

# **The Emergency Department as a Complex System**

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## Introduction

Complex systems theory offers a novel perspective to help understand and improve the functioning of a clinical Emergency Department (ED). At the same time, lessons learned in process re-engineering within the Emergency Department serve to illustrate some of the common principles of complex systems theory as applied to typical management and leadership problems.

The Emergency Department is a good model for a complex system because it is a health care delivery system that is extremely rich in its mission and its processes, yet is relatively self-contained and is limited in size and extent. It shares many common attributes with other complex systems.

## A simple overview of the Emergency Department

Given the appropriate scale, every complex system can look simple. In its simplest form, the Emergency Department (ED) is a clinical unit in which patients enter with an acute medical problem and from which they leave after that problem has been assessed and treated.

The processes that take place within the four walls of the Emergency Department mimic those of the entire hospital so closely that when examined in more detail, it becomes apparent that an Emergency Department is really a scaled down version of a complete hospital: a "mini-hospital" offering the same full breadth of patient care and administrative processes, but in a manner that is abbreviated in time and space.

In some respects the "simple" ED process is the same for each patient: every ED patient goes through an administrative intake process (registration), a series of testing encounters (diagnostic evaluation), one or more therapeutic interventions (treatment), and finally a disposition process (discharge). But this simplest description of the ED process fails to define the elements that make each patient's visit unique, and the more closely the process is examined, the more complicated it appears.

Upon arrival, ED patients must be registered into the hospital's information system and have their demographic and insurance information properly obtained. The patient's medical insurance company or managed care organization may need to be notified. Most patients undergo an initial assessment by a "triage nurse" who makes an initial judgment of how rapidly emergency care needs to be rendered. As soon as critical resources (a room, a stretcher, and a physician) become available, the patient is evaluated by a physician, who often orders a series of patient and problem-specific diagnostic tests such as x-rays, electrocardiogram, and blood tests. The physician may need to make multiple contacts to obtain information about the patient – from the patient's personal physician, from prior medical records on file at the hospital, from the family, and from information available at other hospitals. Depending on the emergency physician's assessment, a series of therapeutic interventions are then initiated. Some of these interventions are a definitive treatment, but others are merely palliative or temporizing. Many patients have complicated social and psychological dimensions in addition to their medical problems, all of which must be sorted out if the ED encounter is to be fully successful.

The patient may be moved into other areas of the hospital in order to have specialized tests such as x-rays or cat scans. While this is all happening, the patient is continuously monitored and periodically reevaluated by machines, nurses, and physicians. When new information is obtained through monitoring, a previously chosen diagnostic or therapeutic intervention may need to be modified.

At some point, a decision is made as to whether the patient needs to be admitted to the hospital or can be safely discharged home. Most patients leave the ED by being admitted to the hospital as an inpatient or by being discharged to home. A small number of patients are held over for prolonged observation in the Emergency Department, while others are transferred to another hospital, leave against medical advice, or

die and are sent to the morgue. No two paths through this “system” are the same for any two patients. Decisions by emergency physicians and emergency nurses as to what specifically to do next for the patient are continuously being made and modified based on new information about the patient that emerges in real time.

### **Role of the Emergency Physician**

The emergency physician functions at several different organizational levels. At the first level, the emergency physician takes care of patients one at a time. The role is that of clinical doctor and the task at hand is to manage the care of an individual patient. The emergency physician has a separate and individual physician-patient relationship with every patient being treated.

At the second level, the emergency physician cares for many patients simultaneously by providing on-line management of the emergency department as a whole. Here, the emergency physician’s role is akin to that of an orchestra conductor, providing real-time direction to a team of qualified professionals (nurses, techs, and other support staff) each of whom is responsible for the details of his or her particular job.

Off-line, there exists a third level of organizational structure. The physician director of the emergency department must provide leadership and management of the emergency organization, including the actual design of patient care processes, scheduling of staff, deployment of physical space, and allocation of resources.

## **The Emergency Department as a complex system**

At several different levels, the Emergency Department exhibits many of the features typical of complex systems. The presence of many threshold phenomena and other non-linear cause-effect relationships is one of these features. Another is an extreme volatility, as evidenced by a high sensitivity to initial conditions and to small changes in the clinical environment. The presence of innumerable feedback loops is also a common feature of complex systems that is shared by the emergency department, as is the fact that new and unexpected behaviors can emerge out of situations that appear stable by all common metrics. Fractal attributes (attributes of fractional dimensionality) are often mentioned as an important contributor to complexity in systems. To have true fractional dimensionality, an attribute must be infinitely self-similar at all scales of magnification – any truncation short of infinity causes fractal treatments to fail for the system at some scale. The emergency department is not a true fractal system by any measure, but many parts of it do exhibit self-similarity at several scales, and this does raise the overall complexity of the system.

In the Emergency Department we recognize a system dominated by complexity in four interlocking domains: the individual patient, the ED caregivers, the clinical decision-making, and the practice environment. This complex system may be uniquely optimized to operate at the edge of chaos.

### **The patient**

Every patient who comes through the door is an unknown, with a condition that unfolds over time in a functionally non-deterministic way. It is true that each patient's medical condition is a state function, but the set of initial conditions that define the state and determine the patient's future course are too numerous and have too many interdependencies to be fully understood or specified. The most visible manifestations of this uncertainty about the immediate future are the many ED patients who are attached to monitoring devices to provide constant surveillance of their heart rates, breathing patterns, blood pressures, and cardiac rhythms. Although an initial evaluation often allows a generally correct prediction as to a patient's probable trajectory through the system, new aspects of the patient's clinical situation often emerge unexpectedly while the patient is in the ED. When a patient suddenly develops a new life-threatening symptom, such as a cardiac arrhythmia, the entire ED system must initiate a series of unplanned responses and interventions. These unscheduled actions in turn cause perturbations in the other three domains.

## **The caregivers**

ED caregivers arrive in the department at the beginning of a shift, are assigned to perform one of several generally defined roles, and thereafter define their own behavior through a series of time-critical interactions with their patients, their colleagues, and the surrounding environment. Each caregiver has a different nominal role in the ED. The nurse, physician, respiratory therapist, and ED technician all perform actions needed to take care of patients. Each one must recognize and prioritize a large number of simultaneous demands for action and must independently resolve competing priorities. At any moment, the "next move" of any caregiver is unknown to others in the system, and may not even have been decided yet. Because of new patients entering the system or changes occurring in the condition of existing patients, caregivers experience frequent interrupts that force a continuing reprioritization of tasks. The emerging events that drive actions in the ED are so unpredictable that it would be impossible to write a script to govern the actions of any ED caregiver for more than a few moments at a time on even the quietest day.

Unexpected events that are minor (such as a patient who suddenly vomits in an examination room) may be handled by a single caregiver who works to restore order to the immediate area. If the problem is of greater magnitude, additional workers may be recruited for assistance as necessary. Major unexpected events (such as a patient who suddenly has cardiac arrest) are met by a highly organized response from large teams of caregivers, but these teams are self-organizing for the immediate need, act together for a common end without formal governance, have no prior plan nor rehearsal to guide them, and dissolve themselves immediately when their existence is no longer required.

Teams grow by recruitment, and can become as large as necessary to respond to perturbations in the system. A multiple trauma case, for example, can cause a team to grow rapidly to include people outside the Emergency Department. In extreme cases, chaotic events originating with a single patient can cause disorder to ripple through multiple departments of the hospital and even to affect other hospitals in the region, as when the hospital runs out of a particular blood type and must call for assistance from outside sources.

Functional structures that depend on self-organization at many different levels are often recognized as indicators of complexity in a system.

## **Clinical decision-making**

Algorithmic clinical decision trees will never be rich enough nor subtle enough to handle a normal mix of clinical situations, because clinical decision-making is a complex process. What is the correct diagnostic pathway? What is the likely diagnosis? What medication should be administered? The number of decision nodes is vast, and in the Emergency Department such decision-making often must occur under pressure of time and with incomplete evidence.

Rules cannot drive clinical decisions, because the process of clinical decision-making is characterized by the logic of partial-set-membership ("fuzzy logic") and by the need to recognize the gestalt of emergent patterns before they are fully defined. The emergency physician must recognize impending chaotic behaviors before they emerge, prevent them when possible, contain them when they do emerge, and wrestle them back into some form of order before releasing them from the emergency department into other areas of the hospital or back into the general population.

The tools that are used to perform these tasks include many that are commonly associated with complex systems: self-organizing responses to evolving situations, identification and mastery of smaller, controllable subsystems, recognition of (and response to) similarity at different scales, action in response to changing probabilities, and dynamic anticipation ("leading the system").

### **The practice environment**

Unmanageably large amounts of information are needed to accurately describe what is happening inside an ED, because many agents interact in rapidly a small space. Because of the large amount of unpredictable activity, the baseline condition of a stable ED appears chaotic to an outsider, but is easily recognized by ED staff as "under control." An ED can go from being very busy to very quiet and then back to busy again all within a short period of time, without ever becoming chaotic, yet an ED can be driven from a controlled condition into a chaotic condition very rapidly in any of a number of ways.

A single patient may bring a high degree of chaos into the system. This can be because of extreme injury or risk to the patient, as when a patient arrives in cardiac arrest, or because of risk that extends from the patient to involve caregivers, as when a patient arrives with a hazardous material contamination. It can occur when sociopolitical factors accompany the medical problem, as when the President of the United States arrives with a bullet wound to the chest, or when a gang member arrives and a rival gang gathers in the waiting room.

Chaos can result when several patients with time-critical conditions arrive simultaneously, as when multiple victims of a severe automobile crash are all brought to the same Emergency Department. At times, patients who (one by one) have a simple condition, such as the flu, may arrive in such numbers that they simply overwhelm the resources of the system. Chaos can be the result when internal resources cease to be available, as when the hospital runs out of admission beds, or when the CAT scan machine breaks down. Expected resources can fail to materialize in unexpected ways, as when a personal conflict within the department prevents an effective team from forming to address a medical need that has arisen.

But no matter how severe the problems faced by ED staff, no matter how chaotic the situation may be in the clinical arena of the ED, and no matter how overloaded the department, new patients keep coming into the system. The faucet cannot be turned off.

### **An Emergency Physician's perspective on complex systems management**

When somebody collapses to the ground at a fast food restaurant, the operational fabric of the restaurant is completely disrupted. When somebody walks into a library after having been shot in the chest, a panicked chaos results. These, and nearly every other sort of unexpected human event, would be routine cases for an Emergency Department.

The ED is a place uniquely designed to accommodate and to respond in a meaningful way to multiple complex stressors of great magnitude, arriving singly or grouped, in any order, at any time, without warning. Complexity and chaos are literally a way of life in the ED, and emergency physicians have developed a variety of approaches and strategies for managing that complexity.

### **A complex system optimized to operate on the edge of chaos**

In a very real sense, the Emergency Department is optimized to live at the edge of chaos, to handle a multitude of different problems simultaneously, none of which can be predicted in advance. It is a system designed to be resilient to whatever the external environment has to offer. It is perhaps the only system extant that has been specifically designed to cope with any and every eventuality that can befall a person. Its door is always open, 24 hours a day, 365 days a year, and situations that would totally disrupt another type of organization are routinely handled in the Emergency Department with no more disturbance than if someone had walked in asking for a hamburger to eat or a book to read.

Because Emergency Departments are complex systems that must function on the edge of chaos, many Emergency Department leaders and managers have recognized principles and have developed skills and insights that may be applicable to other complex environments. The landscape of complex systems management and leadership is briefly surveyed with reference to certain real-life situations that have arisen and been addressed in the ED.

### Effecting change in complex systems

How can one take an organization from “here” to “there?” How does one effect major change in a complex system? This is a central question for those with management and leadership responsibility for complex systems.

#### *Traditional process re-engineering*

A traditional process re-engineering approach begins with every stakeholder explicitly and laboriously plotting out every perceived process step and decision point in excruciating detail. The justification for this approach seems to be the notion that once the process is completely mapped in all its detail, opportunities for redesign will suggest themselves. The unspoken premise is that with enough effort, the entire complex system can be understood and grasped at one time. This rarely turns out to be true. What often happens in practice is that several months into the reengineering program the process is only 60% mapped out, while 60% of what has been mapped is obsolete or incorrect, and 60% of the participants have lost interest and dropped out.

Simple systems and simple groups of individuals may be managed in simple ways, but like ocean liners, large complex systems are difficult to turn, and like cats, large complex groups are difficult to herd. Efforts to manage events by controlling entire complex systems will not work: such systems are too big and too complicated for anyone to be able to control completely. Efforts to design "complete" solutions will fail: just when it appears that total control of the system has been achieved, a situation will arise that cannot be addressed by the "complete solution".

The brute force, head-on approach to changing a complex system often fails in unexpected ways. The complex system, by the nature of its complexity, has many unrecognized ways to absorb and dissipate externally applied force. To manage complex systems, alternative strategies are needed. One strategy that has often proven successful is to identify a smaller, critical subsystem that is susceptible to change, and to apply force only to the subsystem. This is especially effective when forces already at work within the complex system can be redirected to propel change in the desired direction, much as an Aikido master uses the kinetic energy of an attacker to compel a change in direction in such a way that it cannot be opposed.

#### *The "85/15" rule*

The "85/15" rule stands in contrast to the traditional "map everything, control everything" approach. The 85/15 rule is a mathematically derived formula showing that most of the net behavior of a complex system is determined by approximately 15% of the components of that system. Even if it is impossible to "get your hands around" 100% of the system, it may be possible to change the overall behavior of the system by changing the behavior of a critical 15%.

When attempting to change a complex system, the key to success often is to find the right 15% and to effect the right change in that 15%. To change the direction of a battleship, one must find the key part of the ship that controls the ship's direction — the rudder. One mantra for changing complex systems is: “find the rudder.”

In many situations, the largest component of human behavior output depends strongly on the information that is made available to the participants, and the way in which that information is presented. In some cases, information displays can be the rudder that changes the course of human behavior.

### *Using information displays to change human behavior*

Human behavior and interactions among people are among the most complex systems that exist and among the most difficult to change. It can be all but impossible to induce people to do things differently when they have been doing them in the same way for a long time.

Direct approaches, such as telling people to behave differently, usually fail. Intense and ongoing staff education efforts often are only marginally more successful: immediate changes in behavior are seen, but behaviors often slip back to baseline after several weeks or months. Past experience predicts the future: if a particular aspect of a complex system has resisted change in the past, a continued frontal assault direct approach is likely to fail.

Simple information displays can have a surprising power to change human behavior that has been refractory to traditional efforts.

### *Case history*

At a time when the institution was making efforts to increase the patient census, a busy day in the already-overworked ED meant complaining staff, decreased morale, and even efforts to divert ambulances to other hospitals.

How to go about changing this prevailing attitude and culture? All the usual methods were underway: hiring new people, setting clear standards, opening lines of communication, and leading from the top – but an additional innovative effort proved to be a catalyst that dramatically improved the effectiveness of these traditional methods.

In the spirit of the "Top Ten Scores" listed on video games, we elected to display the "Top Ten Days" on the screens of our clinical information system. This display shows not only the total count for each of the top ten days, but also shows the count at each hour of the day, so that as the day unfolds, the current census can be put into the context of the top ten days. Several interesting things happened in immediate response to this display of information.

On a day that is busy, but not busy enough to be a candidate for the "top ten" list, complaints are muted, because "only a wimp complains when it's not even a top ten day." On a day that has potential to develop into a "top ten" day, the count is watched, hour by hour, with anticipation. Morale is up as the entire staff shares a sense of accomplishment, especially when a "top ten" day is handled with grace and ease. Instead of complaints, staff can be heard saying "we only need three more to make the top ten!" Late at night, nurses go out into the arrival area to make sure everybody possible gets registered before midnight.

A problem that had existed for years and was responding only slowly to intense efforts by a new administration yielded immediately to a simple formatted display of information.

### **Improving performance and removing bottlenecks**

Another central question for leaders and managers of complex systems is how to improve efficiency and performance in a system that is unmanageably large and complicated.

### *The traditional approach*

Once again, the traditional approach lies in efforts to map and track the detailed functioning of the dysfunctional system and then to educate, train, incentivize, and otherwise motivate those responsible for poorly functioning components of the system. Unfortunately, increasing the performance of the carburetor can only do so much for an automobile whose engine is the wrong size and type to begin with.

### *Simplifying the sources of complexity*

The key to the efficiency problem can sometimes be found by examining the sources of complexity in the system. One of the principles of complex systems theory is that a few very simple elements can give rise to very complex, elegant and harmonious systems. When a complex system arises as a result of the interaction of very simple sub-processes, its complexity is rich and harmonious. In contrast, systems that are over-designed often have unnecessary complexity designed into them: too many detailed rules, too many steps, and too many components. Such excessive complexity can also arise through generations of modifications to what started out as a simple system.

The practical application of this principle is that complex systems work better when the root processes that comprise them are few, simple, and straightforward. When a complex system can be simplified to produce the same results with fewer rules, fewer steps, and fewer components, the effect is nearly always beneficial.

### *Case history*

Traditional processing of emergency department "stat" blood tests in the hospital's central laboratory was a complicated process. Delays and confusion engendered by this process affected every part of the emergency department, and were detrimental to patient care.

Under the old system, a physician deciding to order a test must first find the chart and write the order for the test. The chart is then given to a nurse, who notes the need to draw blood, adding this to his or her personal task list. The chart is flagged for attention by an order entry clerk, who enters the order into a laboratory computer system and fills out a lab request slip. When the patient's blood specimen has been drawn, it is brought to the clerk's desk where it is attached to the lab request slip and is hand carried or sent by pneumatic tube to an area of the laboratory known as "accessions". From accessions, blood tubes are distributed to other areas of the lab, where they may be put into queues to be run along with the next batch of similar blood tubes from other areas of the hospital. When the test has been completed, the results are sent back or called back to the clerk in the Emergency Department, who writes the results on the chart. If the results are critically abnormal, the clerk is supposed to notify the physician immediately, but routine results are left on the chart to be found only when the physician remembers to look for them.

The traditional process involves at least 7 people performing 8 critical steps. Many of the steps require volitional action, and others are queued up to be performed at a convenient time. Any violation of the "rules" – such as an incompletely filled out lab slip – results in failure to perform the test. There are opportunities for delay at every step, so the time required to obtain a lab test result can range from 60 minutes to many hours. When a test that was ordered is not performed for some reason, it can be several hours before the physician learns that no result is forthcoming.

After many years of failed efforts to speed up this complicated process and to make it more reliable, a new administration scrapped the old system in favor of one requiring fewer people and fewer steps. Under the new system, a physician marks the desired test on a sheet of paper, and hands that paper directly to a technologist who operates a "mini-laboratory" inside the emergency department. The technologist obtains the blood sample and runs the test. Three minutes later, the technologist returns the sheet of paper complete with results to the physician: two people, three steps.

As anticipated, point of service laboratory testing caused a substantial decrease in patient throughput time. An unexpected side benefit was that the turnaround time also improved dramatically for specimens that still had to go to the main lab for special tests. Investigation showed the reason for this unexpected improvement: the laboratory technologist stationed in the Emergency Department now took personal responsibility for tests that were sent back to the main lab, conveying a message of urgency to his or her colleagues and obtaining streamlined service as a result of personal connections.

### **Correctness and completeness**

The most efficient system is of little value if it lacks correctness and completeness in its outputs. Assuring correctness and completeness is very difficult for a complex system when taken as a whole, yet this is precisely the task faced by managers and leaders of such systems.

### ***Traditional analysis***

A traditional approach tracks current performance as measured by gross outputs, and compares that performance against historically similar measures. So long as gross outputs remain constant or improve, everything is believed to be fine. When gross output measures decline, a series of hypotheses are developed to explain what may have gone wrong. Usually the most popular hypotheses suggest that transient external effects are responsible for the downturn, and that things will correct themselves over time. If the problem persists, spot audits are used to investigate alternative theories that seem to have high face validity or that support the historical biases of important persons in the enterprise. When this approach works, it is nearly always by accident, because the number of possible internal problems in a sufficiently complex system is large enough to make comprehensive post-hoc investigation infeasible.

### ***Local Feedback Loops***

The worst type of system to manage is a unidirectional multi-step process with no feedback loops, in which it is impossible to identify whether or not the final outcome is correct or complete at all. The addition of a single global feedback loop, in which only the final output is scrutinized, can demonstrate that "problems exist," but cannot determine at which step in the process the problem is occurring. In any multi-step process, multiple local feedback loops can ensure that the output of any sub-process is complete and correct, making post-hoc audit and analysis unnecessary.

Highly localized feedback loops are a hallmark of well-designed processes, and are critically important to complex systems, where the output of one process has a non-linear effect on the output of another process. If a multi-step process has a local feedback loop for each step, then any errors identified in a subprocess will be fixed before they can exert an effect on the final output. If each step in the process is demonstrated by its local feedback loop to be correct, then the overall process will be correct.

The familiar childhood game "telephone" illustrates the problems of the absence of local feedback loops in a multistep process. In this game, verbal information is passed from one person to another in a chain of people with no local feedback permitted. After a surprisingly small number of transmissions, a global feedback loop is applied, as the "final" version of the message is compared to the "original" message, often with hilarious results. The game works because of the absence of feedback loops at each step in the process. If the completeness and correctness of transmission were verified at each step of the process, no degradation of information would occur, and the fun would be gone.

Local feedback loops improve the quality of the final product, and permit the easy identification of local problems wherever they occur.

### ***Case history***

Traditional Emergency Department billing is a classic example of one-way downstream data flow in which feedback loops may be global at best, or may be missing completely. When receipts are co-mingled with other hospital revenue, there may be no way to ever assess billing performance for a single department. When receipts are not co-mingled, the gross revenues are examined on a monthly basis, but even so, when revenues go up or down, the best that can be done is to suspect that "something may have changed." In an increasingly competitive environment with shrinking resources, this can lead to a death spiral of decreasing revenues and flailing attempts to change things with no way to know what really needs to be changed.

In the traditional system, every patient who entered the emergency department is registered into the hospital's mainframe registration computer system, where clerks enter whatever incomplete demographic and insurance information can be obtained from these sick emergency patients at the moment of arrival. There is no system to ensure or enforce any particular quality of information, and once entered, the data is never again reviewed. The patient is seen by nurses and physicians, and the clinical encounter is recorded sketchily in a clinical chart. There is no system to ensure or enforce any particular quality of clinical information, nor is the written record ever again reviewed except as part of spotty routine "quality assurance" protocols that have little effect on the general quality of the clinical information recorded. Clerks look at the clinical chart and enter billable charges and diagnoses into a mainframe computer billing system. No effort is made to ensure that the charges or diagnoses are correct, nor are they ever reviewed in any systematic way. An automatic bill is generated that goes either to the insurance company or to the patient. No further attention is paid to any aspect of this billed account until a denial of payment or a patient complaint is received several weeks or months later. Open unpaid claims automatically "roll over" to bad debt with no effort to determine or correct the reason for non-payment. The sole financial outcome measure used to manage this entire process system is the annual net revenues received, sometimes broken out by month and by payor.

In this traditional unidirectional process, incomplete information flowed into the billing process from ED registration clerks, clinical personnel, and coding clerks with no feedback at any step to determine whether the information transmitted was correct or complete. Year after year, a poor overall financial outcome came as a complete surprise.

A new ED administration has redesigned the system with feedback loops at every stage of the process to ensure that all components of the data are as complete and correct as they can possibly be, before any bill is ever generated. Implementation of these feedback loops permitted the recognition and automatic correction of a large number of systematic problems that previously led to poor financial outcomes. Among the historical problems that were found and corrected were the systematic non-billing of large numbers of patients, the incorrect assignment of insurance information for many patients, routinely incorrect worker's compensation information on nearly all cases, incomplete recording of clinical information, routine violation of contractual agreements by third-party payors, and many other minor problems.

With the institution of multiple local feedback loops, regular analysis starts not with the monthly revenues received, but with the cohort of patients who entered the system. Failures at each stage of the process are identified and addressed on an ongoing patient-by-patient basis, and the individual cases are aggregated into a significantly enhanced monthly revenue figure.

The more complex the system, the more critical the need for local feedback loops that can ensure correctness and completeness of each step in a multi-step process.

## **Lessons learned in the design and redesign of the Emergency Department**

Complex systems, by virtue of their complexity, are inherently difficult to describe in detail. A more fruitful approach is to seek simple components and simple rules that can generate or influence the behaviors of the system. Several rules and aphorisms have proven particularly helpful in the design and redesign of Emergency Department systems.

### **Follow the 85/15 rule**

Some systems are so complex that it is impossible to control every aspect of the entire system, yet in almost every case, most of the outputs we wish to affect are dominated by 15% of the component parts of the system. The challenge is to find the right 15% and effect the right change or intervention to obtain the desired result. Although it is often said that the rest of the system will "flip" or self-organize in the desired direction, in reality it is our perception of the direction that has "flipped." This is because the perceived direction of an organization is based mainly on the output that was caused by the 15% of the components

that have been modified. When the net output changes, the direction of the organization is perceived to have changed. Over time, of course, the shared perception of a new direction will cause self-organizing new or changing components gradually to become aligned with the desired direction as well.

### **Follow the 80/20 rule**

A corollary to the 85/15 rule is that when initial efforts are directed at the most influential components of the system, the first 20% of effort expended will yield 80% of all the change that is possible. This is because subsequent efforts can only be directed at components that make progressively smaller contributions to the net output. When applied to process design, this rule reminds us to design for the common situations that produce the greatest output, and to avoid wasting time on complicated designs that will handle less common exceptions. This rule underlies a guiding aphorism for designers of complex systems: "good enough, push on" (GEPO).

### **Apply "just-in-time" design principles**

Avoid over-design and over-engineering. Many more complex projects have failed due to over-design than to under-design. The reason for this is that at every stage of the design process, assumptions must be made. Not all of these assumptions can be perfectly correct. Within a complex system, small errors of input can produce large variances in output, thus the a priori design of secondary stages within a complex system is highly likely to be seriously flawed even if the initial assumptions were 99% correct.

If a major investment of time and resources is made in the "one right way," and that "right" way does not work, then a major investment has been wasted in a futile effort. Instead of trying to try to design a comprehensive system before testing out any of the parts, it is better to effect small, inexpensive changes, test them in practice, revise them as necessary, and then move on after seeing their consequences. Avoiding over-design saves time and money, enables immediate progress, and keeps everyone open to new ideas.

### **Establish minimum specifications**

Sometimes the best way to design a process or system is not to design the process itself at all. Instead, the right approach sometime is just to define the minimum specifications for key results that the process is meant to achieve, and then to let the agents of the process self-organize to achieve those results. When this is done, the resulting process often is far more flexible and economical than one that was designed and imposed from above. Sometimes, unforeseen benefits will emerge that will be more important than the original purpose of the process.

### **Recognize palpable synecdoche**

Palpable synecdoche is the principle that the particular small interactions a person has with an organization completely define the organization for that person. For a family member in the waiting room, the Emergency Department is the chairs, coke machines, and magazines available. The cleanliness of the bathroom and the smile of the registration representative define the hospital for that family member, even though the designer may have been more concerned with traffic patterns and architectural details in the interior of the hospital.

### **Expect unintended consequences**

When old processes are changed or new processes constructed, there will always be outcomes that are unanticipated. Some will be beneficial, others harmful.

### **Invest in people**

In a complex system, the most important components are the people who make it work. It is impossible to pre-specify every response to every possible situation. The skill, intelligence, and innovation of the people comprising the organization will determine the outcome when unexpected situations require immediate response.

### **Sunshine the data**

Hidden and secret information leads to mistrust, misunderstanding, defensive behavior, and miscommunication. When information that accurately describes the current status of any subsystem is displayed for all to see, people respond in such a way as to make the information reflect favorably upon them and their part of the process.

## **Summary**

Complex systems theory can offer useful insight into how to improve Emergency Department patient care processes and how to approach and solve management problems in the ED. The converse is equally interesting: The Emergency Department is a living laboratory for complexity science, unique in the ability to put an orderly wrapper around events that would be chaos-inducing in other environments. Why is the ED able to respond to such a wide range of inputs and situations that would perturb or cripple other systems? What are the factors that optimize the ED for managing inherently complex situations? These and other similar questions are interesting to students of management science and others with an interest in the practical applications of complexity theory. Similar considerations could most likely be applied to many other health care entities, such as an Intensive Care Unit (ICU), a comprehensive full service hospital, a managed care organization, or a vertically integrated system of primary care providers, hospitals, and outpatient services.