# Schrodinger's Cat Scan

## Reflections on Clinical Uncertainty

***By Daniel J. Bressler, MD, FACP***

**IN THE LATE 1920S, THE LATEST** findings of theoretical physics were captured in a model of the behavior of subatomic particles. This model, called quantum mechanics, posed that aspects of such particles, including their location, could not be described definitively but only probabilistically. The model explained all known experimental observations about this dimension of the world. Despite that, two of the world's most famous physicists, Erwin Schrodinger and Albert Einstein were uncomfortable with this strangeness of the quantum world being "neither this nor that." In a series of exchanged letters they proposed various thought experiments to analogize their objection. The one that has stuck historically comes from Schrodinger and has come to be known as The Schrodinger Cat Paradox.

Schrodinger imagined a cat in a box in which was located a vial of poison and a hypersensitive Geiger counter adjusted to detect a high energy electron coming from a specific atom. If the counter detected the electron, it would activate a hammer to break the vial which would release the poison and kill the cat. If no electron was detected, then no hammer-strike, no poison release, and the cat would be alive. Through this thought experiment, Schrodinger, with Einstein, was attempting to show the absurdity of the quantum view, which held that the electron's location could only be said to have a known location once it was observed. Before that observation, the electron (and thus the cat) were supposed to be in a state called "quantum indeterminacy," and thus the cat was both dead and alive.

The locations of quantum objects, like the electron, are described in quantum theory as existing in multiple locations at once (called *superposition*). These multiple locations, according to the descriptive equations, "collapse" into one position once observed. Don't worry if this is not intuitively obvious. Richard Feynman, the Nobel Prize-winning Caltech physicist, is widely quoted as saying, "If you think you understand quantum mechanics, you don't understand quantum mechanics."

### Clinical Uncertainty "versus" Quantum Uncertainty

How is this relevant to clinical medicine? Like quantum physicists, clinicians are frequently dealing with the issue of uncertainty. A patient presents to us with puzzling symptoms. We conduct our investigations, including a focused interview, a physical examination, laboratory testing of various body fluids, imaging studies, and physiologic monitoring. Once we have sent the patient for a supposedly definitive test — let's call it an old vernacular term, a "CAT scan" — we wait, a bit like Schrodinger, to find out if our patient "has something or doesn't," if their symptoms or signs correlate with a disease. Between the decision to order the test and the time of the arrival of the results, the patient and the doctor are in a state of "clinical indeterminacy." In many cases even after the scan results arrive, there remains a persistent level of such indeterminacy. We want (and our patients expect) a definitive answer, but so often the best we can offer them is a probabilistic one. We say things at this point like: *You might have cancer. You may have had a stroke. There may be early signs of multiple sclerosis.*

Clinical indeterminacy is caused by a kind of superposition of clinical possibilities (the so-called "differential diagnosis") encountering informational inadequacy or conflict. One obvious response is to simply do more testing. And yet, gathering more information has its own costs: money, time, pain, risk. A biopsy, for example, can solve a diagnostic dilemma, but often does not. With the Schrodinger Box, we open it and, voila — the cat is determined to be either alive or dead. With our patient, we do the test and sometimes — like stacking Russian dolls — there is simply another layer of more ambiguity. That said, one key difference between the Schrodinger Cat conundrum and a medical one is the iterative nature of clinical decision making. Repeatedly returning to a diagnostic or therapeutic dilemma allows additional and additive reconsiderations and adjustments. We use both different techniques and take advantage of time, per se, to reduce uncertainty.

Uncertainty comes in many shapes and sizes. Prognostic: What will the outcome be with no intervention? How much can we improve upon that with treatment? Diagnostic: Might the results of the test give a false negative or false positive? How much to trust a positive

PET scan in a patient with a lung nodule or a negative treadmill test in a patient with chest pain? Might a biopsy cause new problems such as a pneumothorax or infection? Therapeutic: Might the standard treatment fail or result in an unacceptably severe side effect?

## How the Medical Profession Has Intellectually Responded to Clinical Uncertainty

One helpful development that we as a profession have invented are clinical guidelines for dealing with uncertainty. Some of the more common ones include the Fleischner Society criteria dealing with pulmonary nodules; the BiRADS system interpreting breast imaging; American Urologic Association on using PSA to screen for prostate cancer; The American Heart Association guidelines for initiating statin therapy for hyperlipidemia; the American Academy of Dermatology ABCDE criteria for deciding which pigmented skin lesions to biopsy. But remember, these guidelines create "rules of reasonableness" rather than absolute truths. There will always be patients whose clinical stories defy the guidelines: the benign appearing lung nodule that grows rapidly and metastasizes; the BiRADS Class 5 mammogram with innocent pathology; the low risk patient whose first presentation of coronary heart disease is sudden death; the low PSA prostate cancer; dark irregular skin lesion that turn out to be nothing but an irritated keratosis. If you practice long enough, you are bound to choose a reasonable clinical path with a deleterious outcome: choosing to treat a condition that would have behaved innocently if left alone; and doing watchful waiting on a condition that exploded unexpectedly. We can take all the facts of the case into consideration, apply the best available data and guidelines, draw on Bayes' Theorem to guide us with respect to pre- and post-test probabilities and still produce a bad outcome for our patient. Like Schrodinger's Cat, we can be both right and wrong.

## The Challenges in Communicating Uncertainty

Thinking probabilistically is much easier in the abstract than in the concrete case of your own patient's health. Not only are there the cluster of clinical facts, there is also the dual communication variable that arises from the beliefs, experiences and personalities of the

doctor and the patient. What is each of their risk tolerances? How much do each of them approach uncertainty from a scientific perspective and how much from a religious or spiritual perspective? Are the doctor or patient more "aggressive" or more stoical? Does the doctor or the patient have in their memory an example of someone that did particularly well or badly with the proposed clinical pathway? How much do both of them tolerate waiting in a setting of uncertainty?

We know that some patients, when sick, regress to a more infantile state and want the doctor to play the role of parent. They say, in other words: just tell me what to do, Doc. They want certainty the way a child, when she hears thunder, wants to be told, "Everything will be all right." Other patients want us to be a "mere consultant" to their own role as the CEO of their own life. As the old Oslerian proverb advises, physicians need to try to understand both what sort of disease the patient has and what sort of patient has the disease. As doctors we have a complex role to play, doing our best to be as reassuring as the facts allow. We have to think in the language of probabilities and talk in a language that is appropriate to the patient's personality, sometimes in stark statistical terms and sometimes with a softer (more reassuring) gloss.

## Uncertainty Is Inevitable. Expect It

Uncertainty is woven into the fabric of clinical medicine and into reality itself. All the ways of knowing something are fraught with some degree of unreliability. Measurements can be mistaken, our senses can be fooled, our instruments can malfunction, artifacts can masquerade as facts and our inferences can be misled by a host of cognitive biases. If only it was as simple as Sherlock Holmes advised in his oft-quoted guide to logic: "When you have eliminated all which is impossible, then whatever remains, however improbable, must be the truth." If only! The problem with trusting Sherlock in this regard is that it assumes that we have truly eliminated (or in medical terms "ruled out") the entire universe of competing explanations.

### Schrodinger's Cat Scan

Inserting a needle for tissue inspection
We hope it's a target our probes can get at
Dismayed that we haven't gained further direction
Not unlike the condition of Schrodinger's Cat.

The test came back fuzzy, more info is needed
The stakeholders squabble for "this" over "that"
Does the patient have patience to wait and repeat it?
Can we live with that vagueness of Schrodinger's Cat?

The surgeon insists on an en bloc removal
But the stubborn pathologist started a spat
The treating oncologist seeks my approval
I call on the spirit of Schrodinger's Cat.

The challenge of acting in hazy conditions
Is to swing in the darkness when we're up to bat
That is the blessing and curse of physicians
We share with the puzzle of Schrodinger's Cat.

## Uncertainty Is Intractable. Deal With It

No matter how much progress we make at determining the best and most auspicious path for diagnosing and treating puzzling clinical problems, the idea that we will ever always get it right is a fantasy. The scientific method for separating out what is from what isn't so, helps us by crossing off the list of possibilities those that have a high likelihood of being false and thus whittling away at the list. But there will always be stragglers. There will always be exceptions to the rules. Our algorithms will become increasingly accurate, but like any expert system, will have flaws both on the input and the output. Even in the best of scenarios we are always dealing with currently available information. Before angiotensin receptors were discovered, there were no ARBs for hypertension. Before PET scans, diagnostic biopsies and their attendant risk were much more common.

For Schrodinger and Einstein, the Cat Paradox was a thought experiment meant to challenge the strangeness of the quantum world. As doctors we can adapt it to be a rehearsal for approaching a certain kind of clinical scenario. There are limits to knowledge. Omniscience doesn't exist. And however much we study and tap into networks of information, what we still don't know is boundless.

Medicine is a practical craft as well as a science. In our off-hours we might explore the theory of indeterminacy but in our on-hours we are called up to decide and act.

Doing so in full awareness of uncertainty has the potential to make us dithering and indecisive but also has the potential to make us humble — and even, dare I say it, wise. SDP

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*Dr. Bressler, SDCMS-CMA member since 1988, is a former chair of the Biomedical Ethics Committee at Scripps Mercy Hospital and a longtime contributing writer to* San Diego Physician.