**Clinical question.**

In pediatric patients with cardiac arrest due to primary or secondary VF or pulseless VT (prehospital [OHCA] or in-hospital [IHCA]) (P), does the use of more than one shock for the initial or subsequent defibrillation attempt(s) (I), compared with standard management (C), improve outcome (eg. termination of rhythm, ROSC, survival to hospital discharge, survival with favorable neurologic outcome) (O)?

**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).**


Strategy 1 Cochrane “Sequential” and “Defibrillation” All Fields * =0/20 (selected/total)
Strategy 2 Medline “Sequential” and “Defibrillation” All Fields * =4/106
Strategy 3 Medline “Ventricular Fibrillation” and “Electric Countershock” OR Defibrillators MESH HEADING *# = 0/58
Strategy 4 Medline “Ventricular Fibrillation” and “Electric Countershock” OR Defibrillators MESH HEADING *= 7/759
Strategy 5 Medline “Stacked” and “Shocks” All Fields *= 3/37
Strategy 6 ECC Endnote library “Sequential” or “Stack” and “Defibrillation” All Fields = 2/15
Strategy 7 ECC Endnote library “Multiple” and “Defibrillation” All Fields = 4/37

Additionally, worksheets on single versus sequential “stacked” shock question in adults from ILCOR 2005 worksheets were reviewed

The total number of articles identified above will not equal the articles cited in this review worksheet as some were found to be not relevant to the question after manual individual review.

* denotes raw search results
# denotes raw search results limited to studies in infants or children or adolescents (ie “All Child”).

**State inclusion and exclusion criteria**

Included all clinical trials, meta-analyses, practice guidelines, RCTs, reviews, human or animal, no language limitation.

Excluded abstract-only publications, non-peer reviewed work, conference proceedings.

**Number of articles/sources meeting criteria for further review:**

1032  (20 presented in detail)
### Summary of evidence

**Evidence Supporting Clinical Question**

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<th>Poor</th>
<th>Level of evidence</th>
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**Level of evidence**

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

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**Level of evidence**

- **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

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**Level of evidence**

- **A**: Return of spontaneous circulation
- **B**: Survival of event
- **C**: Survival to hospital discharge
- **D**: Intact neurological survival
- **E**: Other endpoint
- *italics = Animal studies*
As posed, the question has several ‘Ps’ (eg primary or secondary VF/VT, OHCA or INCA) and several ‘Os’ (VF termination, ROSC, survival, etc). There are no existing human studies to answer these questions in this specific population (i.e. pediatric patients).

For this reason, the LOE considered is 5 as the study group is adult or animal, not pediatric human, with the exception of Gutgesell 1976, Berg 2005, and Rossano 2006 (LOE 4). The argument for a single defibrillatory shock followed by CPR can be made with support from the medical literature in several ways.

First, if first shock success is relatively high, especially when using biphasic versus monophasic waveforms (van Alem 2003; (LOE 5)) additional shocks would be superfluous and only delay further resuscitation (ie CPR). When duration of VF is longer (ie >5 minutes as is common in OHCA), multiple shocks are not successful in terminating VF (Menegazzi 2008 (LOE 5)).

Second, delays in providing chest compression after the first shock are, by definition, greater if multiple shocks are given (Yu 2002; Rea 2006; Tang 2006; Cammarata 2006 (LOE 5)), and defibrillation success worsens with increasing chest compression interruptions (Eftestol 2002; (LOE5)).

Third, post-arrest myocardial injury and dysfunction may be worsened with multiple shocks (Gazmuri 2000 (LOE 5)). Finally, there is no reduction in thoracic impedance (and therefore increased defibrillatory current to the myocardium) with multiple shocks (Niemann 2003; (LOE 5)), although this is not uniformly reported (Deakin 2008; (LOE 5)). However, it must be noted that out of hospital arrest (likely longer duration VF) is more refractory to defibrillation in general when compared to in-hospital arrest (short duration VF). Support for this notion can be found in adults with OOHCA (Morrison 2005 (LOE 5)) or in-hospital arrest (Mittal 1999 (LOE 5)) as well as children with OOHCA (Berg 2005 and Rossano 2006 (LOE 4)) or in-hospital VF (Gutgesell 1976 (LOE 4)). Using data from 5046 OOHCA events, unwitnessed arrest without bystander CPR and an EMS response time > 6 minutes (ie common OOH arrest conditions) correctly predicted first shock failure for primary VF in adults 100% of the time (Menegazzi, 2008 (LOE 5)). In an adult study of OOHCA, when a sequential shock strategy was discontinued for a single shock approach, survival improved (Becker 2008; (LOE 5)). Finally, in a pediatric review of 57 cases of VF in OOHCA, 50% of patients received a higher than recommended dose for the first shock (3.6 J/kg estimated). Even then, the median number of shocks needed for defibrillation was 3, and there was no survival difference between patients receiving lower or higher doses (Rossano, 2006 (LOE 4)). This would support the safety of a higher first dose strategy, but does not directly address if a sequential shock strategy would be superior.

**Given these facts, and despite the educational appeal of an easy-to-remember uniform recommendation, it may be difficult to recommend a single shock, single dose strategy for all children in all arrest settings. This is especially true since the optimal defibrillation dose, whether single or sequential, is not yet known for children.**

In essence, an ideal approach with LOE 5 extrapolation support from the adult literature, would include a single shock, with an acceptably high success rate, to minimize harmful CPR delays. In patients with a longer duration VF (OOHCA), LOE 5 adult studies and two pediatric series suggest that a single shock of 2 J/kg does NOT provide an acceptably high success rate (Berg 2005, Gutgesell 1976 (LOE 4)) and higher dose defibrillation is NOT more dangerous (Rossano 2006 (LOE 4)). Whether these patients would benefit from a higher dose first shock, multiple or escalating dose subsequent shocks, or CPR has not been prospectively studied in children.

Please note, this question as phrased, “…does more than one shock IMPROVE outcome…” looks for sequential or stacked shock strategies as beneficial. Studies supporting the current recommendation of single shock therefore are listed under “evidence OPPOSING clinical question”.

**Acknowledgements**: The author would like to thank Dr. Bob Berg for 16 years of counsel, advice, encouragement, and friendship.
Citation List

LOE 5, opposing, poor quality, Adult Human. A retrospective review of survival from VF in King County, Washington over a 30 year period encompassing several changes, one of which was going from a sequential shock approach to a single shock followed by 2 minutes of CPR. Improved survival during the period where sequential shocks were discontinued suggests a single shock approach is superior, likely through more provision of CPR.

LOE 4, Supporting, Poor quality. Pediatric human. Observational study of OOH fibrillatory cardiac arrest in children. Primary finding is that 2 J/kg is effective in terminating VF in only ~50%. This small series would call into question the 2 J/kg defibrillation dose for children, but may also cast doubt on a recommendation of a single shock when that single shock is only effective in half of patients.

LOE 5, opposing, good quality, Animal. This swine study demonstrated the effectiveness of an escalating sequential defibrillation strategy using energy-attenuated biphasic waveforms from an adult defibrillator compared to a weight based monophasic strategy. Animals in 1 weight subcategory had less post-resuscitation myocardial dysfunction in the biphasic group.

LOE 5, opposing, good quality, Animal. This swine study associates the failure to achieve threshold coronary perfusion pressures or ETCO2 with a second or third shock using a manual defibrillator. It supports the single shock strategy based on the delays associated with sequential shocks.

LOE 5, Neutral, poor quality, Adult human. This study in adults reveals a distinct difference in first shock success (monophasic) in patients with OOHCA versus in-hospital arrest. Success in OOHCA with 1 shock was less likely than in IHCA. Additionally, death was more common in patients receiving higher energy shocks than low energy defibrillation.

LOE 5, supporting, fair quality, Adult Human. A prospective study in adults examining changes transthoracic impedance (TTI) during elective biphasic cardioversion. TTI falls with sequential shocks giving some support to a sequential shock approach although defibrillator waveform compensation for these changes may likely negate the effect of reduced impedance on defibrillation success.

LOE 5, opposing, good quality, Human. A prospective validation of a prediction model for defibrillation success in VF OOHCA. This confirms that interruptions in chest compressions, likely present in a stacked shock scenario, decrease the likelihood of successful defibrillation.

LOE 5, opposing, good quality, Animal. This rat study examined the effects of multiple defibrillatory shocks to an isolated heart preparation. After induced VF, 3 groups received either 0, 6 or 12 shocks. Left ventricular systolic function was
preserved in all three groups, but diastolic dysfunction (elevated diastolic pressures) were observed in the hearts that received multiple defibrillations (the 12 shock group). This is indirect evidence to the risk of multiple shocks from a cardiac function or myocardial injury standpoint.

LOE 4, opposing, fair quality, Pediatric human. This study forms the basis for a 2 J/kg defibrillation dose recommendation in pediatrics, with a first shock success rate (monophasic) of 89%. Of note, these are children with in-hospital arrest (likely brief duration VF, or at least VF of shorter duration than out-of-hospital arrest).

LOE 5, opposing, fair quality, Adult Human. This observational study examines factors associated with a failure of first shock success; these include unwitnessed arrest, prolonged downtime and absence of bystander CPR. Of note, the second shock failure rate was 99% which would speak to the futility of stacked shocks.

LOE 5, opposing, good quality, Adult human. This is another study comparing biphasic to monophasic defibrillation. However, unlike Morrison 2003, this is in patients with induced VF in a catheterization lab (short duration VF). Here the first shock success rate was 99% with 120J biphasic versus 93% of monophasic shocks. This difference between OOHCA and in-hospital CA first shock success speaks to the concepts of VF evolution over time (Weisfeldt et al 3 phase model) and would lend support to a bifurcated recommendation. Single shock strategy for presumed short duration (<4 minutes?) VF and a sequential (escalating biphasic preferably) for longer duration OOHCA.

LOE 5, neutral, good quality. Adult human. This study compares biphasic (RLB) with monophasic (MDS) in OOHCA in those patients treated with advanced life support (versus BLS first responders). First shock success (120J for RLB, 200J for MDS) did not reach a statistically significant difference, 23% in the RLB group 12% for MDS. In an escalating energy subsequent shock series, RLB waveforms were superior for termination of VF (52% vs. 34%). This relatively poor first shock success would contradict a single shock approach for OOHCA.

LOE 5, opposing, good quality, Animal. This study in swine demonstrates no decrease in thoracic impedance after sequential shocks. This would refute a belief in the benefit of sequential defibrillatory shocks to decrease impedance and therefore increase myocardial current.

LOE 5, opposing, fair quality, Adult human. This study examined the effect on survival to hospital discharge of patients with OOHCA who were treated with a single shock strategy compared with the historical control who had a sequential (stacked shock) resuscitation. Survival was significantly greater in the single shock group and corresponded to a shorter time from defibrillation to chest compressions.

LOE 5, opposing, poor quality, Adult human. This observational study of AED use in OOHCA evaluates the utility of rhythm reanalyses and pulse checks after a single or series of shocks (stacked). This is important in understanding
sources of delay in CPR. Of note, the first shock success in termination of VF in this study was 83.6%, supporting a first shock strategy in OOHCA.

LOE 4, neutral, good quality, Pediatric Human. A chart review study of patients who received defibrillatory shock(s) for VF in OOHCA. This supports three propositions: 1) children are often defibrillated with greater than the recommended 2J/kg dose, 2) a single defibrillation is most often not effective, 3) survival is unrelated to energy dose. This would generally support an approach of a higher initial defibrillation dose.

LOE 5, supporting, good quality. Adult human. This study was primarily designed to assess two strategies of Biphasic defibrillation in OOH adult fibrillatory cardiac arrest. There was no difference between the lower dose strategy 150-150-150J or the higher dose escalating strategy 200-300-360J with respect to first shock success. In patients who required multiple shocks, there was a greater conversion of VF to an organized rhythm and greater termination of VF for patients in the higher dose, escalating group. In answer to the question of this worksheet, for the narrow subset of patients requiring more than one defibrillation attempt, this paper supports the use of escalating doses if extrapolated to children.

LOE 5, opposing, good quality, Animal. This swine study of AED defibrillation confirms the effectiveness of a single shock strategy versus sequential shocks on ROSC through reduced CPR interruption.

LOE 5, opposing, good quality, Adult human. This study is a comparison of monophasic (MDS) vs. biphasic (BTE) defibrillation in OOHCA. Using 200J in both, there was successful termination of VF with return of an organized rhythm in 69% with BTE vs. 45% with MDS. This refutes the utility of a stacked shock protocol in OOHCA.

LOE 5, opposing, good quality, Animal. This swine study confirms that longer CPR delays are seen when sequential shocks from an AED are used and that these delays impair achievement of a threshold coronary perfusion pressure, worsen outcome (ROSC) and worsen post-resuscitation myocardial dysfunction when compared to a single shock strategy.