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Clinical Antecedents to In-Hospital Cardiopulmonary Arrest*

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While the outcome of in-hospital cardiopulmonary arrest has been studied extensively, the clinical antecedents of arrest are less well defined. We studied a group of consecutive general hospital ward patients developing cardiopulmonary arrest. Prospectively determined definitions of underlying pathophysiology, severity of underlying disease, patient complaints, and clinical observations were used to determine common clinical features. Sixty-four patients arrested 161 ± 26 hours following hospital admission. Pathophysiologic alterations preceding arrest were classified as respiratory in 24 patients (38 percent), metabolic in 7 (11 percent), cardiac in 6 (9 percent), neurologic in 4 (6 percent), multiple in 17 (27 percent), and unclassified in 6 (9 percent). Patients with multiple disturbances had mainly respiratory (39 percent) and metabolic (44 percent) disorders. Fifty-four patients (84 percent) had documented observations of clinical deterioration or new complaints within eight hours of arrest. Seventy percent of all patients had either deterioration of respiratory or mental function observed during this time. Routine laboratory tests obtained before arrest showed no consistent abnormalities, but vital signs showed a mean respiratory rate of 29 ± 1 breaths per minute. The prognoses of patients' underlying diseases were classified as ultimately fatal in 26 (41 percent), nonfatal in 23 (36 percent), and rapidly fatal in 15 (23 percent). Five patients (8 percent) survived to hospital discharge. Patients developing arrest on the general hospital ward services have predominantly respiratory and metabolic derangements immediately preceding their arrests. Their underlying diseases are generally not rapidly fatal. Arrest is frequently preceded by a clinical deterioration involving either respiratory or mental function. These features and the high mortality associated with arrest suggest that efforts to predict and prevent arrest might prove beneficial. ***(Chest 1990; 98:1388-92)***

ACLS = advanced cardiac life support

While the mortality[1-16] and neurologic[17-21] outcome of cardiopulmonary arrest have been well studied, relatively little attention has been given to the clinical pathophysiologic antecedents of in-hospital arrest. The study of the physiologic abnormalities preceding cardiopulmonary arrest might eventually lead to rational approaches to the prevention of arrest, alternate strategies in resuscitation from arrest, or the timely involvement of patients and family members in decisions to resuscitate.

It has been our clinical impression that cardiopulmonary arrest occurring among hospital inpatients is frequently related to noncardiac processes, with the "cardiac arrest" representing the common final pathway of a variety of disturbances. We studied a group of patients developing arrest on the general hospital wards who because of their high mortality[22,23] might benefit from earlier more aggressive interventions or monitoring if adequate predictive tools were available. Prospectively determined definitions of pathophysiologic abnormalities were applied to determine the cause of arrest, and additional clinical information was obtained to help identify any possible common antecedents.

Methods

Over a four-month period (July through October 1987), patients developing arrest on the general inpatient services of the Jackson Memorial Hospital Medical Center, a 1,200-bed University-affiliated county and tertiary care facility, were studied. Patients were identified by daily interviews of the hospital's cardiac arrest team physicians and daily monitoring of all patients admitted to intensive care units or placed on ventilators. Patients developing arrest in the operating or recovery rooms, intensive care units, intermediate units, telemetry unit, or emergency department were excluded from the study. All patients who had cardiac or respiratory arrest had a review of their records within 24 hours of arrest. Follow-up assessments continued until the patient died or was discharged from the hospital. Data collected on each patient included basic demographic information, reasons for hospital admission, current medical problems, clinical and laboratory data, new patient complaints, and nursing observations preceding arrest and survival to hospital discharge. All patients had been cared for by teams of house staff physicians under the supervision of attending physicians.

Patients were considered to have suffered an arrest if there was either a cessation of palpable pulses long enough to require chest compressions or a cessation of respiration long enough to require assisted ventilation. The following prospectively defined terms were applied to categorize the clinical events precipitating arrest. *Car-*

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diac: Monitored ventricular tachycardia or fibrillation preceding apnea or agonal respirations requiring chest compressions and advanced cardiac life support (ACLS) techniques or unwitnessed cardiopulmonary arrest in a patient with clinically significant underlying heart disease and no significant pulmonary, metabolic, or neurologic disease. *Respiratory:* Witnessed apnea or agonal respiration or the occurrence of cardiopulmonary arrest in a patient with acute pulmonary or upper airway disease and no evidence of significant cardiac, metabolic, or neurologic disease. *Neurologic:* Cardiac or respiratory arrest associated with acute neurologic impairment as determined by clinical examination and no underlying significant cardiac, pulmonary, or metabolic disease. *Metabolic:* progressive metabolic disturbance immediately preceding arrest in a patient without significant cardiac, respiratory, or neurologic disease. Abnormalities included were serum sodium level >155 or <125 mmol/L, serum potassium level >5.5 or <3.0 mmol/L, serum osmolality >320 mosm/kg, serum glucose level >27.6 or <3.3 mmol/L, arterial pH >7.55 or <7.25, serum carbon dioxide level >30 or <18 mmol/L, and serum phosphate level <0.3 mmol/L. *Multiple:* The presence of more than one of the processes described above immediately preceding arrest. *Unclassified:* The absence of the criteria listed above. Assignment to this category might thus reflect either no clinically apparent reason for arrest or an insufficiently severe or progressive presentation of the processes described above. An arrest was considered witnessed if any staff member, visitor, or other patient observed the loss of respiratory or apparent cardiac function.

Patients' underlying diseases were classified as rapidly fatal, ultimately fatal, or nonfatal. A process was considered rapidly fatal if there was a 50 percent or greater expectation of death during the current hospitalization. A process was considered ultimately fatal if there was a 50 percent or greater chance of mortality within five years, but death was not anticipated on the current hospitalization. A process was considered nonfatal if there was less than a 50 percent expectation of death during the current hospitalization and no underlying illness with an expected mortality greater than 50 percent in five years. These determinations were made independently by two of the investigators based on review of current literature. When necessary, the advice of relevant subspecialists was sought to weigh the effects of confounding or contributory clinical variables. When a patient had more than one underlying disease, the patient was placed in the poorer outcome category.

Patient complaints and nursing observations were obtained from review of the hospital record and classified as either pertaining to a particular organ system or as "other" (for nonspecific or comfort-related complaints). These complaints/observations were recorded if they either appeared for the first time or were specifically described as increasing in severity during the eight hours preceding cardiac or respiratory arrest. Record review was also conducted to determine if patients had been in an intensive care unit during the current hospitalization, had "do not resuscitate orders" written, or had documented decisions to limit care preceding arrest.

This study was approved by the University of Miami School of Medicine's Investigational Review Board. Comparisons of patient groups with respect to laboratory values and vital signs were made using analysis of variance. Scheffé's test was used to determine the significance of pairwise comparisons. Rates and proportions were examined using χ^2 tests and, when appropriate, Fisher's exact test. A Bonferroni adjustment was used for multiple pairwise comparisons. Data are expressed as the mean ± the SEM; p values less than 0.05 were considered significant.

Results

Sixty-four patients were identified as having cardiopulmonary arrest during the study period. Of these, 59 (92 percent) had cessation of both respiratory and cardiac function while five (8 percent) had respiratory arrest alone. The mean age of patients was 51 ± 2 years. Forty-four patients (69 percent) were male. Arrest occurred a mean of 161 ± 26 hours (range, 4 to 1,026 hours) after hospital admission. Fifty-seven arrests occurred on the general and subspecialty Internal Medicine and Family Medicine services, five occurred on the general and subspecialty Surgery service, and one each occurred on the Neurology and Pediatrics services (Table 1). One patient had a formal "do not resuscitate" order and an additional patient had restrictions placed on the extent and aggressiveness of further therapy considered appropriate, but no "do not resuscitate" order. Resuscitative efforts were discontinued after this information was made known to the team responding to the arrest. One patient had been discharged from an intensive care unit before cardiopulmonary arrest. The underlying disease(s) of patients were ultimately fatal in 26 (41 percent), nonfatal in 23 (36 percent), and rapidly fatal in 15 (23 percent).

The pathophysiologic alterations in these patients predisposing to cardiopulmonary arrest were classified as follows: respiratory in 24 (38 percent), multiple abnormalities in 17 (27 percent), metabolic in 7 (11 percent), cardiologic in 6 (9 percent), and neurologic in 4 (6 percent). Among those classified as having multiple abnormalities, 15 patients had two abnormalities and two patients had three abnormalities. Of these abnormalities, 16 (44 percent) were metabolic, 14 (39 percent) were respiratory, 4 (11 percent) were cardiac, and 2 (6 percent) were neurologic. Six patients (9 percent) did not meet criteria for classification. Although all of these patients had diagnoses that could have placed them in other categories, none had the documented progressive clinical deterioration or severity of disease for inclusion. Categories of arrest and relevant clinical diagnoses are found in Table 2.

Thirty arrests were witnessed. The distribution of witnessed arrests was similar when patients were divided into groups based on the severity of underlying disease. Patients with multiple abnormalities preceding arrest were less likely to have witnessed arrest (3/17 witnessed) compared with patients with other antecedent abnormalities (27/47, p = 0.02). Four of 30 patients with witnessed arrest survived and one of 34

Table 1—*Distribution of Arrests by Hospital Service*

Service	Hospital Admissions	Arrests	Arrests/1,000 Hospital Admissions
All services	16,141	64	4.0
Surgery	10,409	5	0.5*
Medicine	3,276	57	17.4*
Pediatrics	2,164	1	0.5*
Neurology	292	1	3.4

*p<.01 for pairwise comparisons of frequency of arrests.

Table 2—*Patient Categories and Clinical Diagnoses*

Category (No. of Patients)	Clinical Diagnoses	No.
Respiratory (n = 24)	Pneumonia	13
	Chronic obstructive lung disease	3
	Hemoptysis	2
	Airway obstruction	2
	Aspiration	2
	Lung cancer	1
	Aspirin overdose	1
Multiple (n = 17)	Pneumonia	7
	Metabolic acidosis	6
	Aspiration	4
	Hyponatremia	4
	Congestive heart failure	3
	Hypernatremia	2
	Hyperglycemia	2
	Hypophosphatemia	2
	Myocardial infarction	1
	Pneumothorax	1
	Sepsis	1
	Brain abscess	1
	Chronic obstructive lung disease	1
	Hyperkalemia	1
	Hepatic encephalopathy	1
Metabolic (n = 7)	Metabolic acidosis	2
	Hypernatremia	2
	Hyperglycemia	2
	Hyponatremia	1
	Hypoglycemia	1
	Hyperkalemia	1
Cardiac (n = 6)	Congestive heart failure	4
	Myocardial infarction	1
	Angina	1
Neurologic (n = 4)	Intracranial hemorrhage	2
	Seizure	1
	Meningitis	1
Unclassifed (n = 6)	Pulmonary embolus	2
	Asthma	1
	Pneumonia	1
	Sepsis	1
	Aseptic meningitis	1

patients with unwitnessed arrest survived (NS, Fisher exact, $p = 0.14$). Overall, 5 patients (8 percent) survived to hospital discharge. Of these, two had been classified as having nonfatal disease, three were classified as having ultimately fatal disease, and none was classified as having rapidly fatal underlying disease. Four of five survivors and ten of 59 nonsurvivors who had witnessed respiratory arrests did not require chest compressions ($p = .001$). When data were examined for differences in vital signs, severity of underlying disease, pathophysiologic abnormalities, and laboratory test results, the only other statistically significant factor was hematocrit (46 ± 1 percent for survivors and 32 ± 2 percent for nonsurvivors, $p = 0.02$).

The mean values of the most recent laboratory studies obtained in the 24-hour period prior to cardiopulmonary arrest were determined for all patients and compared between groups based on survival, severity of underlying diseases, and category of arrest. Group mean values outside of laboratory normal range were as follows: pH, 7.27 ± 0.04; glucose, 211 ± 34 mg/dl; serum urea nitrogen, 34 ± 6 mg/dl; and creatinine, 2.0 ± 0.4 mg/dl. There were no significant differences among the subgroups analyzed other than hematocrit, as reported above.

Patients' vital signs obtained a mean of 5 ± 1 hours prior to arrest were as follows: heart rate, 99 ± 3 beats per minute; respiratory rate, 29 ± 1 breaths per minute; temperature, $37.2°C \pm 0.17°C$; systolic blood pressure, 118 ± 3 mm Hg; and diastolic blood pressure, 71 ± 2 mm Hg. Patients with respiratory or multiple abnormalities preceding arrest had significantly higher respiratory rates than patients with cardiac, neurologic, or other processes (33 ± 2 and 31 ± 3 breaths per minute, respectively, compared with 21 ± 1, 22 ± 1, and 21 ± 1 breaths per minute, respectively, $p < 0.05$, Scheffé). No other intergroup differences were present.

Electrocardiograms recorded within the 24-hour period preceding arrest were available for 24 patients (38 percent). A total of 38 rhythm, S-T segment, or other abnormalities were observed among these 24 patients. Five electrocardiograms showed evidence of infarction (age indeterminate) and eight showed sinus tachycardia. Nonspecific S-T segment and t-wave changes were present in 13 patients, and premature ventricular contractions were observed in tracings of two patients; none showed changes consistent with acute ischemia or ventricular tachycardia. Reports of electrocardiographic or monitor tracings made during arrest were available for 47 patients. These were described as asystole in 27 (57 percent), sinus bradycardia in 7 (15 percent), ventricular fibrillation in 4 (9 percent), "electromechanical dissociation" in 4, idioventricular in 2 (4 percent), ventricular tachycardia, normal sinus rhythm, and sinus tachycardia in 1 (2 percent) each.

At least one chest roentgenogram preceding or within 48 hours following arrest was available for each of 59 patients. Seventeen patients had normal roentgenograms. In the remaining 42 patients, 64 significant radiologic abnormalities were described on at least one roentgenogram. Abnormalities included diffuse or lobar infiltrates in 28 (44 percent), congestive heart failure in 9 (14 percent), pleural disease in 9, atelectasis in 6 (9 percent), and pneumothorax in 3 (5 percent) and miscellaneous other findings in 9.

At least one change in patient behavior or complaints in the eight-hour period preceding arrest was found in 54 (84 percent) records. Twenty-three (36 percent) had two and one had three. Thirty-four patients (53 percent) had documented deterioration in respiratory function. Complaints such as shortness of breath (10 complaints) and observations such as tachypnea, shal-

low breathing, or labored respiration (18 observations) were most common. Alterations in mental function were present in 27 (42 percent) of the 64 patients studied; these were confined to nursing observations and were most frequently characterized as "change in mental status" (14 observations), agitation (11 observations), and lethargy (5 observations). Eight observations of specific gastrointestinal problems were made in six (9 percent) patients. Nonspecific and comfort-related complaints were noted for 13 (20 percent) patients.

Overall, 45 (70 percent) patients had either a deterioration of respiratory or mental function observed; 16 (25 percent) had a documented deterioration in both systems. Respiratory complaints appeared alone in 13 (20 percent) patients and change in mental function alone appeared in 9 (14 percent). Gastrointestinal complaints and those characterized as "other" appeared as sole complaints in 2 (3 percent) and 4 (6 percent) patients, respectively, and in combination with either respiratory or mental status changes in seven of 13 patients and one of six patients, respectively.

Discussion

We have studied a group of patients who had cardiopulmonary arrest on the general ward services with an emphasis on events preceding arrest. The classification of the underlying pathophysiologic abnormalities was determined conservatively by the use of definitions requiring significant and progressive derangements. Despite this, only six patients failed to meet criteria for one of the diagnostic categories and 18 met criteria for more than one category. The most common abnormalities were those involving the respiratory system, predominantly pneumonias, and multiple abnormalities, predominantly a combination of respiratory and metabolic problems. Of note are the relatively few cases meeting criteria for arrest related to primary cardiac disease. Other studies have reported a greater number of cases associated with cardiac disease, especially coronary artery disease, ranging from approximately 50 percent[2,3,12] to approximately 70 percent.[7,10,24] While this reflects a bias in our population, it is a bias that is likely to be present wherever patients with known or suspected cardiac disease are routinely referred to monitored settings, *ie*, hospitals where both cardiac intensive care and intermediate level monitoring beds are available.

In addition to progressive physiologic derangements, abnormalities in both vital signs and patient behavior in the hours preceding arrest argue against the idea that cardiopulmonary arrest occurs as an acute, isolated event in this population. Eighty-four percent of the charts reviewed documented acute deterioration of the patient's condition, either by the patient's own statement or nursing observation. These complaints most often involved difficulties in breathing or deterioration in mental function, as might be anticipated in patients with underlying pulmonary and metabolic problems. Respiratory rate was elevated significantly above normal in a majority of patients. Whether an elevated respiratory rate will be found to be sufficiently specific to be a useful predictor in patients subsequently arresting awaits further study. Pertinent to this, however, are the findings in two different but related populations. An elevated respiratory rate on discharge from medical intensive care has been found to be more frequent in patients who subsequently either die unexpectedly or require readmission.[26] Sax and Charlson[25] have found that 22 percent of patients presenting to the hospital with acute dyspnea arrest. Moreover, during their survey, only one arrest of 20 occurred without either an antecedent clinical deterioration or new complication after hospital admission.

The high proportion of witnessed arrests without a concomitantly high survival indicates that even interventions made immediately at the time of arrest are generally too little or too late. The effectiveness of earlier interventions in improving survival remains to be tested. Specific clinical criteria to trigger any proposed early intervention may eventually be developed from monitoring techniques, such as respiratory impedance plethysmography. However, our data as well as those of others[25] suggest that it is not necessarily the absence of pertinent information that is a problem, but the response to this information. Thus, the recording of a high respiratory rate did not lead to therapy that prevented arrest. This might have occurred because of inadequate or delayed communication of the information to physicians, perceptions by the physician staff that such information was not important or reliable, insufficient therapy by physician staff, or the failure of maximal, appropriate therapy to prevent arrest. These possibilities are worthy of future investigation.

The mortality associated with cardiopulmonary arrest in this study was high. While a number of studies report survival in the 8 to 15 percent[7,9,12,14,15] range, several studies have noted a poorer outcome in ward patients, similar to that reported herein.[22,23] Fifteen patients (including the two patients with "do not resuscitate" and limitation of care orders) or approximately one quarter of the group studied were expected to die during hospitalization as a result of advanced and untreatable disease. While the accuracy of these predictions is not absolute, the medical benefit of proceeding with full resuscitation in these patients is doubtful because of a uniformly unsuccessful outcome. However, untreatable underlying disease or inappropriate decisions to resuscitate cannot bear all the

responsibility for poor outcome, as has been suggested.[23] The majority (77 percent) of patients were classified as having ultimately fatal or nonfatal disease. Since these categories encompass a wide variety of diseases and possible outcomes with respect to length of survival and quality of life, it is reasonable to attempt resuscitation in a large portion of this group.

Survival from in-hospital cardiopulmonary arrest has apparently changed very little since the introduction of organized cardiac arrest teams. The likelihood of a new technology or technique to change this mortality seems remote, given the variety of derangements that precede and contribute to cardiopulmonary arrest. The central questions of resuscitation research so far as the general hospital ward population is concerned should be to what degree do in-hospital cardiopulmonary arrests represent predictable events, to what degree can prediction lead to intervention that prevents arrest, and to what degree does the prevention of arrest reduce mortality. The present study should be considered an initial step that may provide some direction to efforts seeking to answer these questions. The population studied has been defined as one found primarily on the acute care medical services, and as having a spectrum of pathophysiologic abnormalities, with respiratory and metabolic derangements most prominent. The observation of deterioration in vital signs and in clinical condition of these patients prior to arrest supports the idea that cardiopulmonary arrest is neither a sudden nor unpredictable event. The determination that a majority of patients have other than rapidly fatal underlying diseases and that a substantial number have potentially reversible processes suggests that efforts to improve short-term survival by resuscitation from arrest or prevention of arrest should be supported.

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