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

**Worksheet author(s)**
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(JOINT WORKSHEET)  
**Date Submitted for review:** January 4, 2010

**Clinical question.**
“In adult cardiac arrest (prehospital [OHCA], in-hospital [IHCA]) (P), does the use of any specific composition of conductive material (I) compared with standard conductive material (C), improve transthoracic impedance (O)?”

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

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

**Conflict of interest specific to this question**
Do any of the authors listed above have conflict of interest disclosures relevant to this worksheet? **No for both Drajer and Kerber**

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

**DRAJER:** Several search strategies were used for each data base. Only those with maximal hits were considered
- Embase “defibrillation” AND “pads” AND “impedance” as text words (all fields): 31 hits
- Embase “defibrillation” AND “pads” AND [<1966-2010]/py: 85 hits
- PubMed “defibrillation” AND “electrode pads” as text words (all fields): 52 hits  
  - 55 hits
- Scirus for Scientific Information: “Defibrillation gel composition and thoracic impedance”: 21 hits
- Lilacs (“desfibrilación” AND “electrodos”) 0 hits
- Google Scholar (“defibrillation; pads composition; thoracic impedance”) 187 hits

**KERBER:** A PubMed Mesh search was conducted in 2008 using the following search terms: heart arrest or cardiopulmonary resuscitation or electric countershock or transthoracic resistance or transthoracic impedance and gel or paste. This resulted in 56 hits of which 13 items were selected for further review. An Embase search was conducted using the terms heart arrest and defibrillation and electrodes and impedance. This resulted in 6 additional items of which 2 were selected for further review. I then re-performed the Embase search just using the terms defibrillation and impedance. This resulted in 166 hits of which 5 were selected. An AHA EndNote search was conducted using the terms defibrillation and electrode and impedance; 110 items were identified, of which 2 were identified for further review. In addition I searched my extensive personal files (over 1,000 articles on defibrillation, transthoracic impedance, electrodes, cardioversion and resuscitation). Reference lists of all articles cited were searched for additional articles. These searches were re-run in August 2009, using the same search terms, but confining the searches to articles published in 2008-2009 – 41 hits resulted from these repeated searches. Eight (8) articles were initially identified for further review, but none were deemed relevant as they lacked comparisons of the conductive materials.

**State inclusion and exclusion criteria**

Included articles were peer-reviewed, primarily clinical, but several exceptionally relevant animal, in vitro, and modeling studies were also included. Inclusion criteria were that the articles were relevant to the hypothesis. Abstract-only articles, non-peer reviewed articles, and articles on implantable defibrillators were excluded.

**Number of articles/sources meeting criteria for further review:** 20 articles were deemed relevant and are reviewed in this worksheet.
### Summary of evidence

#### Evidence Supporting Clinical Question

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#### Evidence Neutral to Clinical Question

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<td>Atkins 2004, 66 E</td>
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<td>Berg 2003, 189 E</td>
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#### 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

No opposing evidence was found.
### REVIEWER’S FINAL COMMENTS AND ASSESSMENT OF BENEFIT / RISK:

**DRAJER COMMENTS:**
Studies comparing different type of defibrillation electrodes composition are scarce, especially in the last years where interest has switched to defibrillation waveforms and/or electronic impedance compensation. There are a lot more papers dealing with size, position, skin preparation, pads humidity and even pressure to be applied to paddles than with pads composition. Those papers were not considered for this revision, except when they deal with some aspects of interface materials intended to improve conductance. A similar lack of papers was noted five years ago by Baubin in his ILCOR 2005 worksheet (W73) on the same subject. It must also be considered that up to year 2000, the defibrillation waveform in use was monophasic and from then on biphasic forms of several types were used. Classic works have shown the importance of high concentrated saline and different pastes on improvement of conduction but there are no papers since with a comparison of different electrodes composition and thoracic impedance.

**KERBER COMMENTS:**
Of the 20 relevant papers which were reviewed, 14 supported the hypothesis that the composition of the conductive material defibrillation electrodes/paste lowers the transthoracic impedance. Note that none of these papers dealt with patients undergoing cardiac arrest, and in all of papers the outcomes assessed were (E) – i.e., other than ROSC, survival, etc. This is to be expected, since the hypothesis concerned transthoracic impedance.

The waveforms used in the studies identified by Kerber varied: 6 studies used damped sinusoidal monophasic waveforms, 3 used biphasic truncated exponential waveforms. One study used both. One experimental study did not specify the waveform. Three studies measured impedance in humans, but did not deliver actual shocks.

I interpreted “composition” to include the nature of the material in different types of couplants and pads, as well as the distribution of the couplant material within the electrode itself. No papers presented evidence opposed to the hypothesis, and the 4 neutral ones did not concentrate on impedance per se. Most of the relevant literature dates from the 1980’s and 1990’s when the clinical focus was on transthoracic impedance. At the time it seemed intuitive that lowering impedance would result in higher current flow, which in turn should be beneficial for defibrillation. However, even some of the earlier literature – generally animal studies - found that despite different coupling agents yielding different TTI, defibrillation success was not necessarily improved by lower transthoracic impedance (e.g., Aylward et al., JACC 1985, 682). More recently, clinical studies on this point have appeared and have reached the same conclusion – that when using the biphasic waveforms that have replaced the old monophasic waveforms, TTI differences may still exist, but do not seem to alter defibrillation success or other outcomes (White et al., Resuscitation 2005;64:63-69).

**Benefit/Risk:** Since lower (“improved”) TTI does not appear to directly alter defibrillation success, ROSC or survival, there is no clear benefit obtained by choosing couplants or pads with lower transthoracic impedance. Conversely, higher transthoracic impedance does not clearly increase risk to the patient.

With the increasing use of AED self-adhesive pads, which are steadily displacing the old hand-held metal paddles, the selection of electrode types and couplants will now largely consist of commercially available pad products; impedance differences do exist between such pads but the focus should be on ease and rapidity of electrode pad application in clinical use.

Recent clinical reports (not reviewed in detail in this worksheet) have focused on ROSC and survival, and have concluded that when using biphasic waveforms, transthoracic impedance does not affect defibrillation success, ROSC or survival. “Rapid defibrillation rather than differences in patient impedance accounts for resuscitation success” (White et al., Resuscitation, 2005).

**Acknowledgements:**

**DRAJER:** To María de las Mercedes Di Stéfano and Mariela V. Romano, librarians of the Argentine Society of Cardiology for their invaluable help.

**KERBER:** I thank Tanya Semenko for continuing assistance in navigating the formidable worksheet process, Andrew Pretorius, BS, for help with the searches, and Diane Phillips for always-expert secretarial assistance.
DRAJER CITATION LIST:

Andersen C, Larsen B. [A comparative study of contact media for defibrillation] [Article in Danish] Ugeskr Laeger. 1989; 151(31):1987-8. A comparison was made between two brands of self-adhesive electrodes (Litmann and Nikman) and a common electrode gel. No significant differences were found regarding transthoracic impedance. Although it is not known the specific composition of both examined electrodes, in this case it can be concluded that regarding impedance, gel composition does not matter.

Connel PL, Ewy GA, Dahl CF, Ewy D. Transthoracic impedance to defibrillator discharge. Effect of electrode size and electrode-chest wall interface. J Electrocardiology 1973; 6 (4): 313-7. “Transthoracic impedance of man to direct current defibrillator discharge has been reported to vary from 27 to 110 ohm. This study was designed to determine the effect of paddle electrode size and paddles electrode-chest interface on thoracic impedance”. Sixteen mongrel dogs submitted to DC shocks with different size paddles (diameters of 4.5; 8.0 and 12.8 cm), bare metal, covered with soaked-in- saline gauze, covered with conductive cream or with conductive paste. This historical paper shows the inverse relationship between paddle size and transthoracic impedance and the importance of interface material composition depicting that bare metal-chest contact showed the highest impedance and paste the lowest, being saline and cream with close intermediate values regardless of the electrode size.

Dalzell GW, Cunningham SR, Anderson J, Adgey AA. Electrode pad size, transthoracic impedance and success of external ventricular defibrillation. Am J Cardiol. 1989; 64(12):741-4. “The relationship between external electrode size and transthoracic impedance was analyzed. One hundred and five patients with 123 VF episodes were included. Three types of electrodes were used: small (8/8 cm), intermediate (8/12 cm) and large (12/12 cm). Transthoracic impedance decreased with an increase in pad size (112 +/- 17 vs. 92 +/- 22 vs. 72 +/- 14 ohms respectively, p = 0.0001)”. Although it is not a paper dealing with the intrinsic composition of pads, it stresses the importance of size in obtaining the minimal attainable impedance.

Das DP, Webster JG. Defibrillation Recovery Curves for Different Electrode Materials. IEEE Trans Biomed Eng. 1980; 27(4):230-3. “Sixteen electrode materials were tested for their electrical characteristics and normalized all results to a 1 cm2 area. The electrode pair impedance versus frequency from 5 to 2000 Hz ranged from 20 to 58 000 ohm. It was passed 2 mC through them in less than 5 ms to simulate defibrillation discharge. The resulting recovery curves showed voltage offsets after 5 s of from 300 to 800 mV”. The test was repeated for commercial and own made Ag-AgCl electrodes electroplated with different charges (5 to 2000 mC). The value of this paper is the “in vitro” evaluation of the electrical characteristics of electrodes and the description of a model to test them.

Fumagalli S, Boni N, Padeletti M, Gori F, Boncinelli L, Valoti P, Baldasseroni S, Di Bari M, Masotti G, Padeletti L, Barold S, Marchionni N. Determinants of thoracic electrical impedance in external electrical cardioversion of atrial fibrillation. Am J Cardiol 2006; 98:82-7. “At multivariate linear regression analysis (R = 0.761, p <0.001), female gender (+9.7 +/- 2.0 Omega, p <0.001), body mass index (+1.5 +/- 0.3 for a 1 kg/m(2) increase, p <0.001), hemoglobin concentration (+1.9 +/- 0.6 for a 1 g/dl increase, p = 0.004), and the presence of chronic heart failure (-5.3 +/- 2.0 Omega, p = 0.009) were independent predictors of thoracic electrical impedance. In conclusion, to increase ECV efficacy and minimize complications, the delivered energy should be adjusted in accordance with the clinical variables that independently affect thoracic electrical impedance and, hence, transmyocardial current”. This paper is a good study of several determinants influencing thoracic impedance during external defibrillation of atrial fibrillation in humans with multipulse biowave discharge, but does not define the type of electrodes used neither its composition.

Meyer PF, Gadsby PD, Van Sickle D, Schoenlein WE, Foster KS, Graber GP. Impedance-gradient electrode reduces skin irritation induced by transthoracic defibrillation. Med Biol Eng Comput 2005; 43: 225-9. “A new type of disposable external defibrillation electrode has been developed to reduce the skin irritation commonly associated with defibrillation and synchronized cardioversion. This design employs an impedance gradient to reduce the proportion of current delivered to the electrode periphery”. Thermography readings over the shocked skin of pigs “showed a 50-60% less skin heating and a 44-46% less skin damage than two of the three uniform-impedance electrode designs”. Comparisons were made over five different brands of disposable adhesive electrodes (three tin/stannous chloride and two silver/silver chloride type). From the last two types, one had a stepped impedance increase along its border and the other one a special vinyl matrix intended to diminish the current delivered to the periphery in order to avoid skin burns
produced by the so called “edge-effect”. Both “conductance-modulated” electrodes produce less thermal injury to the animal’s skin as proven by thermography and biopsies.

Razumov KV, Vostrikov VA, Kholin PV. [Optimisation of electroimpulse therapy of life threatening arrhythmia in patients with ischemic heart disease] [Article in Russian]. Anesteziol Reanimatol. 2003 Nov-Dec;(6):45-7. Authors used standard 12 cm defibrillation paddles covered with gauze moistened in normal saline or 7% hypertonic NaCl solution (HS) to revert atrial or ventricular shockable arrhythmias in 230 patients. HS was shown to bring about a TTI decrease by 21% (from 77.0 +/- 0.9 to 61.0 +/- 1.0 ohm) compared to saline. A very striking experiment stressing the importance of electrolyte composition of the conducting media to perform a safer defibrillation/cardioversion.

KERBER CITATION LIST


**Comment:** Level of evidence: 5 (case series). Quality: Good. Outcomes assessed: Resumption of spontaneous circulation, survival of event, discharge. (A,B,C). Biphasic truncated exponential waveform shocks (per Dr. Atkins; not specified in article).

This is a case series evaluating the results of use of pediatric attenuating defibrillation pads in out-of-hospital cardiac arrest. Twenty-seven patients age 0 days to 23 years (i.e., some were adults) were reported. All patients had termination of VF and were admitted to the hospital using these attenuation pads; 5 of the patients survived to discharge. TTI was reported in 4 patients varying from 42 to 113 Ohms, a range similar to previous reports in adults, hence this is neutral to the hypothesis. See also Krasteva, #9.


**Comment:** Level of evidence: 5 (animal study). Quality: Poor (no controls). Outcomes assessed: Transthoracic impedance. Damped sinusoidal waveform shocks.

This animal study assessed transthoracic impedance of three different electrode coupling agents – two commercially available couplant pads and one paste. The paste yielded lower TTI and higher currents than the pads, which supports the hypothesis. However, there was no difference in defibrillation success despite the TTI differences.


**Comment:** Level of evidence: 5 (Animal study). Quality: Fair. Outcomes assessed: Safety and efficacy of attenuated adult biphasic shocks with monophasic weight-based shocks. Neutral to hypothesis. Both biphasic truncated exponential and damped sinusoidal monophasic shocks used.

In piglets an escalating biphasic shock strategy was as safe and effective as a standard monophasic weight-based strategy. TTI was variable comparing attenuated versus standard pads, although it did vary by weight. This is neutral to the hypothesis.


TTI was measured in 9 hirsute and 11 non-hirsute patients before and after shaving the chest. TTI was higher in the hirsute patients compared to the non-hirsute; shaving reduced the TTI. Two different commercially-available self-adhesive electrodes were used. There were differences between the pads and TTI of both of these pads were higher than the TTIs of different self-adhesive pads previously reported by Kerber (1984) – which supports the hypothesis.

Hirsute subjects should have their chests shaved quickly if possible before defibrillation or cardioversion.


In 40 adult males, TTI was measured using commercially available self-adhesive pads versus hand-held paddles with a pad couplant. Differences in TTI were found between the commercially available pads, supporting the hypothesis.


This is a prospective study of 20 male volunteers assessing the effect on TTI of evaporative drying when water-based 3M pads (not self-adhesive pads) are placed between metal defibrillator pads and the skin. Rises in TTI occurred as pad mass decreased due to evaporative loss, which supports the hypothesis. The authors conclude that these specific pads can be safely left on the chest wall for at least 25 minutes before TTI increases.

Note that with widespread use of self-adhesive pads and the phasing out of hand-held metal paddles, the use of couplant pads of this type is disappearing.


This is a follow up study to Deakin et al. 2001; in this study pads were examined after actual shocks were given to 14 cardiac arrest and 12 elective cardioversion patients. TTI rose as evaporation occurred, which supports the hypothesis. The presence of defibrillation current did not cause a change in TTI.


This is an animal study where transthoracic impedance of disposable defibrillation electrodes were compared to the commercially available electrode paste (Redux paste, Hewlett-Packard). Damped sinusoidal monophasic waveform defibrillation was used. Shocks of 100 J and 400 J were administered. The impedance found with the disposable electrodes was significantly higher than that encountered with electrode paste which supports the hypothesis. The authors concluded that electrode paste applied to hand-held paddles were preferable to the particular electrode pads tested.


This in vitro study using damped sinusoid monophasic waveforms showed that impedance varies with various electrode gels studied, thus supporting the hypothesis. The authors concluded that commercially available electrode gels with high impedance are not suitable for use as the interface between paddle electrodes and chest wall.


In 80 patients defibrillated or cardioverted, self-adhesive electrode pads were found to be as effective as historical data from studies using standard hand-held paddles. TTI of self-adhesive pads were similar to TTI encountered in patients receiving shocks from hand-held paddles, thus this study is neutral to the hypothesis.

This is the first-published report showing that self-adhesive electrode pads were effective for defibrillation and cardioversion.


This modeling study assesses the effect of varying structural components of electrodes, i.e., distribution rather than composition of the electrodes. A high resistance perimeter ring (advocated by some to reduce defibrillator burns by achieving better current distribution) improves uniformity of current distribution without increasing the total resistance (impedance). Thus, this is neutral to the hypothesis. See also Atkins et al., #1.


*Comment:* Level of Evidence: 5. Quality: Good. Outcomes assessed: Voltage and current flow through gloved rescuers touching the chest of patients receiving biphasic shocks (E). Supports the hypothesis. Biphasic truncated exponential shocks given.
This is a case series of 43 patients undergoing elective cardioversion for atrial fibrillation or flutter or electrophysiology studies. Gloved rescuers simulating closed-chest massage applied 20 pounds of pressure to the chest of the patients while biphasic shocks were delivered. Rescuers were deliberately placed within the electrical circuit and leakage and voltage current passing through them was measured. The amount of leakage voltage and current was minimal and not painful. The impedance in the rescuer circuit was over 1,000 times the patient transthoracic impedance, due in part to the gloves the rescuers wore and in part due to the nonconductive backing on the self-adhesive pads – this supports the hypothesis.

The important conclusion is that it is unnecessary to interrupt closed-chest compressions during defibrillation if AED pads and gloves are used, since there is only minimal current flow through the rescuers and there should be no danger. This study should lead AHA to rethink its traditional admonition to “clear” the patient about to be defibrillated, providing AED pads (not hand-held paddles) are used and gloves worn. Minimizing compression interruptions enhance the quality of CPR.

**Article 13. Razumov KV, Vostrikov VA, Kholin PV. Optimisation of Electroimpulse Therapy of Life Threatening Arrhythmia in Patients with Ischemic Heart Disease.** Anesteziol Reanimatol. 2003 Nov-Dec;(6):45-47

*Comment:* In this study the authors compared the effect of gauze napkins moisturized with two different solutions as electrode contact material. The different solutions were normal saline versus hypertonic saline and the transthoracic impedance was shown to decrease when hypertonic saline was used. This supports the hypothesis. Biphasic truncated exponential waveform shocks given.


This is a prospective nonrandomized study of 28 patients receiving damped sine wave monophasic shocks from self-adhesive pads (R2 Corp.) for atrial arrhythmias. Ten normal subjects were the control group; they wore the pads for one hour but no shocks were given. Hand-held paddles coated with non-salt containing gels were also studied. The outcomes assessed was transthoracic impedance (TTI). The authors showed declines in TTI in both patients and normal subjects; the declines persisted longer (>24 hours) in the patients who actually received shocks. Salt-containing gels produced TTI declines, but non-salt-containing gels did not. Bare metal paddles without any gel coating were associated with very high TTIs. The authors concluded that TTI declines after shocks result in part from skin impregnation by salt-containing agents, which supports the hypothesis. If bare metal hand-held paddles are used, any couplant is preferable to no couplant at all.