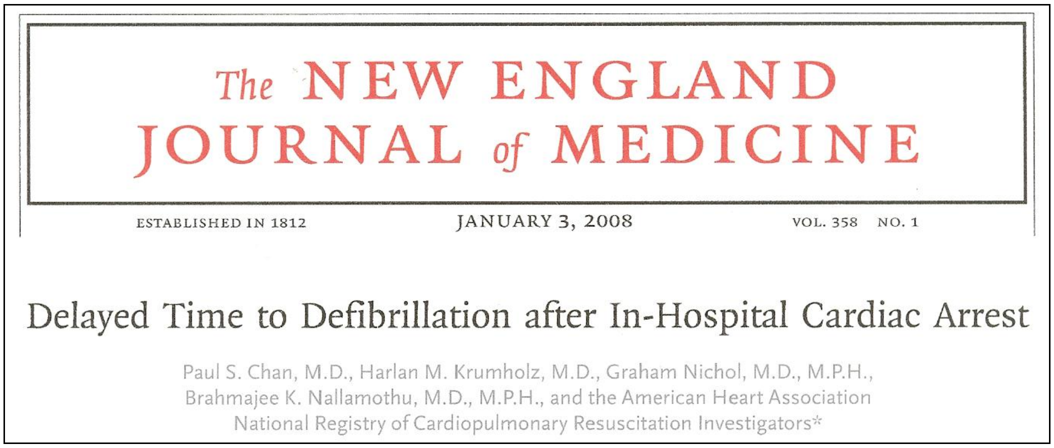
TIME WILL TELL: EARLY DEFIBRILLATION IN THE HOSPITAL

By Judy Boehm, RN, MSN

Part I

An article published January 3rd in the *New England Journal of Medicine* caught the attention of the media.[1] Chan et al. reported on "Delayed Time to Defibrillation after In-hospital Cardiac Arrest", using data from the National Registry of Cardiopulmonary Resuscitation (NRCPR).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Delayed Time to Defibrillation after In-Hospital Cardiac Arrest

Paul S. Chan, M.D., Harlan M. Krumholz, M.D., Graham Nichol, M.D., M.P.H., Brahmajee K. Nallamothu, M.D., M.P.H., and the American Heart Association National Registry of Cardiopulmonary Resuscitation Investigators*

Their conclusions were that 1) delayed defibrillation (longer than 2 minutes after arrest is reported) is common in hospital arrests, and 2) delayed defibrillation is associated with lower rates of survival. Are you surprised at these findings? I am not surprised and could reach the same conclusions based on my experience as a cardiac nurse specialist in a major tertiary care institution. In this March newsletter I will describe the findings of this study, review the public's response to the study, explore what we know about the science of ventricular fibrillation (VF) and defibrillation, and give a brief overview of hospital arrests in general from the NRCPR data – the background information. In next month's newsletter I will describe factors that influence the success of defibrillation and end with ideas on how we can change care and technology to improve time to defibrillation in the hospital.

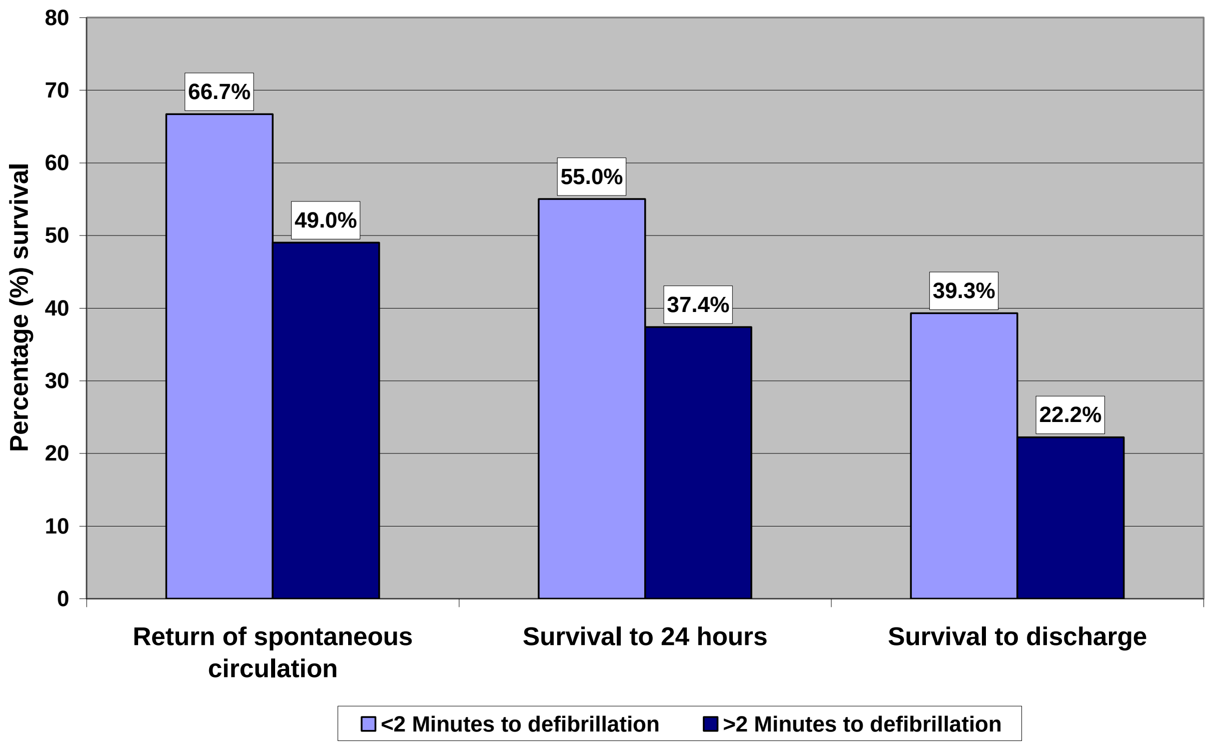
Delayed Time to Defibrillation after In-hospital Arrest

NRCPR
National Registry of CPR

The NRCPR is a multicenter registry of in-hospital cardiac arrests that is sponsored by the American Heart Association (AHA) and managed by Digital Innovation, Inc. Standardized definitions that are used for data collection arise from the AHA Scientific Statement "Recommended guidelines for reviewing, reporting, and conducting research on in-hospital resuscitation: the in-hospital 'Utstein style'."[2] Since the NRCPR began in 2000, more than 120,000 cardiopulmonary resuscitation events have been entered by over 500 hospitals in the U.S., Canada, Germany, Japan, and Brazil. The NRCPR data has been helpful to assess processes of care and outcomes during in-hospital cardiac arrest, defined as cessation of cardiac mechanical activity that is determined by the absence of a palpable central pulse, apnea, and unresponsiveness. The time to defibrillation is calculated from the reported time of recognition of the arrest to the reported time of the first attempted defibrillation.

Chan's report investigated 6789 VF/pulseless ventricular tachycardia (VT) adult cardiac arrests from January 1, 2000 through July 31, 2005 from 369 acute care hospitals. Data was excluded for other than the original arrest, patients with implanted cardioverter defibrillators (ICDs), those receiving intravenous infusions of epinephrine and antiarrhythmics, and those with missing time data or inconsistent times. Cases were included only from the intensive care units (ICUs) and inpatient units. Overall, the median time to defibrillation was reported as 1 minute. The time to defibrillation was delayed (defined in their study as >2 minutes) in 30.1% of the cases. Figure 1 shows that all survival outcomes were significantly lower in those who received delayed defibrillation (p<0.001 for all survival outcomes). Note that when defibrillation was delayed, only 22.2% of patients survived long enough to be discharged from the hospital, as opposed to 39.3% when the shock was given earlier.

Figure 1 Survival Outcomes Related to Time To Defibrillation (Chan)



It can be seen in Figures 2 and 3 that among the survivors, neurologic outcomes (p=0.02) and functional outcomes (p=0.02) were poorer in those who received delayed defibrillation.

Figure 2 Neurologic Outcomes Related to Time to Defibrillation (Chan)

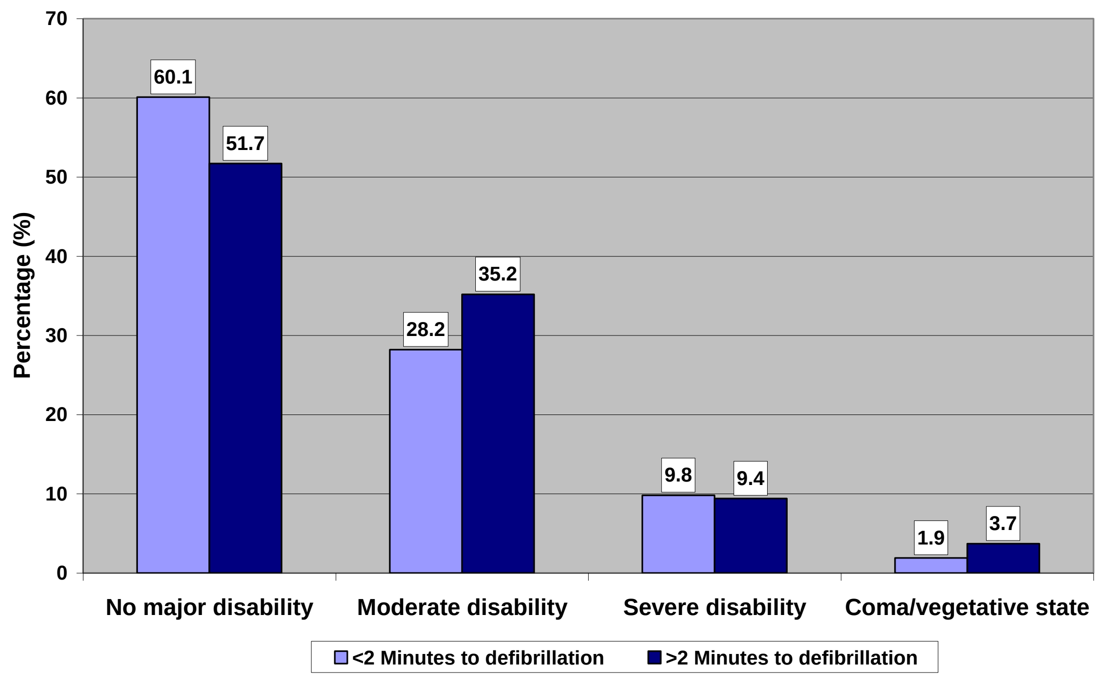
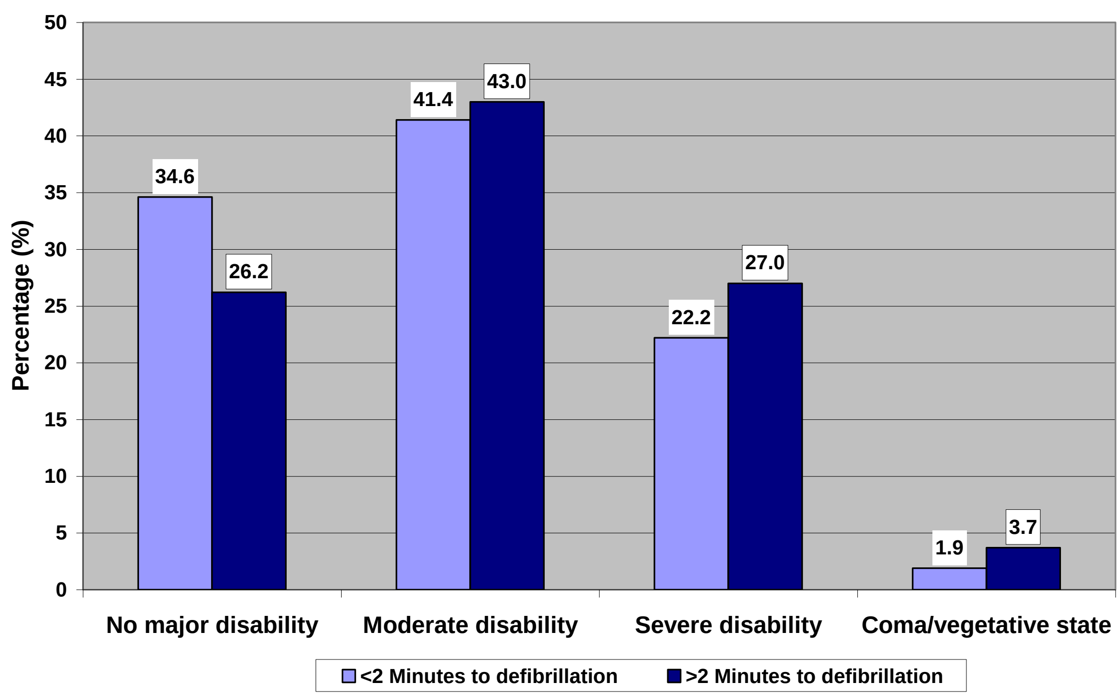
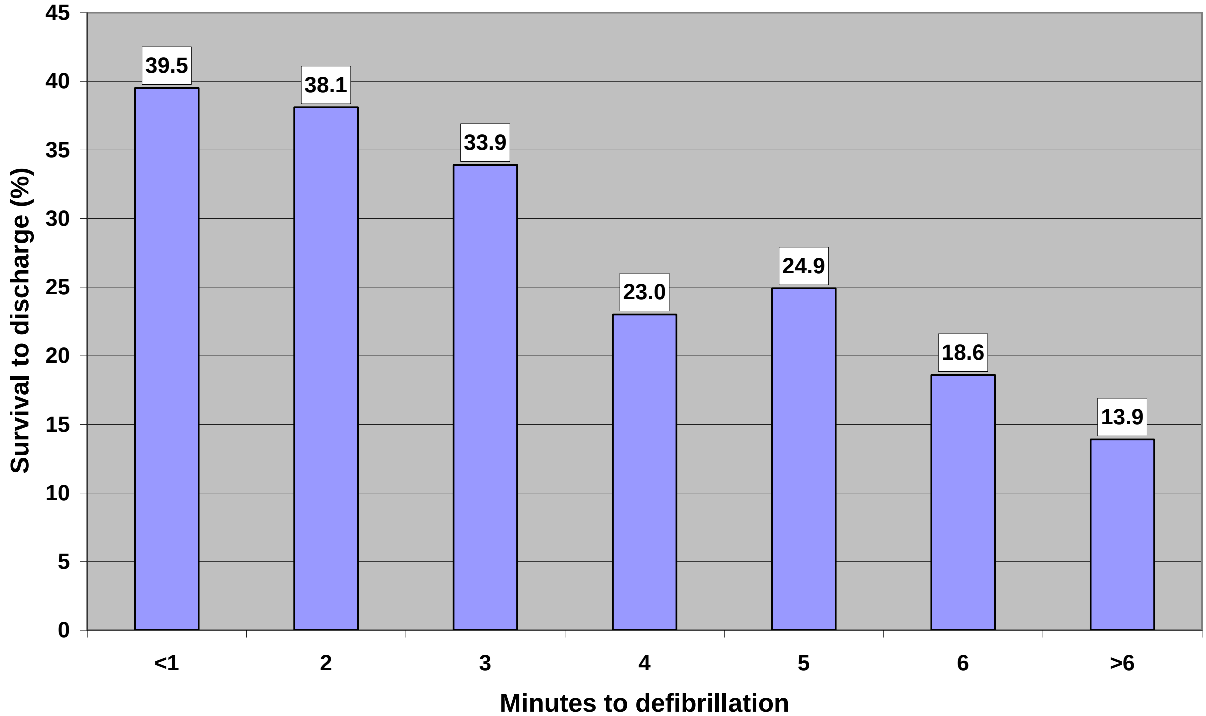


Figure 3 Functional Outcomes Related to Time to Defibrillation (Chan)



It was also found that there was a graded inverse association between survival and longer times to defibrillation (p for trend <0.001); see Figure 4. Thus, time does tell the story related to defibrillation success.

Figure 4 Survival to Discharge Related to Time to Defibrillation (Chan)



Several factors were found associated with delayed time to defibrillation in multivariate analysis:

- Black vs. white race (p=0.009)
- After hours cardiac arrest (p=0.005)
- Unmonitored inpatient hospital bed compared to ICU or telemetry (p<0.001)
- Hospital with <250 beds (p=0.001)
- Non cardiac admitting diagnosis (p<0.001)

There were several limitations with this study. First, although data available in the NRCPR allowed the authors to adjust for key variables that have been linked to survival after cardiac arrest, this study used an observational design, and there are variables that they did not or could not capture. Second, data on time to defibrillation relied on reported times of cardiac arrest and defibrillation from hospital records. The use of multiple clocks and the lack of synchronization between the timing of cardiac monitors and defibrillators within a hospital may lead to variability and discrepancies in calculating time to defibrillation. Also, time to defibrillation was recorded in whole minutes, and shorter intervals of less than one minute could not be assessed. Third, the results related to neurologic and functional status should be interpreted with caution, since these data were missing for 16% of patients surviving to discharge. Lastly, hospitals participating in NRCPR have systems of resuscitation care in place. Performance characteristics, quality of care, and survival outcomes may be different in nonparticipating hospitals.

Chan's study is unique in that it reports on only patients with VF/VT arrests and excludes those with ICDs and antiarrhythmics. Also, the study population is the largest ever recorded for a study of VF in the hospital.

Public Response to This Study

In an editorial that accompanies the above study, Leslie Saxon, MD, points out that physicians spend a lot of time devising strategies to improve survival for out-of-hospital cardiac arrests, but efforts should now be refocused on improving outcomes for hospitalized patients.[3] Approximately 225,000 out-of-hospital cardiac arrests occur annually in the United States. It is a little-known fact that at least double that number of cardiac arrests occur in hospitalized patients. "It is probably fair to say that most patients assume – unfortunately, incorrectly – that a hospital would be the best place to survive a cardiac arrest," she writes.

The public have heard that survival from out-of-hospital cardiac arrest has greatly increased where automated external defibrillators (AEDs) are readily available and used quickly. Valenzuela reported in 2000 a 53% survival to discharge from the hospital in the setting of U.S. casinos with security cameras when AEDs were used by security personnel.[4] The time interval from collapse to attachment of the AED in witnessed events was 3.5 $\pm$ 2.9 minutes, and the interval from collapse to delivery of the first defibrillation shock was 4.4 $\pm$ 2.9 minutes - compared to the interval from collapse to arrival of paramedics at 9.8 $\pm$ 4.3 minutes. The survival to hospital discharge rate was 74% for those who received their first defibrillation no later than 3 minutes after a witnessed collapse and 49% for those who received their first defibrillation after more than 3 minutes.

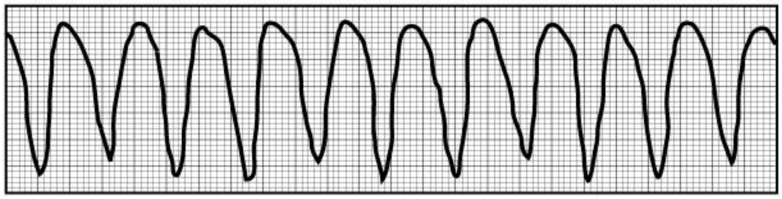
American Airlines began equipping its aircraft with AEDs starting in 1997. In the same 2000 issue of *New England Journal of Medicine*, data was reported on all 200 instances (191 on aircraft and 9 in the terminal) in which AEDs were used up until July 15, 1999.[5] Of those for whom an AED was used, 99 persons had loss of consciousness and a shock was advised in the 14 patients with VF. The first shock successfully defibrillated the heart in 13 patients, and in one patient the shock was withheld upon family request. The rate of survival to discharge from the hospital after shock with the AED was 40%, all with intact neurologic function.

After hearing about these remarkable results with the use of AEDs in the out-of-hospital setting, the public response was amazement to learn from Chan's article that only 34.1% of patients experiencing cardiac arrest in the hospital survived to discharge. Yes, the hospital cohort has been admitted with medical problems, but can't we do better in a setting where competent practitioners and emergency equipment are readily available for medical emergencies? How can 1/3 of hospitalized patients with VF/VT arrests have a shock delivered later than 2 minutes? The New York Times stated that "in the real world, doctors and nurses do not always run fast enough."[6] Dr. Saxon, speaking on her cell phone to the New York Times correspondent, said "You're better off having your arrest at Nordstrom, where I'm standing right now, because there are 15 people around me."

The Science of Ventricular Fibrillation and Defibrillation

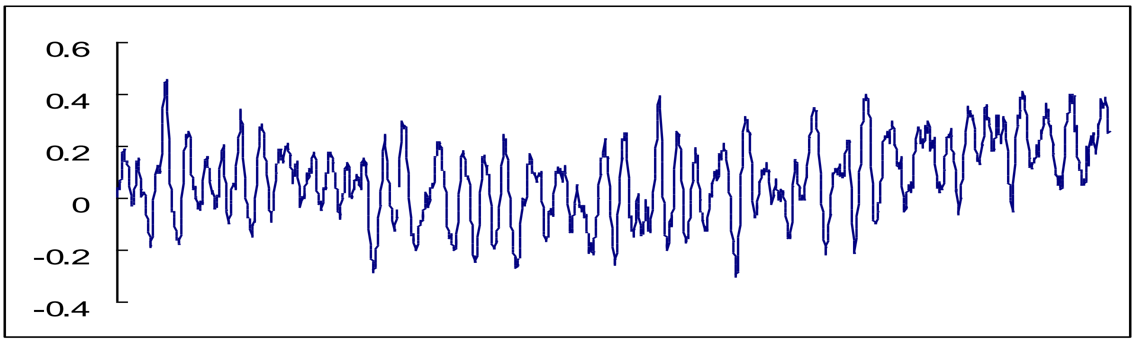
At the onset of a VF cardiac arrest, QRS complexes are regular, widened, and of tall amplitude, suggesting a more organized ventricular tachyarrhythmia; see Figure 5.

Figure 5 Ventricular Tachycardia



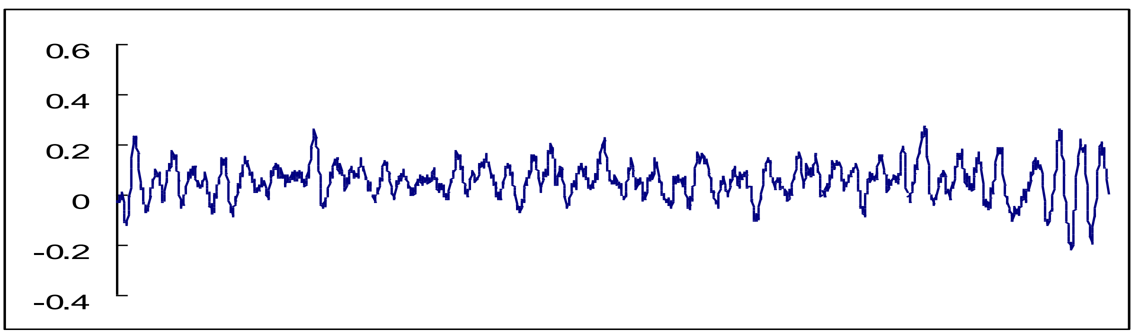
Over a brief period of time, the rhythm becomes more disorganized and high amplitude fibrillatory waves develop – seen on the EKG as *coarse VF* (waveform amplitude greater than 0.2 mV[7]). Coarse VF is depicted in Figure 6.[8] Immediate defibrillation is most often successful if performed at this time.

Figure 6 Coarse Ventricular Fibrillation



Within a few minutes the amplitude decreases and the frequency slows, resulting in *fine VF* (waveform amplitude of 0.2 mV or less); see Figure 7. Defibrillation is more difficult under these circumstances.

Figure 7 Fine Ventricular Fibrillation

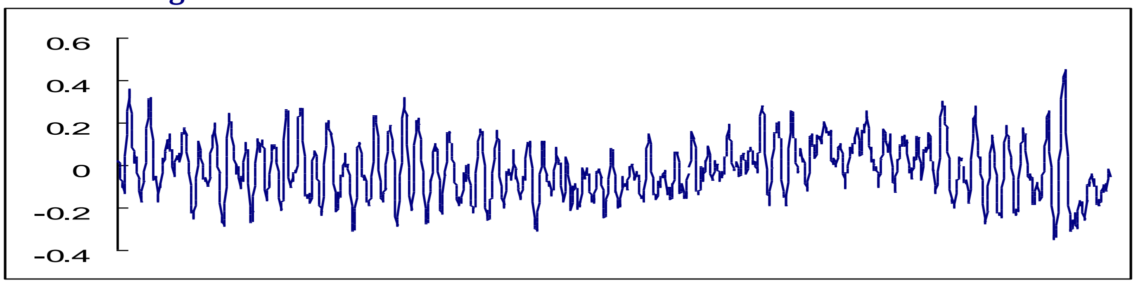


The electrophysiology of a VF cardiac arrest is thought to be a reentry mechanism. At the onset of VF a few large reentry wavefronts develop, showing on the EKG as coarse VF. The myocardial myocytes don't stop contracting and relaxing spontaneously, and a large number are still cooperating. But the myocardium no longer pumps adequately.

Over time more frequent and smaller wavefronts develop and the myocytes contract independently. There is no coordinated mechanical activity of the ventricles and thus no effective ventricular contraction. This shows on the EKG as fine VF.

If CPR is begun and performed well, reperfusion can reverse this process, and the myocytes can "line up" and contract more nearly simultaneously. Coarse VF can return (see Figure 8), which is easier to defibrillate.

Figure 8 Effect of CPR on Ventricular Fibrillation Waveform



Defibrillation consists of delivering a therapeutic dose of electrical energy to the affected heart with a device called a defibrillator. This depolarizes a critical mass of the heart muscle, terminates the arrhythmia, and allows normal sinus rhythm to be reestablished by the sinoatrial node.

The 3-phase model of CPR by Weisfeldt et al. helps us understand how time critical interventions such as defibrillation are to the patient in VF/pulseless VT.[9]

3-Phase time sensitive model of resuscitation

1 Electrical	2 Circulatory	3 Metabolic
• Early defibrillation	• Chest compressions • Ventilations • Defibrillation	• Hypothermia • Cardiopulmonary bypass • Surgical correction
First 4 minutes of arrest	4-10 minutes	After 10 minutes

The first phase, the *electrical phase*, extends from the time of arrest to approximately 4 minutes following the arrest. The most effective intervention during this phase is defibrillation. An example of the efficacy of defibrillation during the electrical phase is the success of the ICD, which provides defibrillation within 15 to 20 seconds after the onset of VF and rarely fails to restore organized electrical activity. The practice of early defibrillation within this electrical phase in out-of-hospital and in-hospital environments results in survival rates approaching 50%.

The *circulatory phase* of VF lasts from approximately 4 to 10 minutes of arrest. The most lifesaving therapy during this phase is to initiate a technique to first provide oxygen delivery, i.e. chest compressions and ventilations, followed by defibrillation. Neimann reported that after 7.5

minutes of untreated VF in animals, 5 minutes of cardiopulmonary resuscitation (CPR) plus epinephrine resulted in a significant improvement in survival compared with immediate defibrillation (64% vs 21% survival).[10] In contrast, after a shorter 5-minute period of untreated VF, use of CPR first failed to provide any benefit over immediate defibrillation.[11] Several clinical studies suggest that the same survival effect may hold true in humans.[12,13]

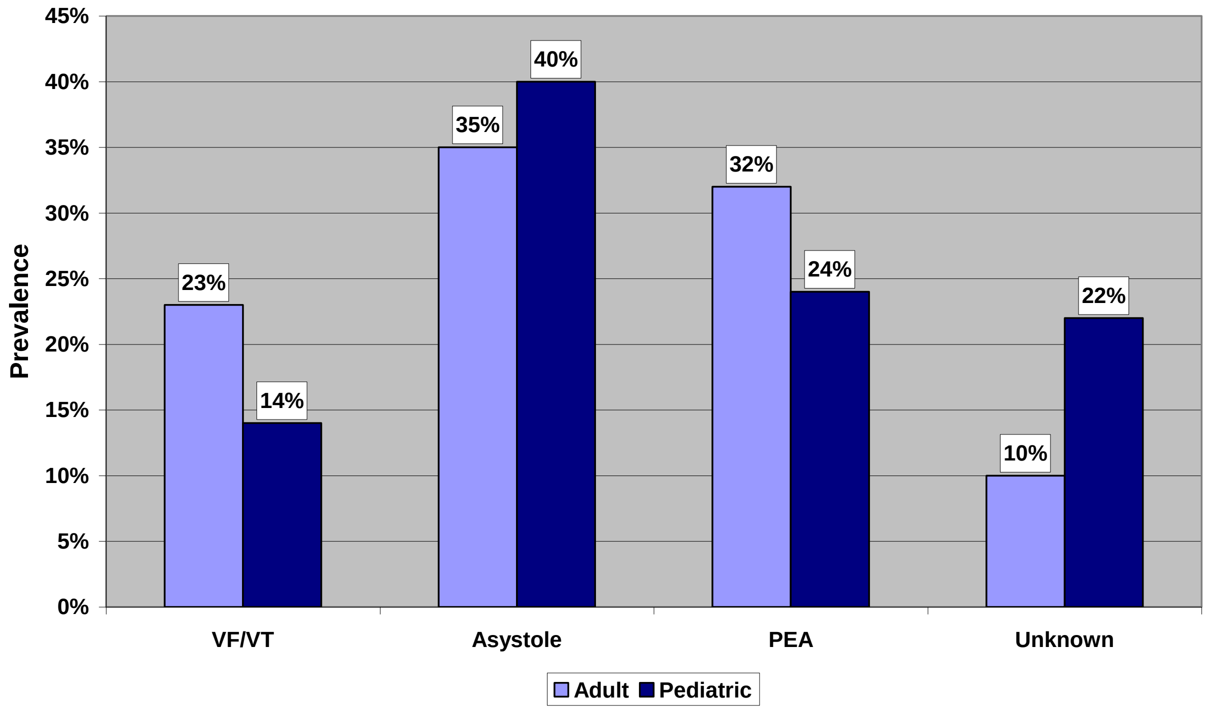
VF is a very energy-intensive process – such that ATP molecules continue to be consumed at a nearly normal rate. If a shock is given within 4-5 minutes, there is enough ATP left so that myocardial cells can generate a pulse. However, membrane potentials degrade and myocardial function decreases over time. Excitability progressively decreases due to the accumulation of ischemic metabolites. If defibrillation is attempted during the circulatory phase, VF may be terminated but either asystole or pulseless electrical activity results as cells run out of high-energy phosphate fuel. It is thought that if CPR is performed, this limited circulation of blood partially restores substrates including oxygen and high energy phosphate levels and washes out deleterious metabolic factors that have accumulated during ischemia. Once the heart is "primed", excitability is improved and it can respond to defibrillation with restoration of a cardiac rhythm and effective pumping.[14]

After approximately 10 minutes of cardiac arrest, in the *metabolic* phase, the effectiveness of both immediate defibrillation and CPR followed by defibrillation decreases rapidly and survival rates are poor. Tissue injury from global ischemia and from reperfusion can result in circulating metabolic factors that cause additional injury to the whole body. Interventions that may protect cells during the metabolic phase so that vital organ function can be returned include the use of hypothermia, cardiopulmonary bypass, and surgical correction of the underlying cardiac pathology.

What Else Have We Learned from NRCPR?

The NRCPR has helped us quantify the prevalence of the various rhythms when a monitor/defibrillator is first attached to the patient in cardiopulmonary arrest in the hospital; see Figure 9.[15]

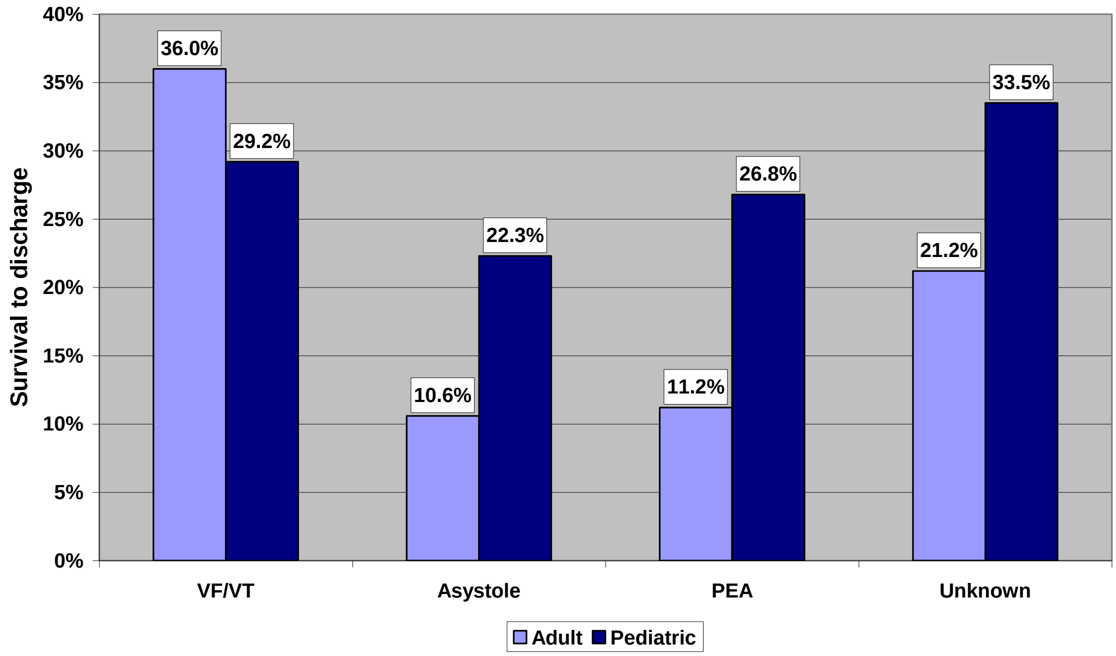
Figure 9 Prevalence of First Documented Pulseless Rhythm from NRCPR Data Through 3/04 (Nadkarni)



Note that asystole and pulseless electrical activity (PEA) are more frequent than shockable rhythms in both adults and children. Most of the arrests in the NRCPR database were associated with progressive respiratory failure, circulatory shock, or both, not a shockable rhythm. It is thought that the incidence of VF as the initial rhythm of cardiac arrest is declining in the U.S. VF is a manifestation of severe, undiagnosed heart disease, primarily coronary artery disease. Rapid evolution in diagnostic testing, primary and secondary prevention, and development of proven medical and interventional therapies have resulted in earlier diagnosis and decline in undiagnosed patients with severe disease. PEA is a ubiquitous response to a wide range of hypoxic/anoxic insults that have progressed to a stage at which compensation by the body is no longer possible.[16] Tang postulates that the use of beta-adrenergic receptor blockers and angiotensin converting enzyme inhibitors significantly shortens the duration of VF, so that other rhythms are identified when the victim is found.[8]

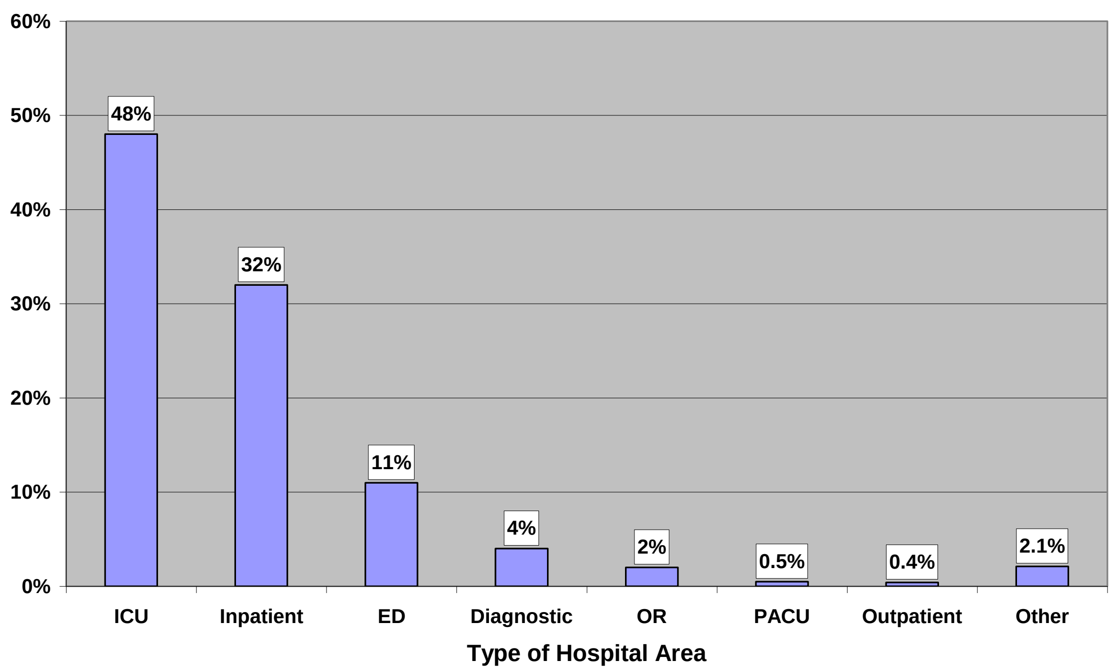
NRCPR has also summarized the rates for survival to discharge classified by the first documented pulseless rhythm; see figure 10.[15] The discharge rates for all rhythms combined in NRCPR for adults is 18% and in children 27%. Note that the discharge rate in adults for VF is more than triple that for asystole or PEA. Thus, as we seek improvements in resuscitation practice, their greatest impact will be with patients found in VF/VT.

Figure 10 Survival to Discharge by First Documented Pulseless Rhythm from NRCPR Data Through 3/04 (Nadkarni)



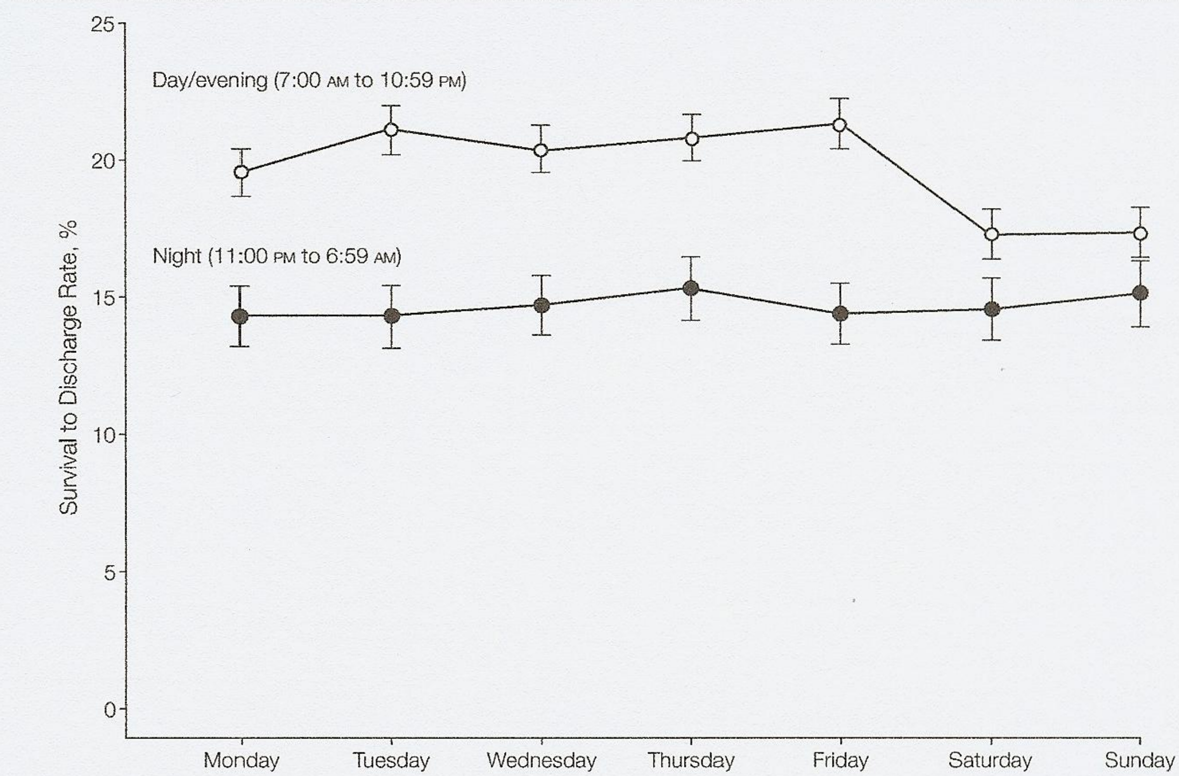
In the first publication from NRCPR, Peberdy describes the event location of the first resuscitation event for in-hospital patients; see Figure 11.[17]

Figure 11 CPR Initial Event Location from NRCPR Data through 6/02 (Peberdy)



In Peberdy's highly publicized article from the February 20th issue of *JAMA*, using NRCPR data through February 2007, it is shown that survival to discharge rates from in-hospital cardiac arrest are lower during nights and weekends, even when adjusted for potentially confounding patient, event, and hospital characteristics.[18] See Figure 12.

Figure 12 Survival to Discharge Rate and Total Arrests by Time Category and Day of Week from NRCPR Data through 2/07 (Peberdy)

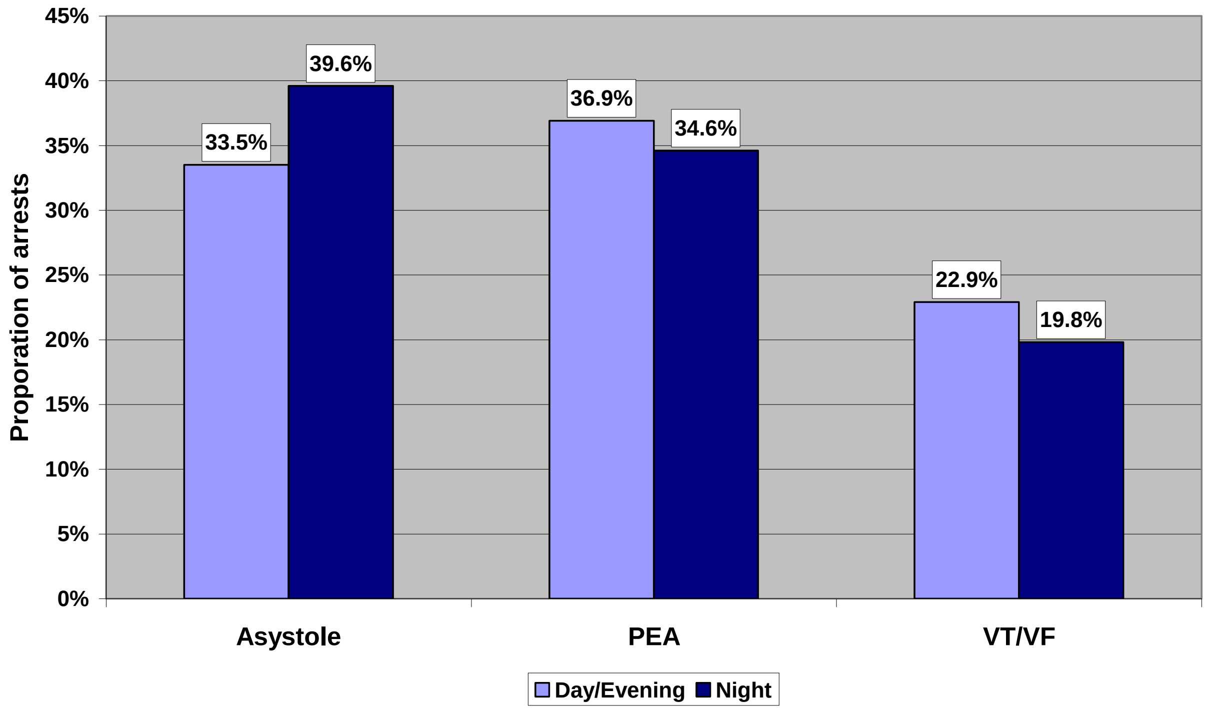


Total arrests, No.	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Day/evening	8973	8827	8636	8529	8518	7657	7453
Night	4141	4002	4144	4100	3978	3888	3902

Error bars indicate 95% confidence intervals.

Cardiac arrests occurring during the night compared with arrests during the day/evening were less likely to be monitored by telemetry/ electrocardiography (74.3% vs. 77.0%; $p<0.001$) or witnessed (75.1% vs. 82.8%; $p<0.001$). The proportion of arrests by first documented rhythm during these two time frames were significantly different ($p<0.001$); see Figure 13. Note that asystole is more common at night, and VT/VF occurs less frequently.

Figure 13 First Documented Rhythm during Time Frames from NRCPR Data through 2/07 (Peberdy)



Conclusion

Part I of this article lays the foundation for what we know about VF/VT arrests in the hospital, especially describing facts gleaned from a large database of in-hospital resuscitations, the NRCPR. Clinicians will be interested not only in how we can improve success when performing defibrillation but also how we can decrease the time to defibrillation so that more lives can be saved. So stay tuned for Part II in the April issue of Code Communications.

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