

## WORKSHEET for Evidence-Based Review of Science for Emergency Cardiac Care

### Worksheet author(s)

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### Clinical question.

"In pediatric patients with cardiac arrest due to primary or secondary VF or pulseless VT (pre-hospital [OHCA] or in-hospital [IHCA]) (P), does the use of a specific energy dose or regimen of energy doses for the initial or subsequent defibrillation attempt(s) (I), compared with standard management (C), improve outcome (e.g. termination of rhythm, ROSC, survival to hospital discharge, survival with favorable neurologic outcome) (O)?"

**Is this question addressing an intervention/therapy, prognosis or diagnosis?** Intervention/ therapy.

**State if this is a proposed new topic or revision of existing worksheet:** New topic

### Conflict of interest specific to this question

Do any of the authors listed above have conflict of interest disclosures relevant to this worksheet? No.

### Search strategy (including electronic databases searched).

1. AHA Endnote 9 library (24.03.08): child AND electric countershock AND heart arrest (37) OR cardiopulmonary resuscitation (39)
2. Clinical trials.gov: electric countershock AND heart arrest (24) OR cardiopulmonary resuscitation (8)
3. Cochrane library: Electric countershock AND heart arrest (1-review), (7-other reviews), (102 clinical trials) OR cardiopulmonary resuscitation - (2-review), (3-other reviews), (65 clinical trials)
4. Pubmed: Child tw/mesh AND electric countershock tw/mesh AND heart arrest tw/mesh (150) OR cardiopulmonary resuscitation tw/mesh (97)  
Review of reference lists of articles.
5. Embase: Child tw/mesh AND defibrillation tw/mesh AND heart arrest tw/mesh (99) OR resuscitation tw/mesh (144)  
Review of reference lists of articles.
6. Google scholar: Child, electric countershock, outcome, heart arrest, cardiopulmonary resuscitation (1141).  
Search updated 10.10.09 and in late 2010, an additional in press article by Tibballs *et al* was added following permission of author and publisher.

### • State inclusion and exclusion criteria

Inclusion:

Completed trials that study dose/regime of defibrillation in pediatric patient(s) or animal model(s) and which have a measure of outcome.

Exclusion:

Abstract only.

### • Number of articles/sources meeting criteria for further review:

32 articles reviewed in detail

## Summary of evidence

### Evidence Supporting Clinical Question

<b>Good</b>				(Tibballs, 2010 in press, with permission) ABCE	(Clark, 2001) A (Tang, 2002) AE (Berg, 2004b) BDE (Berg, 2008) A
<b>Fair</b>				(Rossano, 2006) C	
<b>Poor</b>				(Atkins, 1998), C (Atkins and Jorgenson, 2005) D (Rodriguez-Nunez, 2006) A (Tibballs and Kinney, 2006) ABC	(Babbs, 1980) BE (Gaba and Talner, 1982) BE (Killingsworth, 2002) AE
	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>Level of evidence</b>					

A = Return of spontaneous circulation  
B = Survival of event

C = Survival to hospital discharge  
D = Intact neurological survival

E = Other endpoint  
*Italics = Animal studies*

## Evidence Neutral to Clinical question

<b>Good</b>					
<b>Fair</b>					
<b>Poor</b>				(Khoury and Shavit, 2009), D	
	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>Level of evidence</b>					

A = Return of spontaneous circulation  
 B = Survival of event

C = Survival to hospital discharge  
 D = Intact neurological survival

E = Other endpoint  
*Italics = Animal studies*

## Evidence Opposing Clinical Question

<b>Good</b>					
<b>Fair</b>			(Berg, 2005a) AB		<i>(Berg, 2005b) DE</i>
<b>Poor</b>				(Gutgesell, 1976) E	
	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>Level of evidence</b>					

A = Return of spontaneous circulation  
 B = Survival of event

C = Survival to hospital discharge  
 D = Intact neurological survival

E = Other endpoint  
*Italics = Animal studies*

**REVIEWER'S FINAL COMMENTS AND ASSESSMENT OF BENEFIT / RISK:**

In 2005 the European Resuscitation Council guidelines included a notable departure from the ILCOR recommendations of the same year in terms of defibrillation – changing the weight based energy dose in children from 2/4/4 J/kg to 4J/kg for first and subsequent shocks (Biarent, 2005). This change was attributed to biphasic doses of 3-4J/kg being considered superior to lower doses (Berg, 2004b; Clark, 2001; Faddy, 2003; Tang, 2002) and the apparent safety of these larger defibrillation doses (Gurnett and Atkins, 2000; Rossano, 2006). A more detailed review of the literature suggests that outcomes may possibly be improved by altering energy levels from 2/4/4J/kg to 4/4/4J/kg, but it is based largely on animal data and scanty human reports.

The basis for previous recommendations rests largely on one trial in which mainly pediatric cardiac patients (20/27) had VF rapidly terminated in hospital soon after cardiac operations (Gutgesell, 1976). Animal data existed from a similar era (Geddes, 1974) which supported these energy levels. Preceding the introduction of biphasic waveform defibrillators and with the use of AEDs in pediatric patients, there was a plethora of pediatric animal models and some patient studies to examine and refine an appropriate pediatric energy dose regime. There have been two studies which suggest the energy dose should remain unchanged. The first is an animal model in which 19kg pigs received either ~2/4/4J/kg or 10/15/18J/kg via an AED. The higher doses were 3 times more effective in effecting first shock VF termination, but about 3 times less likely to achieve a good neurological outcome at 24hrs. The higher dose was also associated with impaired myocardial function, so despite a more rapid termination of VF (due to the higher dose), overall outcome was worse and this data supports the use of pediatric attenuated AEDs (Berg, 2005b). The same group of researchers reviewed a 5 year cohort of out of hospital arrests. Following 2J/kg DC shock 7/14 instances of VF/VT reverted in 11 patients, none however to perfusable rhythms and no patients survived. The shocks that terminated VF tended to be lower energy, than those that didn't - 2.3J/kg (median 2.2) vs 4.8J/kg (median 3.8),  $p=0.063$  (Berg, 2005a).

An increasing number of case reports with insufficient information to determine an energy dose effect have been published (Divekar and Soni, 2006; Khoury and Shavit, 2009; Rey, 2007). Several excellent multicentre cohorts of pediatric arrest patients have also been published, but do not contain sufficient energy dose information (Atkins, 2009; Samson, 2006). As a consequence pediatric animal models, together with a heterogeneous group of pediatric patient studies provide contributory data to determining an energy dose for defibrillation in VF/pulseless VT.

Time to successful defibrillation is an important consideration in the treatment of VF/VT. Out of hospital defibrillation within 3 minutes of VF results in >50% survival, with survival dwindling to <5% after 12 minutes of VF (Berg, 2004a). Increased energy results in more rapid VF termination, but at the risk of increased myocardial damage (Babbs, 1980). Clark *et al* showed that ROSC was seen following brief VF, in >80% using 4J/kg and 3J/kg in ~5kg and 9kg pigs respectively, but if 2J/kg was used these rates fell to 25% and 32% respectively – with no differences in surrogates of myocardial dysfunction (Clark, 2001). Similarly Berg *et al* showed in a prolonged VF porcine model that a higher biphasic dose (~10J/kg) was significantly more effective than a lower dose (~2.5J/kg) in terminating VF with first shock success 19/26 versus 8/26. There was however equivalent survival and degrees of myocardial dysfunction in the two groups (Berg, 2008).

A recent in press article by Tibballs *et al* described 48 inpatients with VF/VT that were defibrillated with a mean dose of 1.7J/kg and the dosage and outcome recorded (Tibballs, 2010 in press, with permission). Eighty percent of patients were in PICU/OT and had a cardiac diagnosis, but it is unclear why defibrillation doses lower than current recommended guidelines were delivered. Twenty percent of patients subsequently received internal defibrillation. Initial doses of  $2.0\pm 1.0$ J/kg were successful in 48% and the remainder were unsuccessfully defibrillated with  $1.5\pm 0.7$ J/kg. Subsequently 58% successfully received  $2.6\pm 1.1$  J/kg 1-8 times and the remaining 10 patients were unsuccessfully administered  $3.2\pm 1.2$ J/kg, 1-8 times, eight of these 10 patients received internal defibrillation. Overall 94% of patients recovered from the event and 73% survived at least 12 months. Dose greater or less than 2J/kg was not significantly associated with ROSC or any other outcome, but ~2J/kg resulted in less than 50% ROSC with the first shock.

In a large series of pediatric patients with information on energy doses and outcome there was the suggestion by Rodriguez-Nunez *et al* that an initial and subsequent dose of 4J/kg may lead to improved outcome (Rodriguez-Nunez, 2006). A shockable rhythm was found in 44 patients, initial defibrillation with 2J/kg or less led to 89% of these patients needing more than 1 shock, those receiving > 2J/kg required more than one shock 43% of the time,  $p=0.017$ . Similar to the animal models though this more rapid termination of VF was not associated with superior survival, with only 3 patients surviving one year. Tibballs *et al* earlier described the energy doses used to terminate VF in 7 inpatients. Four had ROSC and survival at 1 year, they received a median dose of 4.3J/kg versus 3.6J/kg in those without a pulsatile rhythm following VF termination,  $p=0.7$  (Tibballs and Kinney, 2006). In the largest group of pediatric patients with VF (n=57) there was no clear association between energy dosage and outcome for the 19 who survived to discharge,

although 16/19 had received doses of >4-6J/kg (Rossano, 2006). Several case reports and a small case series documented large pediatric DC shocks with intact survival ranging from 7 - 9J/kg (Atkins and Jorgenson, 2005; Gurnett and Atkins, 2000; Konig, 2005), hinting at efficacy as well as safety or at least tolerance of these energy doses.

The animal models in particular have explored tolerance and safety of higher defibrillation energy doses. Tang *et al* in a porcine model of out of hospital VF showed no difference between groups of pigs weighing 3.8, 7.5, 15 and 25kg, upon receiving a 50J biphasic shock – in terms of hemodynamic parameters. This suggests safety and efficacy with doses of 13.2J/kg, 6.7J/kg, 3.3J/kg and 2J/kg for the 4 groups respectively (Tang, 2002). Berg *et al* also demonstrated safety and efficacy with a porcine model compared to 2/4/4J/kg in animals that received a first shock of 2-12J/kg (Berg, 2004b). Earlier work indicated that persistent myocardial injury occurred with individual shocks of up to 150J/kg (Gaba and Talner, 1982) and more recently individual doses of 90J/kg were tolerated (Killingsworth, 2002), both of which suggested a generous safety margin, which has been shown in the case reports of AED use (Gurnett and Atkins, 2000; Konig, 2005).

Larger initial defibrillation doses appear to have crept into current practice, this may be a consequence of rounding up of energy doses to suit defibrillators or out of desperation in critical arrest situations. An initial dose of 4J/kg could potentially result in greater first shock success, which may improve outcome and the available safety data would suggest it should be well tolerated (Berg, 2008; Berg, 2004b; Clark, 2001; Rodriguez-Nunez, 2006; Tibballs and Kinney, 2006).

**Acknowledgements:**

Nil.

## Citation List

**1. Atkins DL, Everson-Stewart S, Sears GK, Daya M, Osmond MH, Warden CR, et al. Epidemiology and outcomes from out-of-hospital cardiac arrest in children: the Resuscitation Outcomes Consortium Epistry-Cardiac Arrest. *Circulation*. 2009 Mar 24;119(11):1484-91.**

Worksheet author comments:

LOE 4 pediatric registry study detailing the incidence of OHCA. Outcome (survival) was superior in children and adolescents, compared with the infant and adult age groups.

**2. Atkins DL, Hartley LL, York DK. Accurate recognition and effective treatment of ventricular fibrillation by automated external defibrillators in adolescents. *Pediatrics*. 1998 Mar;101(3 Pt 1):393-7.**

Worksheet author comments:

LOE 4 retrospective review of adolescents receiving 200-360J via an AED. Seven patients had recognised VF and received DC shock with 3/7 discharged from hospital - these patients were 12, 15 and 15 years and are likely to have received greater than 2J/kg, all 3 had 2 - 3 doses of 200J.

**3. Atkins DL, Jorgenson DB. Attenuated pediatric electrode pads for automated external defibrillator use in children. *Resuscitation*. 2005 Jul;66(1):31-7.**

Worksheet author comments:

LOE 4 retrospective review of pediatric AED recipients 8/27 arrested patients (all less than or equal to 8 years old apart from one 10 year old) had VF and were defibrillated with 50J. Five survived to hospital discharge - including an 18month old (2 shocks), a 3 year old (1 shock) and a 6.3kg 4.5 month old (1 shock). The use of > 2J/kg was successful in the resuscitation of these patients, the 3 patients who were shocked and did not survive included 2 drowning victims and 1 patient who had an AED applied after 10 minutes - suggesting long arrest duration was a factor.

**4.Babbs CF, Tacker WA, VanVleet JF, Bourland JD, Geddes LA. Therapeutic indices for transchest defibrillator shocks: effective, damaging, and lethal electrical doses. Am Heart J. 1980 Jun;99(6):734-8.**

Worksheet author comments:

LOE 5 canine defibrillation trial which used 65 dogs (~8kg) including a non defibrillated control group and defibrillated these with 1-500J/kg. Hearts were examined histologically for evidence of damage and energy to dose response curves were constructed. Biological variability was seen, but there was very minimal overlap between defibrillation curves and morphological damage curves. Effective defibrillation was achieved at a median dose of 1.5J/kg and morphological damage occurred at a median dose of 30J/kg.

**5.Berg MD, Banville IL, Chapman FW, Walker RG, Gaballa MA, Hilwig RW, et al. Attenuating the defibrillation dosage decreases postresuscitation myocardial dysfunction in a swine model of pediatric ventricular fibrillation. Pediatr Crit Care Med. 2008 Jul;9(4):429-34.**

Worksheet author comments:

LOE 5 model of 7 minutes duration VF, with 52, approximately 19kg pigs randomized to biphasic 200/300/360 J OR 50/75/85 J. The pediatric dose (~2.5J/kg) was less effective in terminating VF with first shock 8/26 versus the adult dose (~10J/kg) 19/26, p=0.005. Overall ROSC was not different. Troponin was raised in 4/20 paediatric dose pigs and 11/19 of the adult dose group, p=0.02. Left ventricular dysfunction was different from baseline in both groups at 4 hours, although the decrease was greater with the adult group. There was equivalent survival at 24hours in both groups, myocardial dysfunction in both groups and earlier termination of VF in the adult dose group.

**6.Berg MD, Samson RA, Meyer RJ, Clark LL, Valenzuela TD, Berg RA. Pediatric defibrillation doses often fail to terminate prolonged out-of-hospital ventricular fibrillation in children. Resuscitation. 2005a Oct;67(1):63-7.**

Worksheet author comments:

LOE 3 retrospective review of out of hospital cardiac arrests. Failure of 2J/kg DC shock to terminate VF occurred in 7/14 out of hospital shocks to 11 patients. None of the remaining 7 defibrillations which terminated VF led to ROSC, with no survival to hospital discharge. The median time to scene was 11 minutes and this was an important factor. On average the shocks that terminated VF trended to be lower than those that didn't - 2.3J/kg (median 2.2) vs 4.8J/kg (median 3.8), p=0.063 (MWU) - although interestingly this lower dose of monophasic DC was still enough to potentially cause asystole/pulseless electrical activity - perhaps an indicator of the duration of arrest.

**7. Berg RA. Attenuated adult biphasic shocks for prolonged pediatric ventricular fibrillation: support for pediatric automated defibrillators. Crit Care Med. 2004a Sep;32(9 Suppl):S352-5.**

Worksheet author comments:

LOE 5 study that reviews the relevant animal and human studies, specifically with respect to pediatric AED dosing being superior to adult dosing. It also details the variation in outcome (survival) following ROSC from VF arrest after 3 minutes (>50%), as opposed to <5% after 12 minutes without ROSC.

**8. Berg RA, Chapman FW, Berg MD, Hilwig RW, Banville I, Walker RG, et al. Attenuated adult biphasic shocks compared with weight-based monophasic shocks in a swine model of prolonged pediatric ventricular fibrillation. Resuscitation. 2004b May;61(2):189-97.**

Worksheet author comments:

LOE 5 porcine model of 7 minutes of VF randomised to therapy with biphasic AED attenuated to 51/78/81J or monophasic 2/4/4J/kg in 4kg, 14kg and 24kg pigs (n=16 per weight group). Attenuated biphasic shocks resulted in significantly improved survival with good 24hr neurological outcome in the 24kg pigs and superior left ventricular ejection fractions - note that the initial dose of 2J/kg is essentially equivalent between groups - apart from its biphasic nature with the AED. The 4kg and 14kg pigs had strong trends towards better 24hr survival and good outcome in the AED group and equivalent Left ventricle ejection fractions supporting safety in these sized pigs (receiving ~12J/kg and 4J/kg respectively for the first shock) and equivalent efficacy.

**9. Berg RA, Samson RA, Berg MD, Chapman FW, Hilwig RW, Banville I, et al. Better outcome after pediatric defibrillation dosage than adult dosage in a swine model of pediatric ventricular fibrillation. J Am Coll Cardiol. 2005b Mar 1;45(5):786-9.**

Worksheet author comments:

LOE 5 porcine (19kg) model of 7 minutes duration VF randomized to biphasic pediatric dose 50/75/86J ~ 2/4/4J/kg OR adult dose 200/300/360J ~ 10/15/18J/kg. Paediatric dose resulted in less effective 1st shock VF termination 4/16 versus 12/16 (p=0.01). However time until ROSC and 24hr survival were similar - with a trend towards improvement with the pediatric dose. And 24hr survival with good neurologic outcome was superior after pediatric shocks 13/16 versus 4/16, p=0.004 - although the neurologic evaluations were not blinded. Left ventricular ejection fraction decreased less after pediatric shocks (p<0.05) and troponin was elevated in 6/12 adult shocks and not after any pediatric shocks, p=0.005. Suggesting a superior initial termination of VF comes at the expense of myocardial injury and subsequent neurological injury.

**10. Biarent D, Bingham R, Richmond S, Maconochie I, Wyllie J, Simpson S, et al. European Resuscitation Council guidelines for resuscitation 2005. Section 6. Paediatric life support. Resuscitation. 2005 Dec;67 Suppl 1:S97-133.**

Worksheet author comments:

LOE 5 consensus document states that animal models demonstrate pediatric doses of 3-4J/kg give better results than lower or adult doses (which are presumably higher). It goes on to state that doses larger than 4J/kg have succeeded in children with negligible side effects and recommends 4J/kg for first and all subsequent doses.

**11.Clark CB, Zhang Y, Davies LR, Karlsson G, Kerber RE. Pediatric transthoracic defibrillation: biphasic versus monophasic waveforms in an experimental model. Resuscitation. 2001 Nov;51(2):159-63.**

Worksheet author comments:

LOE 5 porcine brief (15sec) VF model - comparing monophasic and biphasic external defibrillators and measuring ROSC at a given energy dose in 12, 3-6kg and 15, 7-12kg pigs. ROSC > 80% was seen with 4J/kg in the smaller pigs and at 3J/kg in the larger pigs - using biphasic shocks, compared with <25% using the same dose as a monophasic waveform. 2J/kg biphasic shocks yielded about 25% (small pigs) and 32% (larger pigs) for ROSC. Pulseless electrical activity was interpreted as a surrogate of post defibrillation myocardial dysfunction. This occurred in two infants with biphasic shocks at 7 and 10J and in one infant with monophasic at 50J and one larger pig also at 50J. For in hospital arrests this animal data supports biphasic 4/4/4J/kg.

**12.Divekar A, Soni R. Successful parental use of an automated external defibrillator for an infant with long-QT syndrome. Pediatrics. 2006 Aug;118(2):e526-9.**

Worksheet author comments:

LOE 4 case report of an 8kg, 8 month old with Long QT syndrome. The AED was modified to give a weight based dose and appears to have given a 3rd dose of 18J, after which ROSC occurred and neurologically intact survival occurred. Specific discussions about the dose prescribed are not discussed in detail within the article.

**13.Faddy SC, Powell J, Craig JC. Biphasic and monophasic shocks for transthoracic defibrillation: a meta analysis of randomised controlled trials. Resuscitation. 2003 Jul;58(1):9-16.**

Worksheet author comments:

LOE 1 adult study of randomised trials of monophasic and biphasic DC shock with varying doses. This found equivalent first shock success and less ST segment deflection with lower doses. Comparison was between mono/biphasic, rather than between different doses of biphasic DC shock.

**14.Gaba DM, Talner NS. Myocardial damage following transthoracic direct current countershock in newborn piglets. Pediatr Cardiol. 1982;2(4):281-8.**

Worksheet author comments:

LO5 piglet (~1-3kg) VF model of escalating doses of monophasic DC shock (20 - 200J/kg). Myocardial technetium scans found evidence of injury at greater than 150J/kg, suggesting a large safety margin.

**15.Geddes LA, Tacker WA, Rosborough JP, Moore AG, Cabler PS. Electrical dose for ventricular defibrillation of large and small animals using precordial electrodes. J Clin Invest. 1974 Jan;53(1):310-9.**

Worksheet author comments:

LOE animal study of VF induced in animals ranging from rabbits to horses. Energy doses required were related to animal weight. It was determined that for subjects up to 7kg, the energy dose was 2J/kg, from 7-40kg was 2-5J/kg and above 40kg was 5-10J/kg, based on a monophasic DC waveform.

**16.Gurnett CA, Atkins DL. Successful use of a biphasic waveform automated external defibrillator in a high-risk child. Am J Cardiol. 2000 Nov 1;86(9):1051-3.**

Worksheet author comments:

LOE 4 case report of a 3 year old with hypertrophic cardiomyopathy, ~ 3 minute VF arrest - which was successfully converted to sinus rhythm with a 150J biphasic DC shock ~ 9J/kg. His initial ECG showed some T wave inversion, but at 4 hours he had normal range troponin and normal ventricular function on echocardiogram. This is a case report of AED use in a 3 year old with a good neurological outcome.

**17.Gutgesell HP, Tacker WA, Geddes LA, Davis S, Lie JT, McNamara DG. Energy dose for ventricular defibrillation of children. Pediatrics. 1976 Dec;58(6):898-901.**

Worksheet author comments:

LOE 4 retrospective case series of defibrillation attempts in 27 children with brief duration VF found 63 of 71 (89%) shocks at 2J/kg or subsequently 4J/kg successful in terminating VF, no other outcome data is available and all VF eventually was terminated. Twenty of these 27 children had congenital heart disease, which lessens the external validity of this study. It appears that some of these children had recurrent VF as they emerged from cardiac surgery for instance and received several distinct and separated doses of 2J/kg because 52/57 (91%) shocks were 2J/kg and were successful. It was the authors "clinical impression," that this was the right dose, but they also suggested that the "threshold for children is not much below 2J/kg".

**18.Khoury A, Shavit I. Out-of-hospital ventricular fibrillation in three adolescents. Arch Dis Child. 2009 Feb;94(2):153-5.**

Worksheet author comments:

LOE 4 case series of 3 adolescents (11,15 and 17yrs) who received defibrillation for out of hospital arrests with normal or near normal neurological outcomes upon discharge from hospital. the 15 year old received 3 200J shocks unsuccessfully before receiving 2 further shocks, with ROSC after the 5th shock (dose not specified). Dose was also not specified for the other two patients. Good outcomes following out of hospital arrests, dose in 15 year old is probably 2-4J/kg with good outcome.

**19.Killingsworth CR, Melnick SB, Chapman FW, Walker RG, Smith WM, Ideker RE, et al. Defibrillation threshold and cardiac responses using an external biphasic defibrillator with pediatric and adult adhesive patches in pediatric-sized piglets. Resuscitation. 2002 Nov;55(2):177-85.**

Worksheet author comments:

LOE 5 animal study (10 pigs 3.8-20.1kg). AED used with pediatric or adult pads at doses of ~2J/kg up to 200J in 20J steps. Larger doses up to 360J were also administered. Defibrillation threshold was steeper with pediatric pads. The mean time to first perfusing beat following VF was ~ 5 seconds with both pad sizes. None of the measured parameters (ST changes, LV dP/dt, time to mean 40mmHg LV pressure) indicated persistent myocardial injury in piglets that received individual shocks of up to 90J/kg. Given this demonstrated safety margin efficacy rather than potential for injury should be the main focus.

**20.Konig B, Bengner J, Goldsworthy L. Automatic external defibrillation in a 6 year old. Arch Dis Child. 2005 Mar;90(3):310-1.**

Worksheet author comments:

LOE 4 case report of a 6 year old with long QT who had an arrest and had compression commenced within 5 minutes. She weighed 20kg and received a 150J biphasic AED shocks for VF, resulting in temporary asystole, subsequent VF again developed and a 2nd 150J shock again resulted in asystole and then sustained sinus rhythm, with palpable pulses. She was discharged from hospital neurologically intact after receiving two ~7J/kg DC shocks.

**21.Rey C, Rodriguez-Nunez A, Medina A, Mayordomo J. Life-saving automated external defibrillation in a teenager: a case report. J Med Case Reports. 2007;1:76.**

Worksheet author comments:

LOE 4 case report of a 14 year old who had an arrest and was attended to within 5 minutes, developed VF and was shocked once with 150J resulting in a perfusing rhythm within 1 minute. He was found to have a cardiomyopathy and was discharged home neurologically intact after receiving probably a 2 - 3 J/kg DC shock.

**22.Rodriguez-Nunez A, Lopez-Herce J, Garcia C, Dominguez P, Carrillo A, Bellon JM. Pediatric defibrillation after cardiac arrest: initial response and outcome. Crit Care. 2006;10(4):R113.**

Worksheet author comments:

LOE 4 observational study of pediatric arrests from Spain found a shockable rhythm in 44 patients. Initial defibrillation with 2J/kg or less led to 89% of these patients needing more than 1 shock. Those receiving more than 2J/kg initially needed more than 1 shock about half as often, 43%,  $p=0.017$ , although ROSC and subsequent survival were not different. Overall ROSC occurred in 28(64%), lasted 20 minutes in 19(43%) and resulted in 4 hospital discharges and 3 survivors at 1 year (6.8%), one of whom had normal pediatric cerebral performance category assessment. This suggests that 2/4/4J/kg for out of hospital and in hospital arrests could be improved by increasing the first shock dose.

**23.Rossano JW, Quan L, Kenney MA, Rea TD, Atkins DL. Energy doses for treatment of out-of-hospital pediatric ventricular fibrillation. Resuscitation. 2006 Jul;70(1):80-9.**

Worksheet author comments:

LOE 4 retrospective review of emergency medical services over a 16 year period for under 18 year olds receiving DC shock for VF. Patients were grouped according to DC dose administered - recommended (2-4J/kg), moderately high (>4-6J/kg) and higher(>6J/kg). Survival was not related to dosage of DC, but duration of CPR, presence of bystander CPR. Survival occurred with doses from 3J/kg to 73J/kg and cumulative doses were 10 and 11J/kg for survivors and non survivors. Of the 19 (33%) survivors to hospital discharge, following a median 20 minute arrest, 16/19 had moderate to high doses of DC shock(>4-6J/kg). Of the 36 non survivors of arrests that lasted at least twice as long (51mins) 31/35 had moderate to high doses of DC shock - potentially corresponding to a relatively less "dense" dose of DC shock. There appears to be use of higher than recommended doses in practice.

**24.Samson RA, Nadkarni VM, Meaney PA, Carey SM, Berg MD, Berg RA. Outcomes of in-hospital ventricular fibrillation in children. N Engl J Med. 2006 Jun 1;354(22):2328-39.**

Worksheet author comments:

LOE 4 pediatric registry study details the frequency, nature and outcome of 1000 pediatric cardiac arrests. Interestingly survival was greater in primary rather than secondary VF, suggesting scope for good outcomes with prompt treatment of VF.

**25.Tang W, Weil MH, Jorgenson D, Klouche K, Morgan C, Yu T, et al. Fixed-energy biphasic waveform defibrillation in a pediatric model of cardiac arrest and resuscitation. Crit Care Med. 2002 Dec;30(12):2736-41.**

Worksheet author comments:

LOE 5 piglet VF (7mins) model using 50J biphasic DC shocks for 3.8kg(13.2J/kg), 7.5kg(6.7J/kg), 15kg(3.3J/kg) and 25kg(2J/kg) animals. Showed no difference in post resuscitation myocardial dysfunction between the different weight pigs, with normalisation of function (LV ejection fraction) within 4hrs. All had ROSC (n=5 in each weight group), the 3.8kg group needed ~3 shocks, the 7.5 and 15kg groups needed ~2 shocks and the heaviest 25kg group needed ~ 5 shocks - suggesting increased impedance in the smallest pigs and a possible dose effect in the largest pigs. Additionally 3 groups of pigs with VF (each n=3) received 50J via an attenuated adult AED. All had ROSC, the 3.7kg group requiring 2.7 shocks, the 13.5kg group requiring 2.3 shocks and the 24kg group requiring 4.7 shocks - again possibly consistent with a dose effect. Haemodynamic function (LV ejection fraction) recovered within 4 hours and was not different between groups defibrillated with the AED. Doses greater than 2/4/4J/kg were associated with ROSC and acceptable function.

**26.Tibballs J, Carter B, Kiraly NJ, Ragg P, Clifford M. External and internal biphasic DC shock doses for pediatric ventricular fibrillation and pulseless ventricular tachycardia. Pediatr Crit Care Med. 2010 in press, with permission.**

Worksheet author comments:

LOE 4, prospective group of inpatients ~80% with cardiac diagnosis in PICU/OT had VF/VT. Initial defibrillation with 1.7J/kg was ineffective in >50%. Subsequent doses of ~ 2-3J/kg were effective, but dose was unrelated to ROSC or long term outcome which included 73% surviving greater than one year. Twenty percent of patients had internal defibrillation, all defibrillation was prompt, probably within three minutes, but

it was not recorded. 2J/kg was ineffective overall and subsequent higher doses were successful in most patients.

**27. Tibballs J, Kinney S. A prospective study of outcome of in-patient paediatric cardiopulmonary arrest. Resuscitation. 2006 Dec;71(3):310-8.**

Worksheet author comments:

LOE 4, prospective group of paediatric cardiac arrest patients (n=111), with VF/VT in 10(9%). Seven of these patients had termination of VF, one spontaneously, the others after monophasic DC shock. The DC doses of those with termination of VF was noted. Four patients reverted to a pulsatile rhythm and survived 1 year, they had an initial dose averaging 3.9J/kg (median 4.3J/kg). The other three patients did not develop a pulsatile rhythm after VF termination, they had a slightly lower initial DC dose of 3.4J/kg (median 3.6J/kg), p=0.7(MWU).