an indirect comparison.

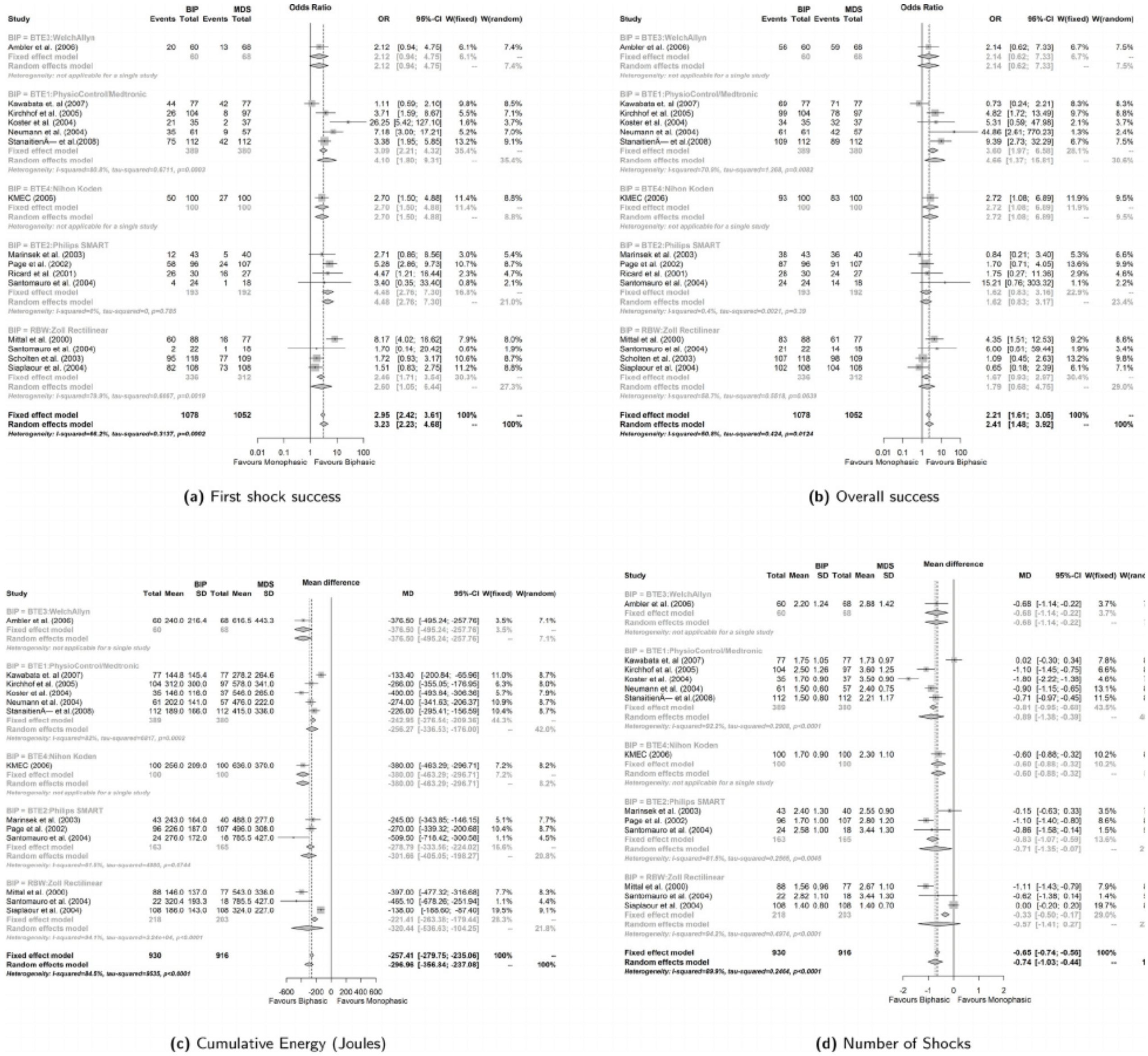

Fig. 2. Comparison between Biphasic and Monophasic, sub-grouped by Biphasic type—(a) First shock success rate. (b) Overall success rate. (c) Cumulative Energy i to achieve success. (d) Number of shocks to achieve success.

Table 2
Direct meta-analysis between biphasic waveforms: BTE1 × RBW and BTE2 × RBW.

Comparison	Number of studies		1st Shock success odds ratio	Overall success odds ratio	Cumulative energy mean difference	Number c mean diffe
BTE1 × RBW	3 [25–27]	Effect size [95% CI]	0.90 [0.52;1.57]	1.39 [0.42;4.56]	23.5 [−4.88;51.88] J	0.15 [−0.0
		Heterogeneity P, I^2	0.19, 40%	0.48, 0%	0.40, 0%	0.40, 0%
BTE2 × RBW	2 [20,28]	Effect size [95% CI]	0.88 [0.45;1.76]	0.70 [0.18;2.69]	15.2 [−77.7; 108.2] J	0.10 [−0.4
		Heterogeneity P, I^2	0.34, 0%	0.28, 13%	0.11, 61%	0.11, 60%

BTE1: PhysioControl Biphasic, BTE2: Philips SMART Biphasic, RBW: Zoll Rectilinear Biphasic.

Table 3 shows the results of the Network Meta-analysis. Through the network meta-analysis it was possible to indirectly compare PhysioControl Biphasic with Philips SMART Biphasic. Similar to the direct meta-analysis results, PhysioControl Biphasic was significantly superior to Monophasic in the 4 outcomes. Both Philips SMART Biphasic and Zoll Rectilinear Biphasic were superior to Monophasic in 3 outcomes (1st shock success, cumulative energy and number of shocks). There were no significant differences in any of the 4 outcomes in comparisons between any of the Bip waveforms.

Discussion

The evidence regarding the efficacy of Biphasic wavef to convert AF to normal sinus rhythm, is sufficiently to id superiority compared to Monophasic waveforms and, alth

Table 3
Network meta-analysis comparing BTE1, BTE2, RBW and MDS: 1st shock success, overall success, cumulative energy and number of shocks.

Waveform	1st Shock success, odds ratio [95% CrI]		
	MDS	BTE1	BTE2
BTE1	3.7 [1.9;7.4]		
BTE2	3.9 [1.7;9.2]	1.1 [0.38;3.0]	
RBW	3.4 [1.7;6.7]	0.9 [0.42;1.9]	0.85 [0.34;2.1]
	Overall success, odds ratio [95% CrI]		
BTE1	4.8 [1.7;16]		
BTE2	1.9 [0.57;8.1]	0.4 [0.07;2.5]	
RBW	2.4 [0.85,7.9]	0.5 [0.14;2.0]	1.3 [0.27;5.5]
	Cumulative energy, mean difference [95% CrI], (J)		
BTE1	−258.1 [−340.1; −179.4]		
BTE2	−282.9 [−399.9; −177.1]	−24.4 [−150.6;97.5]	
RBW	−286.4 [−376.5; −201.9]	−28.2 [−116.8;59.6]	−3.5 [−114.6;112.2]
	Number of shocks, mean difference [95% CrI]		
BTE1	−0.79 [−1.26;−0.32]		
BTE2	−0.67 [−1.29;−0.04]	0.11 [−0.60;0.86]	
RBW	−0.74 [−1.27;−0.23]	0.04 [−0.50;0.57]	−0.07 [−0.77;0.61]

BTE1: PhysioControl Biphasic, BTE2: Philips SMART Biphasic, RBW: Zoll Rectilinear Biphasic, MDS: Monophasic Damped Sine, CrI: Credible Interval.

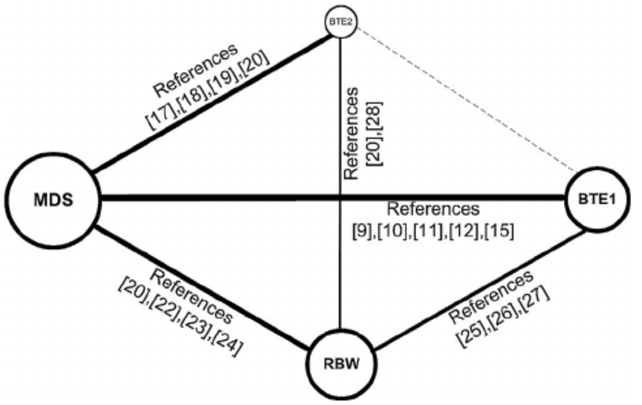

Fig. 3. Network of Clinical Trials comparing defibrillation waveforms for Atrial fibrillation cardioversion—Solid lines represent direct comparison trials and dashed lines represent indirect comparisons. BTE1: PhysioControl Biphasic, BTE2: Philips SMART Biphasic, RBW: Zoll Rectilinear Biphasic, MDS: Monophasic Damped Sine.

this was previously addressed recently[4] the analysis was limited to pool Odds Ratio from the first shock success rate and the Biphasic waveforms were not discriminated. Our review identified similar evidence and it was able to extend the analysis for additional outcomes such as overall success, cumulative energy and number of shocks to restore sinus rhythm. Were identified 15 clinical trials comparing Biphasic with Monophasic, with a total of 2130 patients, and all studies reported significant Biphasic superiority in at least one of the four outcomes. These studies were of variable quality and methodological heterogeneous, specially regarding the energy sequence protocol, where the protocols could be the same for Biphasic and Monophasic groups, or the Biphasic group protocol could be slightly lower than the Monophasic group or even the Biphasic group protocol could be half the Monophasic group.

The pooled results provided evidence that the Biphasic waveform is significantly superior than Monophasic in the four outcomes, and therefore is suggested that Biphasic has superior efficacy over Monophasic. Considering that in all studies, the first shock energy of the Biphasic groups were always equal or slightly lower than the Monophasic, it is possible to assume that Biphasic have a higher chance to convert an AF with the same, or slightly lower, energy. Also the Biphasic, considering a sequence of shocks attempts to convert AF, needs lower cumulative energy and number of shocks to achieve success. Finally, for the overall success it wouldn't be expected significantly different chances, assuming that Monophasic can achieve success at some point, given more attempts and elevated energy, but the pooled results suggests that the use of Monophasic will lower the chances to achieve AF c dioversions after all shocks attempts are tried.

When assessing efficacy between Biphasic, it was identi three clinical trials comparing PhysioControl Biphasic against ZC Rectilinear Biphasic and two trials comparing Philips SMA Biphasic against ZOLL Rectilinear Biphasic. The energy proto sequence showed homogeneity in these trials, possible because t Biphasic groups between studies, had the same energy seque protocol at least in the four initial steps. Through a network m analysis it was possible to aggregate these trials strictly co paring Biphasic waveforms with the trials comparing Bipha with Monophasic, allowing to generate an indirectly compa son between PhysioControl Biphasic and Philips SMART Bipha and resulting in sufficiently evidence to establish the relative e cacy of these three technologies. In the network results there v no significant difference in any of the four outcomes, indicati that whether using PhysioControl, Philips SMART or ZOLL Re tilinear there would be equal chances to convert AF in the f attempt, equivalent chances to convert after all attempts and t same cumulative energy and number of shocks would be neec to achieve successful cardioversion and thus suggesting simi efficacy.

Biphasic defibrillators in general have the capacity to read t patient's transthoracic impedance and with this information, th can adjust its outputs according to the patient, increasing t efficacy to achieve cardioversion. Although PhysioControl, Phil SMART and ZOLL Rectilinear use different circuit topologies a control methods in order to generate its waveforms output, th individual particularities did not result in differential efficacy in t review.

Limitations

Although the Monophasic defibrillators share the common cha acteristic of using the same passive circuit topology, with adjustment regarding the patient transthoracic impedance dur the shock therapy delivery, the components values used, especia the high voltage capacitor capacitance and the current shapi inductor inductance and resistance, vary from one Monopha manufacturer to other. This will result in Monophasic wavefor that are underdamped, critically damped or overdamped for diff ent patient's transthoracic impedance. In this review, the possi efficacy differences between the Monophasic due to these diff ences were not considered.

Also, the dependence of the four outcomes was not evaluat it is possible that the number of shocks and cumulative energy have an opposite relationship and that a study protocol designed to start with a higher initial energy may tend to have a higher first shock success rate but also a higher cumulative energy result.

Additionally, skew was identified in the outcomes cumulative energy and number of shocks in some studies, specifically studies where the energy protocol had a low number of shocks. Even though the predefined statistical methods required the variables to be as close to a normal distribution, for these cases we accepted a level of skewness to apply the statistical evaluation.

No possible heterogeneity between studies associated with differences in the patients characteristics, such as age, body mass index, weight or AF duration, were evaluated.

Conclusion

Evidences points to a Biphasic waveform superiority over Monophasic to perform AF cardioversion, supporting current guidelines recommendations to use less energy when using a Biphasic defibrillator, that is, start with 120 J when using Biphasic and start with 200 J when using Monophasic.[2]

The energy output adjustment method by monitoring the patient's transthoracic impedance, inherent to the Biphasic waveforms, is relevant when performing cardioversion of Atrial fibrillation, but the three methods from different manufacturers evaluated (PhysioControl, Philips SMART and ZOLL Rectilinear) suggests similar efficacy and the use of any of them may result in similar chances, energy and number of shocks to achieve successful AF cardioversion.

Conflict of interest statement

No conflicts of interest to declare.

Acknowledgments

There were no founding sources to this study.

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