

June 12, 1998 Minutes **Lightning Data Center** Centura Health St. Anthony Hospital

Quote of the Month:

"The best analysis of the work {Felix Mendelssohn's *First Walpurgis Night*} is still that written by Ernst Wolff in 1909...The first Allegro begins *con fuoco* with three incisive chords in the winds...A lightning-flash of a figure in F sharp major unleashes wild, elemental thunder which mounts to a *fortissimo assai*...A mighty F major chord tutti apparently concludes this passage of thunder, and harbingers of spring can be heard in the horns and bassoons."

Heinrich Eduard Jacob, 1961

1. Meeting began at 11:30 am and adjourned at 1:30 pm.
2. Members present: Cherington, Clark, Fisher, Hodge, Kamin, Kearm, Keen, Piper, Simmons, Svinarich, Swanson, Toler, T. Wachtel, Walker, Yarnell.
3. I brought the following articles:

a.) Veneman TF et al. Prediction of electrocution after resuscitation in a case of electrocution. *Intensive Care Med* 1998;24:255-7.

"Alternating current...is more dangerous than direct current. It causes tetanic cramps in skeletal muscle, which is susceptible to current frequencies between 15 and 150 Hz...With AC of 25-300 Hz, low voltages (<220V) tend to produce ventricular fibrillation, whereas high voltages generally produce respiratory failure. Current passing through the heart can induce ventricular fibrillation or asystole, and those through the brain can cause transient coma and death through apnoea...Prediction of outcome after resuscitation is usually based on neurological findings, compatible with anoxic encephalopathy. However...caution in predicting the outcome is necessary."

b.) Bassotti G, Fiorella S. Oesophageal pressure during an earthquake. *Lancet* 1998;351:806

"Stress can alter...oesophageal motility." The authors observed "the behaviour of the lower oesophageal sphincter during a natural stress {earthquake}." "On Oct 3, 1997, while doing a manometric examination in a 62 year old woman...in Umbria, Italy, there was an earthquake. The epicentre was...about 35 miles from the city, and the magnitude...was 5.2° on the Richer scale...Sphincter pressure immediately dropped from about 20 mm Hg to about 5 mm Hg...The effects of stress on the lower sphincter is to inhibit tone...might be due to a sudden increase in adrenergic activity, which has been suggested as one cause of the increased incidence of sudden cardiac deaths triggered by an earthquake."

c.) Eisenberg MS. Defibrillation: the spark of life. *Sci Amer* June 1998.

In 1947 Claude S. Beck, surgeon, was first to revive a patient using a defibrillator. "The goal of a defibrillatory shock is to jolt the heart into a momentary standstill...the cardiac muscle cells have the chance to resume work in an orderly sequence again...Most coronary deaths...from sudden cardiac arrest were triggered by ventricular fibrillation...65% of cardiac arrests. About 3% of arrests are caused

by ventricular tachycardia...and the remainder is the consequence of asystolic rhythm...At the instant of fibrillation, the heart pumps no blood, so the pulse ceases and the blood pressure falls to zero...electricity was (and remains) the only means for treating ventricular fibrillation...Defibrillators could be powered by direct current..DC machines are safer because there were fewer postshock complications such as heart blocks..DC allowed relatively portable batteries to power the device and used capacitors for collecting and concentrating the charge...'Smart' defibrillators interpret the patient's rhythm and will deliver a shock only if ventricular fibrillation is present."

4. Steve Marshburn, President & Founder LS&ESSI, Inc. wrote a note about the discussion in the May minutes of what to do if lightning is 6 to 8 miles away. Steve pointed out that he "was struck 'inside' the bank where he was employed. It was a sunny day. The storm was 10 miles up the Atlantic Coast. The bolt hit the drive-up window, came through the ungrounded speaker."
5. Ken Langford sent to us via fax a summary of his "Whereabouts During LDC Meetings." His itinerary (that included a speech to the Denver-Boulder chapter of American Meteorological Society on May 7) was distributed to the members. His busy schedule has kept him away from recent meetings. He ended his message with the following comments: "I regret missing so many LDC meetings. They have been a joyful part of my life...I am very grateful to receive the minutes. Wishing everyone at LDC the best!" Ken, thanks for your kind remarks. All of us miss your presence at the recent meetings and hope that you will be able to attend them in the near future.
6. Mike Piper, EMS Field Facilitator of our Emergency Department spoke to the group about ventricular fibrillation and the use of portable defibrillators. He said that there is a 3 minute early response time to reach a patient with ventricular fibrillation. The defibrillator that he brought would not provide a shock if it detects movement artefacts.

Mike, along with David Kearns and Tom Svinarich, lead a discussion about out-of-hospital-cardiac arrest cases, including lightning cases. If the portable defibrillator detects ventricular fibrillation, the machine instructs the operator to deliver the shock. If the patient is in asystole, one should give CPR for 1 minute and check cardiac rhythm. If asystole follows ventricular fibrillation, the clinical prognosis is very poor. We all appreciated Mike's very informative presentation.

7. Thomas Svinarich, MD gave us a presentation about Ventricular Fibrillation, Cardiac Physiology, and Lightning. Tom obtained his degree in electrical engineering at Carnegie-Mellon University; his medical degree at Ohio State University; his residency at Lederman. I shall make no attempt to summarize his excellent presentation here. His outline on handouts are included with these minutes.

I shall mention several clinical points were made by either Tom or others during the discussions. If there is no perfusion of organs because of ventricular fibrillation, brain death occurs before other tissues. Cardiac muscle cell death occurs shortly after brain death. Cardiac depolarization coincides closely with QRS; repolarization coincides closely with the T-wave. The vulnerable period to electrical current is just prior to the T-wave. There is a dispersion of refractoriness at the time. Lightning-related cardiac arrest may be the consequence of 2 events: a.) current injury to cardiac muscle resulting in arrhythmias; b.) increase

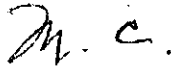
in circulating catecholamines resulting in arrhythmias. Phil Yarnell observed that in our experience, cardiac arrest was more often the primary injury leading to brain damage rather than primary brain damage.

8. Rich Keen distributed Rocky Mountain Seminars (sponsored by Rocky Mountain National Park) for 1998. Rich's seminar will be given on August 14-16. The title is: Weather, Climate & Stars.
9. The June 13, 1998 issue of *The Lancet* contains the following Research Letter: Could lightning injury be magnetically induced? by Cherington, H Wachtel, and Yarnell.
10. These minutes reflect the wide ranging, lively comments of the member present. They do not represent stated positions of LDC.
11. **Please note that the next meeting will be held on the 3rd Friday of July** instead of the usual 2nd Friday. The meeting will be at 11:30 am in the Main Auditorium of Centura Health - St. Anthony Central on

**JULY 17, 1998.**

**Dr. Mary Ann Cooper** of the University of Illinois at Chicago will speak to us about her lightning research projects.

Respectfully submitted,

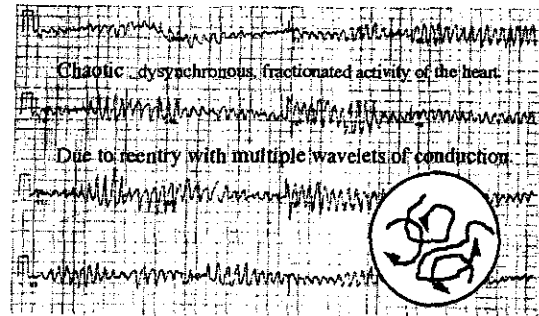


Michael Cherington, MD  
Chair, Scientific Committee, LDC

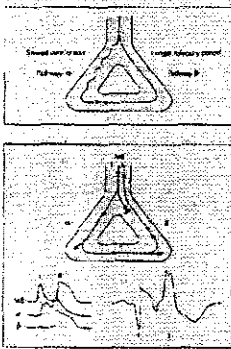
# Ventricular Fibrillation

Mechanisms and relationship to lightning strikes

# Ventricular Fibrillation



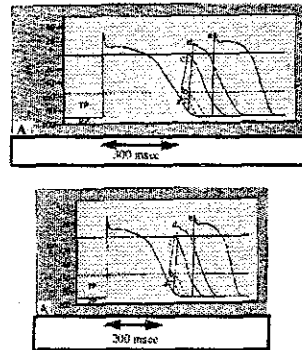
## Reentry



Unidirectional Block occurs when tissues have differences in refractory periods.

Dispersion of refractoriness promotes reentry.

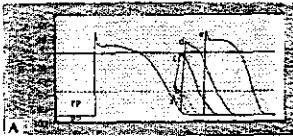
## Refractory Period



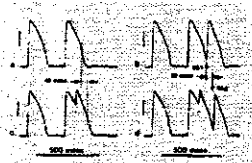
Action potential duration is the primary determinant of refractory period.

- APD altered by:
- ischemia
  - infarction
  - drugs, electrolytes
  - abn of ion channel expression
  - graded depolarizations

## Graded depolarization versus normal depolarization

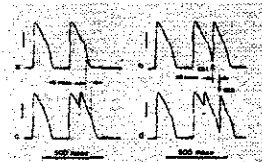


Partially depolarized cells have partially inactivated Na channels and fully depolarized cells have completely inactivated Na channels and are refractory to physiologic stimuli



Strong shock (10-20 V/cm) during absolute refractory period can result in rapid reactivation of Na current

## Graded depolarization



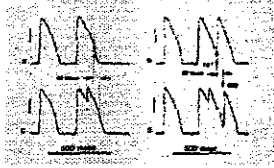
Can initiate arrhythmia.

Does not propagate actively but can depolarize tissue at a distance initiating a wavefront

Prolongs refractoriness locally allowing unidirectional block

When dispersion of refractoriness is sufficient multiple wavelets may be created and if reentry is sustained result in VF

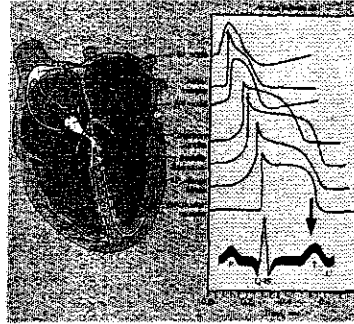
### Graded Depolarization



#### Can terminate VF

Synchronize myocardial activation by depolarizing excitable and refractory tissue  
 Prevent propagation by homogeneously increasing refractoriness

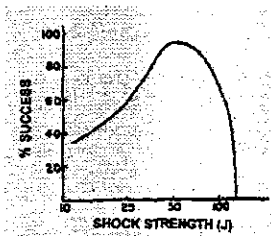
### Vulnerable Period



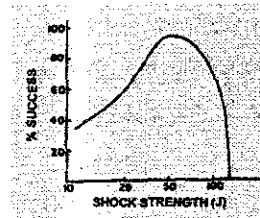
stimulation of heart just before peak of T wave gives highest probability of inducing VF

some myocardial cells are recovering excitability and some are still refractory, maximum dispersion of refractoriness

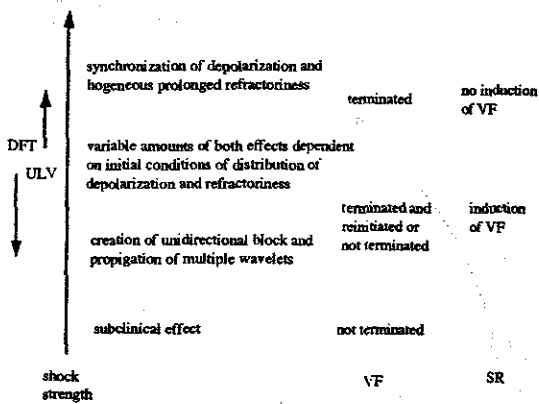
### Defibrillation threshold is a probability function



### Fibrillation induction with shock during vulnerable period demonstrates probability function and upper limit of vulnerability ULV



ULV and DFT are related implying physiologic relationship between fibrillation induction and termination



### Other determinants of DFT/ULV

- electrode positioning
- anatomic variables
- cardiac disease
- drug therapy
- Shock Waveform monophasic/ biphasic

## Described Cardiovascular effects of lightning strikes

- myocardial heat injury resulting in ECG changes, arrhythmia or congestive heart failure
- adrenal stimulation and catecholamine release resulting in hypertension, tachycardia, arrhythmia in susceptible individuals

How can VF occur in the absence of direct hit, side splash, or ground strike leading to direct myocardial injury?

Predictions of myocardial voltage gradients induced by internal shocks, external shocks, and AC EM sources have been attempted

Fields of 10-20 V/cm have been modeled with transvenous and transthoracic DC defibrillation in pigs taking into account electrode position, impedance of various tissues, and thoracic shape and anatomy on CT scan

Fields of 5 V/cm shown to prolong refractoriness of depolarized tissue and may induce VF during vulnerable period?

EM sources of 550-1400 kV/m at 60 Hz suspected to be sufficient to cause VF in a spherical chest model

## Near lightning strike and VF

If a near lightning strike is able to induce transmural voltage gradients in a range that is sufficient to depolarize fully refractory myocardium, but is below the ULV, and occurs during the vulnerable period, VF can be produced.

A near lightning strike that induces voltage gradients that are lower or higher (above ULV), or which does not occur during the vulnerable period will not induce VF.

A model describing the myocardial voltage gradient induced by a near lightning strike should be created as a first test of this hypothesis.