

Complications

A Surgeon's Notes on an Imperfect Science

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The Case of the Red Leg

Seeing patients with one of the surgery professors in his clinic one afternoon, I was struck by how often he had to answer his patients' questions, "I do not know." These are four little words a doctor tends to be reluctant to utter. We're supposed to have the answers. We want to have the answers. But there was not a single person he did not have to say those four little words to that day.

There was the patient who had come in two weeks after an abdominal hernia repair: "What's this pain I feel next to the wound?"

There was the patient one month after a gastric-bypass operation: "Why haven't I lost weight yet?"

There was the patient with a large pancreatic cancer: "Can you get it out?"

And to all, the attending gave the same reply: "I do not know."

A doctor still must have a plan, though. So to the hernia patient, he said, "Come back in a week and let's see how the pain's doing." To the gastric-bypass patient, "It'll be all right," and asked her to come back in a month. To the cancer patient, "We can try to get it out"—and although another surgeon thought he shouldn't (given the tumor's appearance on a scan, operation would be futile and risky, the colleague said), and he himself thought the odds of success were

slim at best, he and the patient (who was only in her forties, with still-young children at home) decided to go ahead.

The core predicament of medicine—the thing that makes being a patient so wrenching, being a doctor so difficult, and being a part of a society that pays the bills they run up so vexing—is uncertainty. With all that we know nowadays about people and diseases and how to diagnose and treat them, it can be hard to see this, hard to grasp how deeply the uncertainty runs. As a doctor, you come to find, however, that the struggle in caring for people is more often with what you do not know than what you do. Medicine's ground state is uncertainty. And wisdom—for both patients and doctors—is defined by how one copes with it.

This is the story of one decision under uncertainty.

It was two o'clock on a Tuesday afternoon in June. I was in the middle of a seven-week stint as the senior surgical resident in the emergency room. I had just finished admitting someone with a gallbladder infection and was attempting to sneak out for a bite to eat when one of the emergency room physicians stopped me with yet another patient to see: a twenty-three-year-old, Eleanor Bratton, with a red and swollen leg. (The names of patients and colleagues have been changed.) "It's probably only a cellulitis"—a simple skin infection—"but it's a bad one," he said. He had started her on some intravenous antibiotics and admitted her to the medical service. But he wanted me to make sure there wasn't anything "surgical" going on—an abscess that needed draining or some such. "Would you mind taking a quick look?" Groan. No. Of course not.

She was in the observation unit, a separate, quieter ward within the ER where she could get antibiotics pumped into her arm and wait for admitting to find her a bed upstairs. The unit's nine beds are arrayed in a semicircle, each separated by a thin blue curtain, and I found her in Bed 1. She looked fit, athletic, and almost teenage, with blond hair tight in a ponytail, nails painted gold, and her eyes fixed on a television. There did not seem anything seriously ill about her.

She was lying comfortably, a sheet pulled up to her waist, the head of the bed raised. I glanced at her chart and saw that she had good vital signs, no fever, and no past medical problems. I walked up and introduced myself: "Hi, I'm Dr. Gawande. I'm the senior surgical resident down here. How are you doing?"

"You're from surgery?" she said, with a look that was part puzzlement and part alarm. I tried to reassure her. The emergency physician was "only being cautious," I said, and having me see her to make sure it was nothing more than a cellulitis. All I wanted to do was ask a few questions and look at her leg. Could she tell me what had been going on? For a moment she said nothing, still trying to compute what to think about all this. Then she let out a sigh and told me the story.

That weekend she had gone back home to Hartford, Connecticut, to attend a wedding. (She had moved to Boston with some girlfriends the year before, after graduating from Ithaca College, and landed work planning conferences for a downtown law firm.) The wedding had been grand and she had kicked off her shoes and danced the whole night. The morning after, however, she woke up with her left foot feeling sore. She had a week-old blister on the top of her foot from some cruddy sandals she had worn, and now the skin surrounding the blister was red and puffy. She didn't think too much of this at first. When she showed her foot to her father, he said he thought it looked like a bee sting or maybe like she'd gotten stepped on dancing the night before. By late that afternoon, however, riding back to Boston with her boyfriend, "my foot really began killing me," she said. The redness spread, and during the night she got chills and sweats and a fever of one hundred and three degrees. She took ibuprofen every few hours, which got her temperature down but did nothing for the mounting pain. By morning, the redness reached halfway up her calf, and her foot had swelled to the point that she could barely fit it into a sneaker.

Eleanor hobbled in on her roommate's shoulder to see her internist that afternoon and was diagnosed with a cellulitis. Cellulitis is

your garden-variety skin infection, the result of perfectly ordinary bacteria in the environment getting past the barrier of your skin (through a cut, a puncture wound, a blister, whatever) and proliferating within it. Your skin becomes red, hot, swollen, and painful; you feel sick; fevers are common; and the infection can spread along your skin readily—precisely the findings Eleanor had. The doctor got an X ray to make sure the bone underneath was not infected. Satisfied that it was not, she gave Eleanor a dose of intravenous antibiotics in the office, a tetanus shot, and a prescription for a week's worth of antibiotic pills. This was generally sufficient treatment for a cellulitis, but not always, the doctor warned. Using an indelible black marker, she traced the border of the redness on Eleanor's calf. If the redness should extend beyond this line, the doctor instructed, she should call. And, regardless, she should return the next day for the infection to be checked.

The next morning, Eleanor said—this morning—she woke up with the rash beyond the black line, a portion stretching to her thigh, and the pain worse than ever. She phoned the doctor, who told her to go to the emergency room. She'd need to be admitted to the hospital for a full course of intravenous antibiotic treatment, the doctor explained.

I asked Eleanor if she had had any pus or drainage from her leg. No. Any ulcers open up in her skin? No. A foul smell or blackening of her skin? No. Any more fevers? Not since two days ago. I let the data roll around in my head. Everything was going for a cellulitis. But something was pricking at me, making me alert.

I asked Eleanor if I could see the rash. She pulled back the sheet. The right leg looked fine. The left leg was red—a beefy, uniform, angry red—from her forefoot, across her ankle, up her calf, past the black ink line from the day before, to her knee, with a further tongue of crimson extending to the inside of her thigh. The border was sharp. The skin was hot and tender to the touch. The blister on the top of her foot was tiny. Around it the skin was slightly bruised. Her toes were uninvolved, and she wiggled them for me

without difficulty. She had a harder time moving the foot itself—it was thick with edema up through the ankle. She had normal sensation and pulses throughout her leg. She had no ulcers or pus.

Objectively, the rash had the exact appearance of a cellulitis, something antibiotics would take care of. But another possibility lodged in my mind now, one that scared the hell out of me. It was not for logical reasons, though. And I knew this perfectly well.

Start

→ Decisions in medicine are supposed to rest on concrete observations and hard evidence. But just a few weeks before, I had taken care of a patient I could not erase from my mind. He was a healthy fifty-eight-year-old man who had had three or four days of increasing pain in the left side of his chest, under his arm, where he had an abrasion from a fall. (For reasons of confidentiality, some identifying details have been changed.) He went to a community hospital near his home to get it checked out. He was found to have a small and very ordinary skin rash on his chest and was sent home with antibiotic pills for cellulitis. That night the rash spread eight inches. The following morning he spiked a fever of one hundred and two degrees. By the time he returned to the emergency room, the skin involved had become numb and widely blistered. Shortly after, he went into shock. He was transferred to my hospital and we quickly took him to the OR.

Compare this explanation to those in research articles,

He didn't have a cellulitis but instead an extremely rare and horrendously lethal type of infection known as necrotizing fasciitis (fash-see-EYE-tiss). The tabloids have called it a disease of "flesh-eating bacteria" and the term is not an exaggeration. Opening the skin, we found a massive infection, far worse than what appeared from the outside. All the muscles of the left side of his chest, going around to his back, up to his shoulder, and down to his abdomen, had turned gray and soft and foul with invading bacteria and had to be removed. That first day in the OR, we had had to take even the muscles between his ribs, a procedure called a birdcage thoracotomy. The next day we had to remove his arm. For a while, we actually thought

we had saved him. His fevers went away and the plastic surgeons reconstructed his chest and abdominal wall with transfers of muscle and sheets of Gortex. One by one, however, his kidneys, lungs, liver, and heart went into failure, and then he died. It was among the most awful cases I have ever been involved in.

What we know about necrotizing fasciitis is this: it is highly aggressive and rapidly invasive. It kills up to 70 percent of the people who get it. No known antibiotic will stop it. The most common bacterium involved is group A *Streptococcus* (and, in fact, the final cultures from our patient's tissue grew out precisely this). It is an organism that usually causes little more than a strep throat, but in certain strains it has evolved the ability to do far worse. No one knows where these strains come from. As with a cellulitis, they are understood to enter through breaks in the skin. The break can be as large as a surgical incision or as slight as an abrasion. (People have been documented to have gotten the disease from a rug burn, a bug bite, a friendly punch in the arm, a paper cut, a blood draw, a toothpick injury, and chicken pox lesions. In many the entry point is never found at all.) Unlike with a cellulitis, the bacteria invade not only skin but also deep underneath, advancing rapidly along the outer sheaths of muscle (the fascia) and consuming whatever soft tissue (fat, muscle, nerves, connective tissue) they find. Survival is possible only with early and radical excisional surgery, often requiring amputation. To succeed, however, it must be done early. By the time signs of deep invasion are obvious—such as shock, loss of sensation, widespread blistering of the skin—the person is usually unsalvageable. <

End

Standing at Eleanor's bedside, bent over examining her leg, I felt a little foolish considering the diagnosis—it was a bit like thinking the ebola virus had walked into the ER. True, in the early stages, a necrotizing fasciitis can look just like a cellulitis, presenting with the same redness, swelling, fever, and high white blood cell count. But there is an old saying taught in medical school: if you hear hoofbeats in Texas, think horses not zebras. Only about a thousand cases of necrotizing fasciitis occur in the entire United States each year,

mainly in the elderly and chronically ill—and well over *three million* cases of cellulitis. What's more, Eleanor's fever had gone away; she didn't look unusually ill; and I knew I was letting myself be swayed by a single, recent, anecdotal case. If there were a simple test to tell the two diagnoses apart, that would have been one thing. But there is none. The only way is to go to the operating room, open the skin, and look—not something you want to propose arbitrarily.

Yet here I was. I couldn't help it. I was thinking it.

I pulled the sheets back over Eleanor's legs. "I'll be back in a minute," I said. I went to a phone well out of her earshot and paged Thaddeus Studdert, the general surgeon on call. He called back from the OR and I quickly outlined the facts of the case. I told him the rash was probably just a cellulitis. But then I told him there was still one other possibility that I couldn't get out of my head: a necrotizing fasciitis.

The line went silent for a beat.

"Are you serious?" he said.

"Yes," I said, trying not to hedge. I heard an epithet muttered. He'd be right up, he said.

As I hung up the phone, Eleanor's father, a brown-and-gray-haired man in his fifties, came around with a sandwich and soda for her. He had been with her all day, having driven up from Hartford, but when I was seeing her, it turned out, he had been gone getting her lunch. Catching sight of the food, I jumped to tell him not to let her eat or drink "just yet" and with that the cat began crawling out of the bag. It was not the best way to introduce myself. He was immediately taken aback, recognizing that an empty stomach is what we require for patients going to surgery. I tried to smooth matters over, saying that holding off was merely "routine procedure" until we had finished our evaluation. Nonetheless, Eleanor and her father looked on with new dread when Studdert arrived in his scrubs and operating hat to see her.

He had her tell her story again and then uncovered her leg to examine it. He didn't seem too impressed. Talking by ourselves, he told me that the rash looked to him only "like a bad cellulitis." But could he say for sure that it was not necrotizing fasciitis? He could not. It is a reality of medicine that choosing to *not* do something—to not order a test, to not give an antibiotic, to not take a patient to the operating room—is far harder than choosing to do it. Once a possibility has been put in your mind—especially one as horrible as necrotizing fasciitis—the possibility does not easily go away.

Studdert sat down on the edge of her bed. He told Eleanor and her dad that her story, symptoms, and exam all fit with cellulitis and that that was what she most likely had. But there was another, very rare possibility, and, in a quiet and gentle voice, he went on to explain the unquiet and ungente effects of necrotizing fasciitis. He told them of the "flesh-eating bacteria," the troublingly high death rate, the resistance to treatment by antibiotics alone. "I think it is unlikely you have it," he told Eleanor. "I'd put the chances"—he was guessing here—"at well under five percent." But, he went on, "without a biopsy, we cannot rule it out." He paused for a moment to let her and her father absorb this. Then he started to explain what the procedure involved—how he would take an inch or so of skin plus underlying tissue from the top of her foot, and perhaps from higher up on her leg, and then have a pathologist immediately look at the samples under the microscope.

Eleanor went rigid. "This is crazy," she said. "This doesn't make any sense." She looked frantic, like someone drowning. "Why don't we just wait and see how the antibiotics go?" Studdert explained that this was a disease that you cannot sit on, that you had to catch it early to have any chance of treating it. Eleanor just shook her head and looked down at her covers.

Studdert and I both turned to her father to see what he might have to say. He had been silent to this point, standing beside her, his brow knitted, hands gripped behind him, tense, like a man trying to

stay upright on a pitching boat. He asked about specifics—how long a biopsy would take (fifteen minutes), what the risks were (a deep wound infection was the biggest one, ironically), whether the scars go away (no), when it would be done if it were done (within the hour). More gingerly, he asked what would happen if the biopsy were positive for the disease. Studdert repeated that he thought the chances were less than 5 percent. But if she had it, he said, we'd have to "remove all the infected tissue." He hesitated before going on. "This can mean an amputation," he said. Eleanor began to cry. "I don't want to do this, Dad." Mr. Bratton swallowed hard, his gaze fixed somewhere miles beyond us.

In recent years, we in medicine have discovered how discouragingly often we turn out to do wrong by patients. For one thing, where the knowledge of what the right thing to do exists, we still too frequently fail to do it. Plain old mistakes of execution are not uncommon, and we have only begun to recognize the systemic frailties, technological faults, and human inadequacies that cause them, let alone how to reduce them. Furthermore, important knowledge has simply not made its way far enough into practice. Among patients recognized as having heart attacks, for example, it is now known that an aspirin alone will save lives and that even more can be saved with the immediate use of a thrombolytic—a clot-dissolving drug. A quarter of those who should get an aspirin do not, however; and half who should get a thrombolytic do not. Overall, physician compliance with various evidence-based guidelines ranges from over 80 percent of patients in some parts of the country to less than 20 percent in others. Much of medicine still lacks the basic organization and commitment to make sure we do what we know to do.

But spend almost any amount of time with doctors and patients, and you will find that the larger, starker, and more painful difficulty is the still abundant uncertainty that exists over what should be done in many situations. The gray zones in medicine are considerable, and every day we confront situations like Eleanor's—ones in which

clear scientific evidence of what to do is missing and yet choices must be made. Exactly which patients with pneumonia, for example, should be hospitalized and which ones sent home? Which back pains treated by surgery and which by conservative measures alone? Which patients with a rash taken to surgery and which just observed on antibiotics? For many cases, the answers can be obvious. But for many others, we simply do not know. Expert panels asked to review actual medical decisions have found that in a quarter of hysterectomy cases, a third of operations to put tubes in children's ears, and a third of pacemaker insertions (to pick just three examples), the science did not exist to say whether the procedures would help those particular patients or not.

In the absence of algorithms and evidence about what to do, you learn in medicine to make decisions by feel. You count on experience and judgment. And it is hard not to be troubled by this.

A couple weeks before seeing Eleanor, I had seen an arthritic and rather elderly woman (she was born before Woodrow Wilson was president) who had come in complaining of a scaring abdominal pain that radiated into her back. I learned that she had recently been found to have an aortic aneurysm in her abdomen and instantly my alarm bells went off. Examining her gingerly, I could feel the aneurysm, a throbbing and tender mass just deep to her abdominal muscles. She was stable, but it was on the verge of rupturing, I was convinced. The vascular surgeon I called in agreed. We told the woman that immediate surgery was the only option to save her. We warned her, however, that it was a big surgery, with a long recovery in intensive care and probably in a nursing home afterward (she still lived independently), a high risk that her kidneys would not make it, and a minimum 10 to 20 percent chance of death. She did not know what to do. We left her with her family to think on the decision, and then I returned fifteen minutes later. She said she would not go ahead with surgery. She just wanted to go home. She had lived a long life, she said. Her health had long been failing. She had drawn up her will and was already measuring her remaining days in coffee

spoons. Her family was devastated, but she was steady-voiced and constant. I wrote out a pain medication prescription for her son to fill for her, and half an hour later she left, understanding full well that she would die. I kept her son's number and, when a couple weeks had passed, called him at home to hear how he had weathered the aftermath. His mother, however, answered the telephone herself. I stammered a hello and asked how she was doing. She was doing well, she said, thank you. A year later, I learned, she was still alive and living on her own.

Three decades of neuropsychology research have shown us numerous ways in which human judgment, like memory and hearing, is prone to systematic mistakes. The mind overestimates vivid dangers, falls into ruts, and manages multiple pieces of data poorly. It is swayed unduly by desire and emotion and even the time of day. It is affected by the order in which information is presented and how problems are framed. And if we doctors believed that, with all our training and experience, we escape such fallibilities, the notion was dashed when researchers put us under the microscope.

A variety of studies have shown physician judgment to have these same distortions. One, for example, from the Medical College of Virginia, found that doctors ordering blood cultures for patients with fever overestimated the probability of infection by four- to ten-fold. Moreover, the highest overestimates came from the doctors who had recently seen *other* patients with a blood infection. Another, from the University of Wisconsin, found evidence of a Lake Wobegon effect ("Lake Wobegon: where the women are strong, the men are good-looking, and all the children are above average"): the vast majority of surgeons believed the mortality rate for their own patients to be lower than the average. A study from Ohio University and Case Western Reserve Medical School examined not just the accuracy but also the confidence of physicians' judgments—and found no connection between them. Doctors with high confidence in a judgment they made proved no more accurate than doctors with low confidence.

David Eddy, a physician and expert on clinical decision making, reviewed the evidence in an unflinching series of articles published over a decade ago in the *Journal of the American Medical Association*. And his conclusion was damning. "The plain fact is," he wrote, "that many decisions made by physicians appear to be arbitrary—highly variable, with no obvious explanation. The very disturbing implication is that this arbitrariness represents, for at least some patients, suboptimal or even harmful care."

But in the face of uncertainty, what other than judgment does a physician have—or a patient have, for that matter? Months after seeing Eleanor that spring afternoon, I spoke with her father about the events that had unfolded.

"It felt like it was five minutes from having a swollen foot to being told that she could possibly be losing her life," Mr. Bratton said.

A chef who had owned his own delicatessen for seventeen years and now taught at a culinary arts school in Hartford, he knew no one in Boston. He knew our hospital was affiliated with Harvard, but he knew enough to realize that this did not necessarily mean we were anything special. I was just the resident on duty that day; Studdert was likewise just the surgeon on call. Eleanor had left things to her father now, and he tried to take stock. Some clues were encouraging. Studdert's being in scrubs and an operating hat, having just come from the OR, seemed to suggest experience and know-how. Indeed, it turned out he had seen a number of patients with necrotizing fasciitis before. He was also self-assured, without being bullying, and took time to explain everything. But Bratton was shocked at how young he appeared. (Studdert was, in fact, just thirty-five.)

"This is my daughter we are talking about," Bratton remembered thinking at the time. "Isn't there anybody better than you?" Then he knew what to do. He turned to Studdert and me and spoke softly.

"I'd like another opinion," was what he said.

We agreed to the request, and it did not upset us. We were not oblivious to the conundrums here. Eleanor's fever had gone away; she didn't look unusually ill; and likely the biggest reason I had thought of flesh-eating bacteria was that terrible case I had seen a few weeks before. Studdert had put a numeric estimate on the chances of the disease—"well under five percent" he had said—but we both knew it was a stab in the dark (a measure of probability and confidence, but how good is that?) and a vague one at that (how *much* less than 5 percent?). Hearing what someone else might think seemed useful, we both thought.

But, for the Brattons, I had to wonder how useful it would be. If opinions disagreed, then what? And if they did not, wouldn't the same fallibilities and questions remain? Furthermore, the Brattons did not know anyone to call and had to ask if we had any ideas.

We suggested calling David Segal, a plastic surgeon on staff who like Studdert had seen such cases before. They agreed. I called Segal and filled him in. He came down within minutes. In the end what he gave Eleanor and her father was mainly confidence, from what I could see.

Segal is a rumpled and complexly haired man, with pen stains on his white coat and glasses that seem too large for his face. He is the only plastic surgeon I know who looks like he has a Ph.D. from M.I.T. (which, as it happens, he does). But he seemed, as Bratton later put it, "not young." And he did not disagree with what Studdert had said. He listened to Eleanor's story and looked carefully at her leg and then said that he too would be surprised if she turned out to have the bacteria. But he agreed that it could not be ruled out. So what else was there but to biopsy?

Eleanor and her dad now agreed to go ahead. "Let's get it over with," she said. But then I brought her the surgical consent form to sign. On it, I had written not only that the procedure was a "biopsy of the left lower extremity" but also that the risks included a "possible need for amputation." She cried out when she saw the words. It took

her several minutes alone with her father before she could sign. We had her in the operating room almost immediately after. A nurse brought her father to the family waiting area. He tracked her mother down by cell phone. Then he sat and bowed his head, and made some prayers for his child.

There is, in fact, another approach to decision making, one advocated by a small and struggling coterie in medicine. The strategy, long used in business and the military, is called decision analysis, and the principles are straightforward. On a piece of paper (or a computer), you lay out all your options, and all the possible outcomes of those options, in a decision tree. You make a numeric estimate of the probability of each outcome, using hard data when you have it and a rough prediction when you don't. You weigh each outcome according to its relative desirability (or "utility") to the patient. Then you multiply out the numbers for each option and choose the one with the highest calculated "expected utility." The goal is to use explicit, logical, statistical thinking instead of just your gut. The decision to recommend annual mammograms for all women over age fifty was made this way and so was the U.S. decision to bail out Mexico when its economy tanked. Why not, the advocates ask, individual patient decisions?

Recently, I tried "treeing out" (as the decision buffs put it) the choice Eleanor faced. The options were simple: to biopsy or not biopsy. The outcomes quickly got complicated, however. There was: not being biopsied and doing fine; not being biopsied, getting diagnosed late, going through surgery, and surviving anyway; not being biopsied and dying; being biopsied and getting only a scar; being biopsied and getting a scar plus bleeding from it; being biopsied, having the disease and an amputation, but dying anyway; and so on. When all the possibilities and consequences were penciled out, my decision tree looked more like a bush. Assigning the probabilities for each potential twist of fate seemed iffy. I found what data I could from the medical literature and then had to extrapolate a good deal. And determining the relative desirability of the outcomes seemed

impossible, even after talking to Eleanor about them. Is dying a hundred times worse than doing fine, a thousand times worse, a million? Where does a scar with bleeding fit in? Nonetheless, these are the crucial considerations; the decision experts argue, and when we decide by instinct, they say, we are only papering this reality over.

Producing a formal analysis in any practical time frame proved to be out of the question, though. It took a couple of days—not the minutes that we had actually had—and a lot of back and forths with two decision experts. But it did provide an answer. According to the final decision tree, we should *not* have gone to the OR for a biopsy. The likelihood of my initial hunch being right was too low, and the likelihood that catching the disease early would make no difference anyway was too high. Biopsy could not be justified, the logic said.

I don't know what we would have made of this information at the time. We didn't have the decision tree, however. And we went to the OR.

The anesthesiologist put Eleanor to sleep. A nurse then painted her leg with antiseptic, from her toes up to her hip. With a small knife, Studdert cut out an inch-long ellipse of skin and tissue from the top of her foot, where the blister was, down to her tendon. The specimen was plopped into a jar of sterile saline and rushed to the pathologist to look at. We then took a second specimen—going deeper now, down into muscle—from the center of the redness in her calf, and this was sent on as well.

At first glance beneath her skin, there was nothing apparent to alarm us. The fat layer was yellow, as it is supposed to be, and the muscle was a healthy glistening red and bled appropriately. When we probed with the tip of a clamp inside the calf incision, however, it slid unnaturally easily along the muscle, as if bacteria had paved a path. This is not a definitive finding, but enough of one that Studdert let out a sudden, disbelieving, "Oh shit." He pulled off his gloves and gown to go see what the pathologist had found, and I followed right

behind him, leaving Eleanor asleep in the OR to be watched over by another resident and the anesthesiologist.

An emergent pathology examination is called a frozen section, and the frozen section room was just a few doors down the hallway. The room was small, the size of a kitchen. In the middle of it stood a waist-high laboratory table with a black slate countertop and a canister of liquid nitrogen in which the pathologist had quick-frozen the tissue samples. Along a wall was the microtome that he had used to slice micron-thin sections of the tissue to put on glass slides. We walked in just as he finished preparing the slides. He took them to a microscope and began scanning each one methodically, initially under low power magnification and then under high power. We hovered, no doubt annoyingly, awaiting the diagnosis. Minutes passed in silence.

"I don't know," the pathologist muttered, still staring through the eyepieces. The features he saw were "consistent with necrotizing fasciitis," he said, but he wasn't sure he could clinch the diagnosis. He said he would have to call in a dermatopathologist, a pathologist who specializes in looking at skin and soft tissue. It took twenty minutes before the specialist arrived and another five before he could make his call, our frustration growing. "She's got it," he finally announced grimly. He had detected some tiny patches where the deep tissue had begun to die. No cellulitis could do that, he said.

Studdert went to see Eleanor's father. When he walked into the crowded family waiting area, Bratton caught the expression on his face and began yelling, "Don't look at me like that! *Don't look at me like that!*" Studdert took him to a private side room, closed the door behind them, and told him that she appeared to have the disease. He would have to move fast, he said. He was not sure he could save her leg and he was not sure if he could save her life. He would need to open her leg up, see how bad things were, and then go from there. Bratton was overcome, crying and struggling to get out words. Studdert's own eyes were wet. Bratton said to "do what you have to

do." Studdert nodded and left. Bratton then called his wife. He told her the news and then gave her a moment to reply. "I will never forget what I heard on the other end of the line," he later said. "Something, some sound, I cannot and will never be able to describe."

Decisions compound themselves, in medicine like in anything else. No sooner have you taken one fork in the road than another and another come upon you. The critical question now was what to do. In the OR, Segal joined Studdert to offer another set of hands. Together they slit open Eleanor's leg, from the base of her toes, across her ankle, to just below her knee, to get a full view of what was going on inside. They pulled the opening wide with retractors.

The disease was grossly visible now. In her foot and most of her calf, the outer, fascial layer of her muscles was gray and dead. A brownish dishwater fluid was seeping out with a faint smell of decay. (Tissue samples and bacterial cultures would later confirm that this was toxic group A *Streptococcus* advancing rapidly up her leg.)

"I thought about a BKA," a below-knee amputation, Studdert says, "even an AKA," an above-knee amputation. No one would have faulted him for doing either. But he found himself balking. "She was such a young girl," he explains. "It may seem harsh to say, but if it was a sixty-year-old man I would've taken the leg without question." This was partly, I think, a purely emotional unwillingness to cut off the limb of a pretty twenty-three-year-old—the kind of sentimentalism that can get you in trouble. But it was also partly instinct again, an instinct that her youth and fundamentally good health might allow him to get by with just removing the most infested tissue (a "debridement") and washing out her foot and leg. Was this a good risk to take, with one of the deadliest bacteria known to man loose in her leg? Who knows? But take it he did.

For two hours, using scissors and electrocautery, he and Segal cut and stripped off the necrotic outer layers of her muscle, starting from the webbing of her toes, going up to the tendons of her calf.

They took out tissue going three-quarters of the way around. Her skin hung from her leg like open coat flaps. Higher up, inside the thigh, they reached fascia that looked pink-white and fresh, very much alive. They poured two liters of sterile saline through the leg, trying to wash out as much of the bacteria as possible.

At the end, Eleanor seemed to be holding steady. Her blood pressure remained normal. Her temperature was ninety-nine degrees. Her oxygen levels were fine. And the worst-looking tissue had been removed from her leg.

But her heart rate was running a bit too fast, one hundred and twenty beats a minute, a sign that the bacteria had provoked a systemic reaction. She was requiring large amounts of intravenous fluid. Her foot looked dead. And her skin was still burning red with infection.

Studdert stood firm with his decision not to take more, but you could see he was uneasy about it. He and Segal conferred and thought of one other thing they could try, an experimental therapy called hyperbaric oxygen. It involved putting Eleanor in one of those pressure chambers they put divers in when they get the bends—a perhaps kooky-sounding notion but not a ludicrous one. Immune cells require oxygen to kill bacteria effectively and putting a person under double or higher atmospheric pressure for a few hours a day increases the oxygen concentration in tissue tremendously. Segal had been impressed by results he had gotten using the therapy in a couple of burn patients with deep wound infections. True, studies had not proven that it would work against necrotizing fasciitis. But suppose it could? Everyone latched onto the treatment immediately. At least it made us feel as if we were doing something about all the infection we were leaving behind.

We did not have a chamber at our hospital, but a hospital across town did. Someone got on the phone and within a few minutes we had a plan for ambulancing Eleanor over with one of our nurses for two hours under 2.5 atmospheres of pressurized oxygen. We left her

wound open to drain, laid wet gauze inside it to keep the tissues from desiccating, and wrapped her leg in white bandages. Before sending her over, we wheeled her from the OR to intensive care, where we could make sure she would be stable enough for the trip.

It was eight o'clock at night now. Eleanor woke up nauseated and in pain. But she was sharp-witted enough to surmise from the crowd of nurses and doctors around her that something was wrong.

"Oh God, my leg."

She reached down to find it, and for a few panicked moments she wasn't sure she could. Slowly, she convinced herself that she could see it, touch it, feel it, move it. Studdert put his hand on her arm. He explained what he had found, what he had done, and what more there would be to do. She took the information with more grit and fight than I knew she had. Her whole family had now arrived to be with her, and looked as though an SUV had hit them. But Eleanor pulled the sheet back over her leg, took in the monitors flashing their green and orange lights and the IV lines running into her arms, and said, simply, "OK."

The hyperbaric chamber that night was, as she describes it, "like a glass coffin." She lay inside it on a narrow mattress with nowhere to put her arms except straight down or folded across her chest, a panel of thick plexiglass a foot from her face, and an overhead hatch sealed tight with turns of a heavy wheel. As the pressure increased, her ears kept popping, as if she were diving down into a deep ocean. Once the pressure reached a certain point, she would be stuck, the doctors had cautioned. Even if she should start throwing up, they could not get to her, for the pressure could only be released slowly or it would give her the bends and kill her. "One person had a seizure inside," she remembered them telling her. "It took them twenty minutes to get to him." Lying there enclosed, more ill than she'd ever imagined one could be, she felt far away and almost totally alone. It's just me and the bacteria in here, she thought to herself.

The next morning, we took her back to the operating room, to

see if the bacteria had spread. They had. The skin over most of her foot and front of her calf was gangrenous and black and had to be cut off. The edges of fascia we had left behind were dead and had to be excised as well. But her muscle was still viable, including in her foot. And the bacteria had not killed anything up in her thigh. She had no further fevers. Her heart rate had normalized. We repacked her wound with wet gauze and sent her back for more hyperbaric oxygen—two hours twice a day.

We ended up operating on her leg four times in four days. At each operation, we had to take a little more tissue, but each time it was less and less. At the third operation, we found the redness of her skin had finally begun to recede. At the fourth operation, the redness was gone and we could see the pink mossy beginnings of new tissue in the maw of her wound. Only then was Studdert confident that not only had Eleanor survived, but her foot and leg had, too.

It is because intuition sometimes succeeds that we don't know what to do with it. Such successes are not quite the result of logical thinking. But they are not the result of mere luck, either.

Gary Klein, a cognitive psychologist who has spent his career observing people who deal routinely with uncertainty, tells the story of a fire commander he once studied. The lieutenant and his team had pulled up to fight an ordinary-seeming fire in a one-story home. He led the hose crew in through the front and encountered the fire in the back kitchen area. They tried dousing it with water. But the flames came right back at them. They tried spraying the fire again but, once more, found little effect. The team retreated a couple of steps to plan another line of attack. Then suddenly, to the bafflement of his men, the lieutenant ordered them out of the building immediately. Something—he didn't know what—didn't feel right. And as soon as they exited, the floor they'd been standing on collapsed. The seat of the fire turned out to be in the basement, not the back. Had they stayed just a few seconds longer, they would have plunged into the fire themselves.

Human beings have an ability to simply recognize the right thing to do sometimes. Judgment, Klein points out, is rarely a calculated weighing of all options, which we are not good at anyway, but instead an unconscious form of pattern recognition. Reviewing the events afterward, the commander told Klein that he had not thought once about the different possibilities in that house. He still had no idea what made him get his crew out of there. The fire had been difficult, but not to a degree that had ever made him flee before. The only explanations seemed either luck or ESP. But questioning him closely about the details of the scene, Klein identified two clues the lieutenant had taken in without even realizing it at the time. The living room had been *warm*—warmer than he was used to for a contained fire in the back of a house. And the fire was *quiet*, when what he had expected was the fire to be loud and noisy. The lieutenant's mind appeared to have recognized in these and perhaps other clues a dangerous pattern, one that told him to give the all-out order. And, in fact, thinking very hard about the situation could well have undermined the advantage of his intuition.

It is still not apparent to me what the clues were that I was registering when I first saw Eleanor's leg. Likewise, it is not obvious what the signs were that we could get by without an amputation. Yet as arbitrary as our intuitions seem, there must have been some underlying sense to them. What there is no sense to is how anyone could have known that, how anyone can reliably tell when a doctor's intuitions are heading down the right track or spinning wildly off.

For close to thirty years, Dartmouth physician Jack Wennberg has studied decision making in medicine, not up close, the way Gary Klein has, but from about as high up as you can get, looking at American doctors as a whole. And what he has found is a stubborn, overwhelming, and embarrassing degree of inconsistency in what we do. His research has shown, for example, that the likelihood of a doctor sending you for a gallbladder-removal operation varies 270 percent depending on what city you live in; for a hip replacement, 450

percent; for care in an intensive care unit during the last six months of your life, 880 percent. A patient in Santa Barbara, California, is five times more likely to be recommended back surgery for a back pain than one in Bronx, New York. This is, in the main, uncertainty at work, with the varying experience, habits, and intuitions of individual doctors leading to massively different care for people.

How can this be justified? The people who pay for the care certainly do not see how. (That is why insurers bug doctors so constantly to explain our decisions.) Nor might the people who receive it. Eleanor Bratton, without question, would have been treated completely differently depending on where she went, who she saw, or even just when she saw me (before or after that previous necrotizing fasciitis case I'd seen; at 2 A.M. or 2 P.M.; on a quiet or a busy shift). She'd have gotten merely antibiotics at one place, an amputation at another, a debridement at a third. This result seems unconscionable.

People have proposed two strategies for change. One is to shrink the amount of uncertainty in medicine—with research, not on new drugs or operations (which already attracts massive amounts of funding) but on the small but critical everyday decisions that patients and doctors make (which gets shockingly little funding). Everyone understands, though, that a great deal of uncertainty about what to do for people will always remain. (Human disease and lives are too complicated for reality to be otherwise.) So it has also been argued, not unreasonably, that doctors must agree in advance on what should be done in the uncertain situations that arise—spell out our actions ahead of time to take the guesswork out and get some advantage of group decision.

This last goes almost nowhere, though. For it runs counter to everything we doctors believe about ourselves as individuals, about our personal ability to reason out with patients what the best course of action for them is. In all the confusion of different approaches that different doctors take to a given problem, somebody must get it right. And each of us—used to making decisions under uncertainty

every day—remains convinced that that somebody is me. For however many times our judgment may fail us, we each have our Eleanor Bratton, our great improbable save.

It was a year before I saw Eleanor again. Passing through Hartford, I called in on her at her family's home, a roomy, spic-and-span, putty-colored colonial with a galumphy dog and beds of flowers outside. Eleanor had moved back home to recover following her twelve days in the hospital, intending to stay only temporarily but instead finding herself nestling in. Returning to a normal life, she said, was taking some getting used to.

Her leg had taken time to heal, not surprisingly. In her final operation, done during her last days in the hospital, we had needed to use a sixty-four-square-inch skin graft, taken from her thigh, to close the wound. "My little burn," she called the result, rolling up the leg of her sweatpants to show me.

It wasn't anything you'd call pretty, but the wound looked remarkably good to my eye. In final form, it was about as broad as my hand and ran from beneath her knee to her toes. Inevitably, the skin color was slightly off, and the wound edges were heaped up. The graft also made her foot and ankle seem wide and bulky. But the wound had no open areas, as there sometimes can be. And the grafted skin was soft and pliant, not at all tight or hard or contracted. Her thigh where the graft had been taken was a bright, cherry red, but still fading gradually.

Recovering the full use of her leg had been a struggle for her. At first, coming home, she found she could not stand, her muscles were so weak and sore. Her leg would collapse right under her. Then, when she'd built the strength back, she found she still could not walk. Nerve damage had given her a severe foot drop. She saw Dr. Studdert and he cautioned her that this was something she might always have. With several months of intense physical therapy, however, she trained herself to walk heel-toe again. By the time of

my visit, she was actually jogging. She'd also started back working, taking a job as an assistant at one of the big insurance company headquarters in Hartford.

A year on, Eleanor remained haunted by what happened to her. She still had no idea where the bacteria came from. Perhaps the foot soak and pedicure she had gotten at a small hair-and-nail shop the day before that wedding. Perhaps the grass, outside the wedding reception hall, that she'd danced barefoot through with a conga line. Perhaps somewhere in her own house. Any time she got a cut or a fever, she was stricken with mortal fear. She would not go swimming. She would not immerse herself in a bath. She would not even let the water in the shower cover her feet. Her family was planning a vacation to Florida soon, but the idea of traveling so far from her doctors frightened her.

The odds—the seeming randomness—were what disturbed her most. "First, they say the odds of you getting this are nothing—one in two hundred fifty thousand," she said. "But then I got it. Then they say the odds of my beating it are very low. And I beat those odds." Now, when she asked us doctors if she could get the flesh-eating bacteria again, we told her, once more, the odds are improbably low, one in two hundred fifty thousand, just like before.

"I have trouble when I hear something like that. That means nothing to me," she said. She was sitting on her living room sofa as we talked, her hands folded in her lap, the sun rippling through a bay window behind her. "I don't trust that I won't get it again. I don't trust that I won't get anything else that's strange or we've never heard of, or that anyone we know isn't going to get such a thing."

The possibilities and probabilities are all we have to work with in medicine, though. What we are drawn to in this imperfect science, what we in fact covet in our way, is the alterable moment—the fragile but crystalline opportunity for one's know-how, ability, or just gut instinct to change the course of another's life for the better. In the actual situations that present themselves, however—a despondent

woman arrives to see you about a newly diagnosed cancer, a victim bleeding from a terrible injury is brought pale and short of breath from the scene, a fellow physician asks for your opinion about a twenty-three-year-old with a red leg—we can never be sure whether we have such a moment or not. Even less clear is whether the actions we choose will prove either wise or helpful. That our efforts succeed at all is still sometimes a shock to me. But they do. Not always, but often enough.

My conversation with Eleanor wandered for a while. We talked about the friends she'd gotten to see now that she was back in Hartford and her boyfriend, who was something called a "fiber-optic electrician" (though what he actually wanted to do, she said, was "high voltage"), about a movie she had recently gone to, and about how much less squeamish she's discovered herself to be after going through her whole ordeal.

"I feel a lot stronger in some ways," she said. "I feel like there is some kind of purpose, like there has to be some sort of reason that I'm still here.

"I think I am also happier as a person"—able to see things in perspective a bit more. "Sometimes," she went on, "I even feel safer. I came through all right, after all."

That May she did go to Florida. It was windless and hot, and one day, off the eastern coast above Pompano, she put one bare foot in the water and then the other. Finally, against all her fears, Eleanor jumped in and went swimming in the ocean.

The water was beautiful, she says.

Notes on Sources

INTRODUCTION

5 Specialized medical journals are where doctors find much of their information on practical problems. Thus, the specific dangers of the large chest mass in children are detailed in articles such as Azizkhan, R. G., et al., "Life-threatening airway obstruction as a complication to the management of mediastinal masses in children," *Journal of Pediatric Surgery* 20 (1985), pp. 816–22. For the most part, the lessons in articles like these are learned the hard way—from experience. Disaster occurs, and we call that a tragedy. But if someone writes it down, we call it science.

At least two articles explain strategies doctors have found using heart-lung pumps to safely manage patients with tumors like Lee's: one, from a team at the University of Pennsylvania, is in the *ASAIO Journal* 44 (1998), pp. 219–21. Another, from a team in Delhi, India, is in the *Journal of Cardiothoracic and Vascular Anesthesia* 15 (2001), pp. 233–36. Both teams describe finding the strategies not through careful research but the way many breakthroughs are found—through happenstance and necessity.

EDUCATION OF A KNIFE

20 K. Anders Ericsson's book on human performance is *The Road to Excellence* (Mahwah, N.J.: Lawrence Erlbaum Press, 1996).