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# Complexity and Chaos in Surgical Start Times

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In this issue of the *Journal of Patient-Centered Research and Reviews*, Cox Bauer et al. provide an elegant and interesting initial foray into the causes for delay of first-case operating room start times.<sup>1</sup> Among the study's main findings were that 88% of first-of-the-day scheduled surgical cases were delayed, and despite late arrival of the patient to the hospital 65% of the time, almost 60% of delayed cases had no listed reason for the delay. A number of potential predictor variables were explored for inclusion in fixed-effects logistic regression models, and key time intervals were investigated. Further documentation and study of the events leading up to surgical start times, along with implementation of Plan-Do-Study-Act cycles, were suggested to tackle this vexing problem.

Certainly, one would suspect (as did the authors) that inadequate or nonstandardized documentation may explain the seemingly high percentage of missing listed explanations for delay as well as the frequent mismatch between the "late arrival" field and cause of delay. I would submit, however, that the authors may well have uncovered an explanation for these delays: in essence, that there is no single or easily described reason.

Here is where complexity science,<sup>cf.2</sup> which has been described as "the study of intraconnected natural systems,"<sup>3</sup> and chaos theory,<sup>cf.4</sup> the study of nonlinear dynamics, come in to play. Medical organizations and their processes are complex, dynamic, potentially fragile systems that often grow more complex over time.<sup>5</sup> Properties characterizing such iterative systems of interacting parts include "self-organization, nonlinear adaptation, internal diversity and distributed control."<sup>3</sup> Furthermore, people (themselves complex interactive

dynamic systems)<sup>6</sup> and processes increasingly rely on technology, which in turn is built of interacting components ("coupled links") that have become increasingly complex.<sup>7</sup> Thus, health care teams are "collections of individual agents with freedom to act in ways that are not always predictable, and whose actions are interconnected so that one agent's actions changes the context for other agents."<sup>8</sup> As nursing informatics and administration professor Thomas Clancy warns, "be prepared for the unexpected."<sup>7</sup>



One element of chaos theory that particularly portends difficulty in reliable prediction of, say, surgical start times in a complex dynamic system, is the so-called butterfly effect, i.e. extreme dependence on initial conditions.<sup>2,4</sup> This is the phenomenon in which a minor perturbation in one location can cause a major change downstream.<sup>4,6</sup> Originally discovered by the meteorologist Edward Lorenz on a supercomputer in the early 1960s,<sup>9</sup> the concept is that a butterfly flying in an alternative direction can cause a major change in weather a few days later at a location a thousand miles away.<sup>4,6</sup>

For this subject, take a hypothetical example of a young woman on her way to her early morning elective surgery. A crying toddler begging her not to leave combined with an overflowing sink delays her departure from the house by 15 minutes. While this action prevents her from being hit by an intoxicated driver head-on had she left on time, the ensuing traffic back-up brings her to the hospital's valet parking 25 minutes later than intended. Throw in one of the parking attendants calling in sick, and she arrives at the hospital check-in desk 35 minutes late. This line is momentarily stalled by a coworker asking computer advice from the receptionist delaying the woman's arrival to the preoperative holding area.

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In the meantime, three patients for later surgeries have already arrived and are being processed ahead of her, further increasing the delay (you get the idea). This description, of course, just deals with the patient's timeline to the preoperative holding area. Certainly, shortly after arrival in the holding area, the computer network could have gone down for several minutes, one of the holding rooms may have been contaminated and therefore unavailable, and multiple other problems in this interconnected process could have arisen. Thus, a number of problems unrelated to the patient's modestly late departure from home may have resulted in the 45-minute-late start time for her particular procedure. Indeed the patient was late, but was it possible to pinpoint any one factor as the cause?

System complexity and its underlying science often make it difficult to "diagnose and treat" system problems such as delayed surgical start times. In addition, because of another principle of chaos theory, self-similarity on multiple scales,<sup>4</sup> a whole systems change may be necessary to effect change rather than a focus on a couple of departments or processes.<sup>10</sup> In fact, because of interdependencies, changes in one part of the system may have "counterintuitive consequences" on other parts.<sup>10</sup>

But all is not hopeless. Plsek and Greenhalgh have noted, "A complex system can adapt its behavior over time," by not focusing completely on traditional linear, reductionist thinking (e.g. "reduce and resolve" approaches focused on a single department).<sup>8</sup> Accepting unpredictability and building more flexibility and cross-communication into multiple interacting departments may achieve better results.<sup>8,11</sup> Simple things such as cross-training and avoiding undue redundancy may well have an impact. Use of the electronic medical record should address the latter, for example, by maintaining clear documentation that avoids having patients asked the same questions by multiple persons along the way.<sup>5</sup> Some redundancy increases patient safety; too much is inefficient. System change is often a matter of will.

Can scientific theories or mathematical models help solve problems such as surgical wait times? Recent use of queueing theory simulations (of which I, admittedly, have no knowledge or experience) in emergency and recovery room wait times, intensive care unit bed flow, outpatient cycle times and other health care management issues is of interest.<sup>12-16</sup> The advantage of

queueing models is they are relatively simple, quick and applicable to systems with unpredictable behavior.<sup>13</sup> While likely better for supply-and-demand situations and less applicable overall to complex, dynamic systems,<sup>13-16</sup> they may nonetheless be useful to guide change in single or closely related departments.

Perhaps selected use of such simulation models — combined with a whole systems approach, patient, clinician and staff coaching, dedication, determination and common sense — can lead to reductions in first-case surgical start delays.

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