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Best evidence topic - Arrhythmia

What cardioversion protocol for ventricular fibrillation should be followed for patients who arrest shortly post-cardiac surgery?

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Summary

A best evidence topic in cardiac surgery was written according to a structured protocol. The question addressed was how many cardioversion attempts should be performed for patients who have gone into ventricular fibrillation post-cardiac surgery prior to performing chest reopening. Using the reported search, 1183 papers were identified. Fifteen papers represented the best evidence on the subject. The author, journal, date and country of publication, patient group studied, study type, relevant outcomes, results and study comments and weaknesses were tabulated. The quality and level of evidence was assessed using the International Liaison Committee of Resuscitation guideline recommendations. The most recent European Resuscitation Council guidelines suggest single attempts at cardioversion, spaced at 2-min intervals, for all patients going into ventricular fibrillation or pulseless ventricular tachycardia. Cardiac surgery presents a unique challenge for these guidelines in that emergency re-sternotomy may provide additional lifesaving interventions once it is deemed that external cardioversion is unlikely to succeed. The 15 papers identified demonstrated that the success of the first attempt at cardioversion for VF/VT was around 78%. The chance of the second shock succeeding was around 35%. The chance of a third shock succeeding was 14%. Very little data were found on the chance of further shocks succeeding. Of note none of these papers were in patients on the intensive care after cardiac surgery. We conclude that, due to the importance of minimising the delay to chest reopening, three shocks should be quickly delivered. If these do not succeed the chance of a 4th shock succeeding is likely to be $<10\%$ and, thus, immediate chest reopening should be performed. (This is a Class-IIa recommendation using ILCOR guideline recommendations.)

Keywords: Cardiothoracic surgery; Defibrillation; Automatic external defibrillator; Ventricular fibrillation

1. Introduction

A best evidence topic was constructed according to a structured protocol, described in the ICVTS [1]. The quality of each study was assessed using the International Liaison Committee on Resuscitation (ILCOR) 2005 protocol [20].

2. Clinical scenario

A 78-year-old patient has returned to your intensive care following a quadruple coronary arterial bypass graft. The operation note states that the targets were very small and there is some lateral ST segment elevation on the monitor. One hour post-surgery he suddenly goes into ventricular fibrillation. The nurses start to massage the patient. You place external pads on the patient and deliver a single 150 J biphasic shock which is unsuccessful. You start to charge for a second shock but the nurses who have just gone on a resuscitation update course recommence cardiac massage and tell you that he needs 2 min of massage. You are aware that a graft may be kinked or occluded or there may be a tamponade and, thus, do not want to delay reopening, but to not want to reopen after a single failed shock, and later resolve to look up how many shocks we should perform prior to reopening.

3. Three-part question

In [patients who go into VF post-cardiac surgery], what is the success rate of each subsequent [defibrillatory shock] to return [cardiac output]?

4. Search strategy

Medline 1950 to August 2007 using OVID Interface.

[exp cardiac surgical procedures/OR exp thoracic surgical procedures/OR exp thoracic surgery/] AND [exp ventricular fibrillation/OR exp Tachycardia, Ventricular/] AND [exp Electric Countershock/OR Heart Arrest/OR exp Cardiopulmonary Resuscitation/]. Embase 1980 to August 2007 [exp Heart sugery/OR exp Thorax Surgery] AND [exp heart ventricle Fibrillation/OR exp Heart Ventricle Tachycardia/] AND [exp heart arrest/OR exp resuscitation/OR exp cardioversion/]. All references searched from Section 2 and 3 of the European Resuscitation Council Guidelines for Resuscitation 2005 [2, 3].

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Table 1
Best evidence papers

Author, date and country Study type	Patient group	Outcomes	Key results	Study weaknesses
Szili-Torok et al., (2002), Acta Cardiologica, The Netherlands, [4] Prospective randomised controlled trial (level 2, good)	14 patients with ICDs (mean age 63±14 years) were randomised into two groups of different transthoracic defibrillation. 50 episodes of VF, with mean duration of 13±3.4 s analysed. 27 episodes received a sequence of 100 J then 200 J biphasic rectilnear shocks, 23 treated with a sequence of 150 then 360 J monophasic damped sine shocks	First shock efficacy Second shock efficacy Most effective waveform for first and second shocks	92% with 100 J biphasic shock (25 episodes). 61% with 150 J monophasic shock (14 episodes) 100% with 200 J biphasic shock (2 episodes). 95% with 360 J monophasic shock (4 episodes) Low-energy biphasic shocks. Overall success rate of: Biphasic shocks: 93% Monophasic shocks: 64%	Small patient group Few patients to compare for the second shock efficacy Patients had either coronary artery disease or cardiomyopathy and were not post-surgical
Higgins et al., (2004), Prehospital Emergency Care, USA, [5] Prospective cohort study (level 3, good)	96 patients (mean age 70±10 years). 77 in VF for mean of 16±5 s and 19 in ventricular tachycardia. VF/VT electrically induced in patients undergoing EP testing or testing for ICD. First shock efficacy of 150 J biphasic shocks delivered to VF patients evaluated and compared to historical control group (68 patients, mean age 69±12 years, in VF for mean 19±9 s) treated with 200 J monophasic shock	First shock efficacy – for VF Second shock efficacy – for VF Most effective waveform	97.4% with 150 J biphasic shock (75/77). 89.7% with 200 J monophasic shock (61/68) 100% with 150 J biphasic shock (2/2) 150 J biphasic shocks are equivalent to monophasic	ICD patients received shock from ICD as primary shock, whereas, EP group received the biphasic shock as primary shock Patients who received biphasic shock were compared to a patient group not selected in the same time period A range of post-shock rhythms were accepted as reversion from VF. Patients are not post-surgical and their VF is induced rather than spontaneous
Stiell et al., (2007), Circulation, Canada, [6] Randomised triple-blinded controlled trial (level 1, good)	The Biphasic study 3-year study involving 221 out-of-hospital cardiac arrest patients received 1 or more biphasic shocks from AEDs that were randomly programmed to give fixed lower energy (114 patients) (150-150-150 J) or escalating higher energy (107 patients) (200-300-360 J) regimes. Initial rhythm in 92.3% was VT/VF, 206 were in VF. Mean age of patients 66 years	Efficacy of fixed lower vs. escalating higher shocks First shock success of VF termination within 5 s	Multiple shocks (≥2): 106 patients. Overall VF termination rate for multiple shocks: Fixed lower: 71.2% (51 patients). Escalating higher: 82.5% (55 patients) 1 shock only: 103 patients. Fixed lower (150 J): 86.8% Escalating higher (200 J): 88.8%	Out-of-hospital cardiac arrest only, excluded patients who suffered cardiac arrest in hospital Patients are not post-surgical Does not specify success of second/third shock, instead it gives an overall success of multiple-shock patients
Martens et al., (2001), Resuscitation, Belgium, [7] Randomised controlled trial (level 1, good)	338 out-of-hospital cardiac arrests. 115 presented with VF with mean age of 65 years. AEDs were randomly assigned either impedance-compensated biphasic truncated exponential (ICBTE) (150-150-150 J) or monophasic truncated exponential (MTE)/monophasic	Defibrillation efficacy (VF termination for at least 5 s) with: ≤3 shocks ≤2 shocks	Biphasic: 98% (53/54) MTE: 67% (32/48) MDS: 77% (10/13) Biphasic: 96% (52/54) MTE: 60% (29/48) MDS: 77% (10/13)	Out-of-hospital patients only Small patient group (115) Non-surgical patients

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Table 1 *(Continued)*

Author, date and country Study type	Patient group	Outcomes	Key results	Study weaknesses
	damped sine (MDS) (200-200-360 J)	First shock	Biphasic: 96% (52/54) MTE: 54% (26/48) MDS: 77% (10/13)	
		Kruskal–Wallis test	Direct comparison between ICBTE and MDS show biphasic shocks have significantly greater shock efficacy for 1/2/3 shocks ($P<0.05$)	
Morrison et al., (2005), Resuscitation, Canada, [8] Prospective randomised controlled trial (level 1, excellent)	The Orbit study AEDs were randomised to produce biphasic (RLB) shocks (120-150-200 J) or monophasic damped sine (MDS) (200-300-360 J). 313 patients in cohort, of which 169 had initially shockable rhythm and 144 were not initially shockable. Of the 212 patients, 83 received MDS and 86 RLB	Shock success (conversion at 5 s to an organised rhythm) for First shock	RLB: 22.9% (19/83) MDS: 12.2% (10/82)	Patients shocked regardless of arrest rhythm Out-of-hospital patients Non-surgical patients
		Second shock	RLB: 26.9% (18/67) MDS: 21.9% (16/73)	
		Third shock	RLB: 16.3% (8/49) MDS: 3.5% (2/57)	
Schwarz et al., (2003), Anesthesiology, Austria, [9] Prospective randomised controlled trial (level 2, good)	Study between Feb 2000 and Jan 2001. 91 patients (mean age 66.5 years) undergoing cardiac surgery were randomly assigned to either a control group that received monophasic damped sine wave shocks (41) or treatment group that received biphasic truncated exponential waveform shocks (50) intra-operatively if they entered VF. Each group received ascending shock energies (2, 5, 7, 10 and 20 J) until defibrillation occurred. Surgeon blinded to shock waveform	Cumulative % success at shock strength: 1st shock (2 J)	Monophasic: 7.3% Biphasic: 16.7%	Does not focus on the number of shocks, but rather the waveform of the shock delivered Patients are undergoing surgery rather than post-surgical Shock delivery is intra-operative rather than transthoracic Removal of aortic clamp was trigger for VF, rather than spontaneous VF Results not specific to one operation, but 4 different cardiac procedures
		2nd shock (5 J)	Monophasic: 22.0% (9/41) Biphasic: 52.1% (25/50)	
		3rd shock (7 J)	Monophasic: 34.1% Biphasic: 66.7%	
		4th shock (10 J)	Monophasic: 51.2% Biphasic: 75.0%	
		5th shock (20 J)	Monophasic: 75.6% Biphasic: 83.3%	
Edelson et al., (2006), Resuscitation, USA, [10] Prospective multi-centre cohort study (level 2, good)	Study conducted between March 2002 and Dec 2005. 60 in-hospital and out-of-hospital patients (mean age 65±16 years) who entered VF were delivered a trans-thoracic biphasic shock with variable compression depth and pre-shock pause	First shock success (removal of VF for at least 5 s)	73% (44) (with 8 s pre-shock pause)	Focus on pre-shock pause (time between last chest compression and first shock), compression depth and other factors affecting first shock success Includes both in- and out-of-hospital arrests. therefore, a single conclusion from one group cannot be determined Low patient number to draw significant conclusions from
		Optimal pre-shock pause and compression depth	Longer pre-shock pause and shallower compression depth associated with significantly decreased first shock success	
Van Alem et al., (2003), Resuscitation,	Study between Jan 2000 and June 2002. 120 out-of-hospital patients (mean age	First shock success (removal of	Biphasic: 69% (35/51) Monophasic: 45% (31/69)	Out-of-hospital cardiac arrests included, no in-hospital patients

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Table 1 *(Continued)*

Author, date and country Study type	Patient group	Outcomes	Key results	Study weaknesses
The Netherlands, [11] Prospective randomised double-blinded trial (level 2, good)	66.5 years) who entered VF received either a biphasic truncated exponential shock (BTE) or monophasic damped sine shock (MDS) of 200 J. AEDs (identical in shape, size and design) programmed for BTE or MDS were randomly assigned to responders. 51 patients received BTE and 69 received MDS. Second and third shocks were 200 and 360 J for both BTE and MDS protocols	VF and return of organised rhythm for at least 2 QRS complexes within 1 min)		Lack of data on subsequent shocks delivered to those patients in whom the first shock failed and VF persisted
		Termination of VF at 5 s after 1st shock	Biphasic: 98% (50/51) Monophasic: 91% (63/69)	
Carpenter et al., (2003), Resuscitation, USA, [12] Retrospective cohort study (level 4, excellent)	Study between Jan 1999 and Aug 2002. 366 out-of-hospital cardiac arrest patients presenting in VF received either a monophasic damped sine (MDS) shock (193 patients, mean age 67 years), biphasic truncated exponential (BTE) shock (105 patients, mean age 67 years) or monophasic truncated exponential (MTE) shock (68 patients, mean age 64 years)	First shock success (removal of organised rhythm and minimum of 2 QRS complexes within 5 s of shock)	MDS: 83.9% (162/193) MTE: 63.2% (43/68) BTE: 89.5% (94/105)	The study is not a randomised controlled trial Pre-hospital setting only, no patients in-hospital or post-surgical Cumulative data only regarding second and third shock success
		≤2 shocks	MDS: 92.2% (178/193) $n=16$ MTE: 75.0% (51/68) $n=8$ BTE: 96.2% (101/105) $n=7$	
		≤3 shocks	MDS: 95.9% (185/193) $n=7$ MTE: 85.3% (58/68) $n=7$ BTE: 97.1% (102/105) $n=1$	
Cammarata et al., (2006), Resuscitation, USA, [13] Experimental study (level 6, excellent)	In 60 domestic pigs, VF was electrically induced, 1 min CPR delivered followed by up to 3 sequential 150 J biphasic shocks	First shock success (restoration of spontaneous circulation)	80% (48/60)	Study limited to pigs, therefore, cannot be directly applied to humans Absence of ischaemic heart disease in the pigs
		Second shock success	15% (9/60) Reduced capability to restore spontaneous circulation due to time required for rhythm analysis and recharging AED	
		Third shock success	5% (3/60) as above	
		Resuscitation protocol	To deliver a single shock or at most 2 shocks prior to resuming chest compressions	
Nieman et al., (2000), J Am College Cardiol, USA, [14]	In 38 pigs, VF was induced for 5 min, after which, 18 received monophasic truncated exponential (MTE) shocks (200-300-	Successful defibrillation (termination of VF regardless of	MTE: 61% (11/18) BTE: 50% (10/20)	Pigs were in VF for 5 min, which is unlikely in patients on CICU, but more likely in out-of-hospital arrests

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Table 1 *(Continued)*

Author, date and country Study type	Patient group	Outcomes	Key results	Study weaknesses
Experimental study (level 6, excellent)	360 J) and 20 received biphasic truncated exponential (BTE) shocks (150-150-150 J). 5 pigs, 3 from BTE and 2 from MTE groups required more than 3 shocks	post-shock rhythm) at first shock		Unable to base practice on studies involving pigs
		Second shock	MTE: 22% (4/18) BTE: 30% (6/20)	Small number of pigs in the study
		Third shock	MTE: 0 BTE: 5% (1/20)	VF induced rather than spontaneous
				Post-shock rhythm not recorded
Schneider et al., (2000), Circulation, Germany, [15] Multicentre randomised controlled trials (level 1, good)	115 out-of-hospital cardiac arrest patients who presented in VF received either 150-150-150 J biphasic shocks (54 patients, mean age 67±13 years) or 200-200-360 J monophasic shocks (61 patients, mean age 66±14 years) from an AED previously randomly assigned to either waveform	Defibrillation (termination of VF for ≥5 s) in the first series of ≤3 shocks	Monophasic: 69% (42/61) Biphasic: 98% (53/54)	Out-of-hospital cardiac arrests Variable causes of arrests Small patient group
		Defibrillation with ≤2 shocks	Monophasic: 64% (39/61) Biphasic: 96% (52/54)	
		Defibrillation with 1 shock	Monophasic: 59% (36/61) Biphasic: 96% (52/54)	
		Total patients defibrillated	Monophasic: 84% (49/58) Biphasic: 100% (54/54)	
Gliner et al., (1998), Biomedical Instrumentation and Technology, Germany, [16] Observational cohort study (level 3, fair)	Dec 1996 to Feb 1998, 100 out-of-hospital cardiac arrest victims presenting in VF (69±15 years) were given 1–3 150 J biphasic truncated exponential (BTE) shocks and their post-shock rhythm was analysed	Defibrillation success (termination of VF into an organised rhythm or asystole for at least 5 s) of 1 shock	86% (86/100)	Discontinuous AED user including flight attendants and police officers, therefore, variation in expertise Out-of-hospital patients only
		≤2 shocks	94% (94/100)	Variation in the time between arrest and application of pads and subsequent first shock delivery
		≤3 shocks	96% (96/100)	
Bardy et al., (1996), Circulation, USA, [17] Prospective randomised blinded study (level 2, good)	294 patients (mean age 65±12 years) in VF (previously induced) received either a 115/130 J truncated biphasic shocks or 200/360 J damped sine wave monophasic shocks	First shock defibrillation efficacy (restoration of supra-ventricular, paced or baseline rhythm within 16 RR intervals of shock)	115 J Biphasic: 89% 130 J Biphasic: 86% 200 J Monophasic: 86% 360 J Monophasic: 96% Biphasic shocks require lower energy despite an equal efficacy to monophasic shocks – allows smaller AEDs to be used Suggests using biphasic shocks of a 130/130/130 J regime as a resuscitation protocol instead of monophasic shocks	Patients undergoing ICD surgery, ICD replacement, or ICD testing Patients first received a transvenous shock which if unsuccessful was followed by a transthoracic shock Induced VF as opposed to spontaneous, therefore, shorter interval between start of VF and first shock compared to in-hospital patients

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Table 1 *(Continued)*

Author, date and country Study type	Patient group	Outcomes	Key results	Study weaknesses
White et al., (2005), Resuscitation, USA, [18] Retrospective cohort study (level 4, excellent)	Cardiac arrest data over Dec 1996 to Dec 2001 from two EMS systems (57 by Mecklenburg EMS and 45 by Rochester EMS) were analysed retrospectively, with focus on the differences in transthoracic impedance for successful vs. unsuccessful outcome. 102 witnessed out-of-hospital arrests where patients presented in VF/VT were given a non-escalating regime of 150 J biphasic shocks	First shock success Cumulative 2nd shock success Cumulative 3rd shock success 3 shock success of 102 patients	90% (CI: 83–95) 98% (CI: 93–100) 99% (CI: 95–100) 101/102 (1 required 5 shocks)	Patients included who presented in VT as well as VF, therefore, not a complete reflection of in-hospital cardiac arrests Shock considered successful if 5 s post-shock, the rhythm was non-shockable (includes asystole), and, therefore, shock success is not reversion to sinus rhythm

Cochrane Database of Systematic reviews was searched on 28th of August 2007 using the search term 'resuscitation' searched. Cochrane Controlled Trials register searched on 28th of August 2007 using the search term 'resuscitation'.

5. Search outcome

Four hundred and eighty-six abstracts were identified from Medline, 352 abstracts from Embase, 28 papers from the Cochrane database of systematic reviews and 155 from the Cochrane controlled trials register. There were 162 references in sections 2 and 3 of the ERC guidelines. From these studies, 15 represented the best evidence on the topic (Table 1).

6. Comments

Current guidelines from the European Resuscitation Council [2, 3] state that 2 min should be left between attempts at cardioversion for patients who arrest and go into ventricular fibrillation or ventricular tachycardia (VF/VT). But in patients post-cardiac surgery, prompt chest reopening is known to improve outcomes, thus, waiting for 2 min between each shock may result in a delay that may impair outcome should cardioversion prove unsuccessful. Therefore, having a protocol for the number of attempts at defibrillation prior to reopening the chest is of paramount importance.

In eight studies [4, 5, 7–9, 11, 15, 17], monophasic shocks were compared to biphasic shocks, and in all these papers, biphasic shocks were found to be more successful or equivalent to monophasic shocks at defibrillation. In five [4, 5, 7, 15, 17] of these comparative studies, the success at the first attempt at defibrillation was between 86 and 98%. In contrast, two of the studies [8, 9] showed relatively lower first shock success rates ranging from 16.7 to 22.9%. However, in one of the latter studies by Schwartz et al. [9], intra-operative shocks were delivered during cardiac surgery on 91 patients, therefore, the first shock energy was lower at 2 J compared to the higher energies (100–150 J) used for the transthoracic delivery in the other studies.

Two animal studies were performed. Cammarata et al. [13] induced VF in 60 pigs, then delivered three sequential 150 J biphasic shocks. The first shock success was 80%, which steeply declined to 15% success for the second shock and further dropped to 5% for the third shock success. These results strongly suggest that a maximum of three shocks should be delivered to patients in VF/VT, as after this point, the chance of successful defibrillation is very small. The second study was by Nieman et al. [14], who induced VF in 38 pigs, who either received three escalating monophasic shocks (200-300-360 J) or fixed biphasic shocks (150 J). Both shock waveforms displayed a similar reduction in shock success from first to third shocks. The first shock success was 50% for biphasic shocks, followed by 30% for second shock and 5% at third shock. The results of both papers suggest that the fourth shock success would be below 5%. These animal studies have the obvious limitation of involving pigs as the subjects, however, in combination (98 pigs) the similar pattern of reduction from first to third shock success indicates that proceeding to a fourth shock would not be beneficial to patients in VF.

Of course we must acknowledge the wide range of papers from which we obtained these data, including papers looking at ICDs, electrophysiological studies, all the way to out-of-hospital arrests and animal studies and we must furthermore acknowledge that the success of a second shock after 2 min of CPR has not yet been reported in any paper that we found. However, when the data are combined from all 15 papers, although not all record the second and third shock success, the average success rate of sequential shocks declines from 77.6% for the first shock, 34.8% for the second shock and to 13.9% for third shock success. Data on fourth shock success was only recorded in one paper [9]. Overall, the data suggest that the likelihood of conversion from VF/VT to an organised rhythm declines dramatically from first to second shock, and declines further from second to third shock, which indicates that proceeding to reopening after the third shock is preferable due to the minimal chance of fourth shock success. Mackay et al. [19] reported the results of 79 chest reopenings over six years and found that the major determinant of survival was chest reopening within 10 min.

7. Clinical bottom line

We conclude that due to the importance of minimising the delay to chest reopening, three shocks should be quickly delivered. If these do not succeed the chance of a 4th shock succeeding is likely to be less than 10% and, thus, immediate chest reopening should be performed. (This is a Class-IIa recommendation using ILCOR guideline recommendations.)

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eComment: Cardioversion protocol for ventricular fibrillation: a more differentiated approach

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Without any doubt, the authors are right in their statement that more than three shocks are hardly effective in patients with ventricular fibrillation shortly after cardiac surgery [1]. However, I am not quite sure that this is the case when external cardiac massage (by hand and not by machines) is effective (patients on the Intensive Care Unit will mostly have an arterial pressure monitoring) and concomittant with the shocks a single dose of Amiodarone is applied.

In the Netherlands, and I suppose this is the case in other European countries, it is no longer common practice to have residents of the Cardiothoracic surgery department in the hospital during the night. Due to the regulations on working hours, the number of residents needed for around the clock service is huge. Because of this, it can take 10 to 15 min before somebody capable of reopening the chest has arrived at the Intensive Care Unit. In our case, we experienced some good results from a fourth or even fifth shock, Amiodarone and of course, effective cardiac massage.

I advise to add to the recommendation: While waiting for somebody capable of reopening the chest, external cardiac massage should be continued and after a single dose of 5 mg/kg body weight of Amiodarone, two more shocks can be tried.

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