Complications
A Surgeon's Notes on an Imperfect Science

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Author's Note

The stories here are true. In order to tell them while protecting people's confidentiality, however, I have needed to change the names of some patients, their families, and a few of my colleagues. In certain instances, I have also needed to change minor identifying details of individuals. Nonetheless, wherever such changes were made, I have indicated so in the body of the text.
Education of a Knife

The patient needed a central line. “Here’s your chance,” S., the chief resident, said. I had never done one before. “Get set up and then page me when you’re ready to start.”

It was my fourth week in surgical training. The pockets of my short white coat bulged with patient printouts, laminated cards with instructions for doing CPR and using the dictation system, two surgical handbooks, a stethoscope, wound-dressing supplies, meal tickets, a penlight, scissors, and about a buck in loose change. As I headed up the stairs to the patient’s floor, I rattled.

This will be good, I tried to tell myself: my first real procedure. My patient—fiftyish, stout, taciturn—was recovering from abdominal surgery he’d had about a week before. His bowel function hadn’t yet returned, leaving him unable to eat. I explained to him that he needed intravenous nutrition and that this required a “special line” that would go into his chest. I said that I would put the line in him while he was in his bed, and that it would involve my laying him out flat, numbing up a spot on his chest with local anesthetic, and then threading the line in. I did not say that the line was eight inches long and would go into his vena cava, the main blood vessel to his heart. Nor did I say how tricky the procedure would be. There were “slight
risks" involved, I said, such as bleeding or lung collapse; in experienced hands, problems of this sort occur in fewer than one case in a hundred.

But, of course, mine were not experienced hands. And the disasters I knew about weighed on my mind: the woman who had died from massive bleeding when a resident lacerated her vena cava; the man who had to have his chest opened because a resident lost hold of the wire inside the line which then floated down to the patient's heart; the man who had had a cardiac arrest when the procedure put him into ventricular fibrillation. But I said nothing of such things when I asked my patient's permission to do his line. And he said, "OK," I could go ahead.

I had seen S. do two central lines; one was the day before, and I'd attended to every step. I watched how she set out her instruments and laid down her patient and put a rolled towel between his shoulder blades to make his chest arch out. I watched how she swabbed his chest with antiseptic, injected lidocaine, which is a local anesthetic, and then, in full sterile garb, punctured his chest near his clavicle with a fat three-inch needle on a syringe. The patient didn't even flinch. S. told me how to avoid hitting the lung with the needle ("Go in at a steep angle; stay right under the clavicle"), and how to find the subclavian vein, a branch to the vena cava lying atop the lung near its apex ("Go in at a steep angle; stay right under the clavicle"). She pushed the needle in almost all the way. She drew back on the syringe. And she was in. You knew because the syringe filled with maroon blood. ("If it's bright red, you've hit an artery," she said. "That's not good.")

Once you have the tip of this needle poking in the vein, you have to widen the hole in the vein wall, fit the catheter in, and thread it in the right direction—down to the heart rather than up to the brain—all without tearing through vessels, lung, or anything else. To do this, S. explained, you start by getting a guidewire in place. She pulled the syringe off, leaving the needle in place. Blood flowed out. She picked up a two-foot-long twenty-gauge wire that looked like the steel D string of an electric guitar, and passed nearly its full length through the needle's bore, into the vein, and onward toward the vena cava. "Never force it in," she warned, "and never ever let go of it." A string of rapid heartbeats fired off on the cardiac monitor, and she quickly pulled the wire back an inch. It had poked into the heart, causing momentary fibrillation. "Guess we're in the right place," she said to me quietly. Then to the patient: "You're doing great. Only a couple minutes now." She pulled the needle out over the wire and replaced it with a bullet of thick, stiff plastic, which she pushed in tight to widen the vein opening. She then removed this dilator and threaded the central line—a spaghetti-thick, yellow, flexible plastic tube—over the wire until it was all the way in. Now she could remove the wire. She flushed the line with a heparin solution and sutured it to his chest. And that was it.

I had seen the procedure done. Now it was my turn to try. I set about gathering the supplies—a central-line kit, gloves, gown, cap, mask, lidocaine—and that alone took me forever. When I finally had the stuff together, I stopped outside my patient's door and just stood there staring, silently trying to recall the steps. They remained frustratingly hazy. But I couldn't put it off any longer. I had a page-long list of other things to get done: Mrs. A needed to be discharged; Mr. B needed an abdominal ultrasound arranged; Mrs. C needed her skin staples removed... And every fifteen minutes or so I was getting paged with more tasks—Mr. X was nauseated and needed to be seen; Miss Y's family was here and needed "someone" to talk to them; Mr. Z needed a laxative. I took a deep breath, put on my best don't-worry-I-know-what-I'm-doing look, and went in to do the line.

I placed the supplies on a bedside table, untied the patient's gown behind his neck, and laid him down flat on the mattress, with his chest bare and his arms at his sides. I flipped on a fluorescent overhead light and raised his bed to my height. I paged S. to come. I put on my gown and gloves and, on a sterile tray, laid out the central line, guidewire, and other materials from the kit the way I remembered S. doing it. I drew up five cc's of lidocaine in a syringe, soaked
two sponge-sticks in the yellow-brown Betadine antiseptic solution, and opened up the suture packaging. I was good to go.

S. arrived. “What’s his platelet count?”

My stomach knotted. I hadn’t checked. That was bad: too low and he could have a serious bleed from the procedure. She went to check a computer. The count was acceptable.

Chastened, I started swabbing his chest with the sponge-sticks. “Got the shoulder roll underneath him?” S. asked. Well, no. I had forgotten this, too. The patient gave me a look. S., saying nothing, got a towel, rolled it up, and slipped it under his back for me. I finished applying the antiseptic and then draped him so only his right upper chest was exposed. He squirmed a bit beneath the drapes. S. now inspected my tray. I girded myself.

“Where’s the extra syringe for flushing the line when it’s in?” Darrin. She went out and got it.

I felt for landmarks on the patient’s chest. Here? I asked with my eyes, not wanting to undermine my patient’s confidence any further. She nodded. I numbed the spot with lidocaine. (“You’ll feel a stick and a burn now, sir.”) Next, I took the three-inch needle in hand and poked it through the skin. I advanced it slowly and uncertainly, a few millimeters at a time, afraid to plunge it into something bad. This is a big goddam needle, I kept thinking. I couldn’t believe I was sticking it into someone’s chest. I concentrated on maintaining a steep angle of entry, but kept spearing his clavicle instead of slipping beneath it.

“Ow!” he shouted.

“Sorry,” I said. S. signaled with a kind of surfing hand gesture to go underneath the clavicle. This time it did. I drew back on the syringe. Nothing. She pointed deeper. I went in deeper. Nothing. I took the needle out, flushed out some bits of tissue clogging it, and tried again.

“Ow!”

Too superficial again. I found my way underneath the clavicle once more. I drew the syringe back. Still nothing. He’s too obese, I thought to myself. S. slipped on gloves and a gown. “How about I have a look,” she said. I handed her the needle and stepped aside. She plunged the needle in, drew back on the syringe, and, just like that, she was in. “We’ll be done shortly,” she told the patient. I felt utterly inept.

She let me continue with the next steps, which I bumbled through. I didn’t realize how long and floppy the guidewire was until I pulled the coil out of its plastic sleeve, and, putting one end of it into the patient, I very nearly let the other touch his sterile bedsheet. I forgot about the dilating step until she reminded me. Then, when I put in the dilator, I didn’t push quite hard enough, and it was really S. who pushed it all the way in. Finally we got the line in, flushed it, and sutured it in place.

Outside the room, S. said that I could be less tentative the next time, but that I shouldn’t worry too much about how things had gone. “You’ll get it,” she said. “It just takes practice.” I wasn’t so sure. The procedure remained wholly mysterious to me. And I could not get over the idea of jabbing a needle so deeply and blindly into someone’s chest. I awaited the X-ray afterward with trepidation. But it came back fine: I had not injured the lung and the line was in the right place.

Not everyone appreciates the attractions of surgery. When you are a medical student in the operating room for the first time, and you see the surgeon press the scalpel to someone’s body and open it like fruit, you either shudder in horror or gasp in awe. I gaped. It was not just the blood and guts that enthralled me. It was the idea that a mere person would have the confidence to wield that scalpel in the first place.

There is a saying about surgeons, meant as a reproach: “Sometimes wrong; never in doubt.” But this seemed to me their strength. Every day, surgeons are faced with uncertainties. Information is inadequate; the science is ambiguous; one’s knowledge and abilities are never perfect. Even with the simplest operation, it cannot be
taken for granted that a patient will come through better off—or even alive. Standing at the table my first time, I wondered how the surgeon knew that he would do this patient good, that all the steps would go as planned, that bleeding would be controlled and infection would not take hold and organs would not be injured. He didn’t, of course. But still he cut.

Later, while still a student, I was allowed to make an incision myself. The surgeon drew a six-inch dotted line with a marking pen across a sleeping patient’s abdomen and then, to my surprise, had the nurse hand me the knife. It was, I remember, still warm from the sterilizing autoclave. The surgeon had me stretch the skin taut with the thumb and forefinger of my free hand. He told me to make one smooth slice down to the fat. I put the belly of the blade to the skin and cut. The experience was odd and addictive, mixing exhilaration from the calculated violence of the act, anxiety about getting it right, and a righteous faith that it was somehow good for the person. There was also the slightly nauseating feeling of finding that it took more force than I’d realized. (Skin is thick and springy, and on my first pass I did not go nearly deep enough; I had to cut twice to get through.)

The moment made me want to be a surgeon—not to be an amateur handed the knife for a brief moment, but someone with the confidence to proceed as if it were routine.

A resident, however, begins with none of this air of mastery—only a still overpowering instinct against doing anything like press a knife against flesh or jabbing a needle into someone’s chest. On my first day as a surgical resident, I was assigned to the emergency room. Among my first patients was a skinny, dark-haired woman in her late twenties who hobbled in, teeth gritted, with a two-and-a-half-foot-long wooden chair-leg somehow nailed into the bottom of her foot. She explained that the leg had collapsed out from under a kitchen chair she had tried to sit upon and, leaping up to keep from falling, she inadvertently stomped her bare foot onto the three-inch screw sticking out of it. I tried very hard to look like someone who had not just got his medical diploma the week before. Instead, I was determined to be nonchalant, world-weary, the kind of guy who had seen this sort of thing a hundred times before. I inspected her foot and could see that the screw was imbedded in the bone at the base of her big toe. There was no bleeding, and, so far as I could feel, no fracture.

“Wow, that must hurt,” I blurted out idiotically.

The obvious thing to do was give her a tetanus shot and pull out the screw. I ordered the tetanus shot, but I began to have doubts about pulling out the screw. Suppose she bled? Or suppose I fractured her foot? Or something worse? I excused myself and tracked down Dr. W, the senior surgeon on duty. I found him tending to a car-crash victim. The patient was a mess. People were shouting. Blood was all over the floor. It was not a good time to ask questions.

I ordered an X ray. I figured it would buy time and let me check my amateur impression that she didn’t have a fracture. Sure enough, getting one took about an hour and it showed no fracture—just a common screw imbedded, the radiologist said, “in the head of the first metatarsal.” I showed the patient the X ray. “You see, the screw’s imbedded in the head of the first metatarsal,” I said. And the plan? she wanted to know. Ah, yes, the plan.

I went to find Dr. W. He was still tied up with the crash victim, but I was able to interrupt to show him the X ray. He chuckled at the sight of it and asked me what I wanted to do. “Pull the screw out?” I ventured. “Yes,” he said, by which he meant “Duh.” He made sure I’d given a tetanus shot and then shooed me away.

Back in the room, I told her that I would pull the screw out, prepared for her to say something like “You?” Instead she said, “OK, Doctor,” and it was time for me to get down to business. At first I had her sitting on the exam table, dangling her leg off the side. But that didn’t look as if it would work. Eventually, I had her lie with her foot jutting off the end of the table, the board poking out into the air. With every move, her pain increased. I injected a local anesthetic where the screw went in and that helped a little. Now I grabbed her foot in one hand, the board in the other, and then for a moment I
froze. Could I really do this? Should I really do this? Who was I to presume?

Finally, I just made myself do it. I gave her a one-two-three and pulled, too gingerly at first and then, forcing myself, hard. She groaned. The screw wasn’t budging. I twisted, and abruptly it came free. There was no bleeding. I washed the wound out, as my textbooks said to for puncture wounds. She found she could walk, though the foot was sore. I warned her of the risks of infection and the signs to look for. Her gratitude was immense and flattering, like the lion’s for the mouse—and that night I went home elated.

In surgery, as in anything else, skill and confidence are learned through experience—haltingly and humiliatingly. Like the tennis player and the oboist and the guy who fixes hard drives, we need practice to get good at what we do. There is one difference in medicine, though: it is people we practice upon.

My second try at placing a central line went no better than the first. The patient was in intensive care, mortally ill, on a ventilator, and needed the line so that powerful cardiac drugs could be delivered directly to her heart. She was also heavily sedated, and for this I was grateful. She’d be oblivious to my fumbling.

My preparation was better this time. I got the towel roll in place and the syringes of heparin on the tray. I checked her lab results, which were fine. I also made a point of draping more widely, so that if I flopped my guidewire around by mistake again, I could be sure it wouldn’t hit anything unsterile.

For all that, the procedure was a bust. I stabbed the needle in too shallow and then too deep. Frustration overcame tentativeness and I tried one angle after another. Nothing worked. Then, for one brief moment, I got a flash of blood in the syringe, indicating I was in the vein. I anchored the needle with one hand and went to pull the syringe off with the other. But the syringe was jammed on too tightly, so that when I pulled it free I dislodged the needle from the vein.

The patient began bleeding into her chest wall. I applied pressure the best I could for a solid five minutes, but her chest still turned black and blue around the site. The hematoma made it impossible to put a line through there anymore. I wanted to give up. But she needed a line and the resident supervising me—a second-year this time—was determined that I succeed. After an X-ray showed that I had not injured her lung, he had me try again on the other side with a whole new kit. I still missed, however, and before I turned the patient into a pincushion he took over. It took him several minutes and two or three sticks to find the vein himself and that made me feel better. Maybe she was an unusually tough case.

When I failed with a third patient a few days later, however, the doubts really set in. Again, it was stick, stick, stick, and nothing. I stepped aside. The resident watching me got it on the very next try.

Surgeons, as a group, adhere to a curious egalitarianism. They believe in practice, not talent. People often assume that you have to have great hands to become a surgeon, but it’s not true. When I interviewed to get into surgery programs, no one made me sew or take a dexterity test or checked if my hands were steady. You do not even need all ten fingers to be accepted. To be sure, talent helps. Professors say every two or three years they’ll see someone truly gifted come through a program—someone who picks up complex manual skills unusually quickly, sees the operative field as a whole, notices trouble before it happens. Nonetheless, attending surgeons say that what’s most important to them is finding people who are conscientious, industrious, and boneheaded enough to stick at practicing this one difficult thing day and night for years on end. As one professor of surgery put it to me, given a choice between a Ph.D. who had painstakingly cloned a gene and a talented sculptor, he’d pick the Ph.D. every time. Sure, he said, he’d bet on the sculptor being more physically talented; but he’d bet on the Ph.D. being less “flaky.” And in the end that matters more. Skill, surgeons believe, can be
taught; tenacity cannot. It’s an odd approach to recruitment, but it continues all the way up the ranks, even in top surgery departments. They take minions with no experience in surgery, spend years training them, and then take most of their faculty from these same home-brewed ranks.

And it works. There have now been many studies of elite performers—international violinists, chess grand masters, professional ice-skaters, mathematicians, and so forth—and the biggest difference researchers find between them and lesser performers is the cumulative amount of deliberate practice they’ve had. Indeed, the most important talent may be the talent for practice itself. K. Anders Ericsson, a cognitive psychologist and expert on performance, notes that the most important way in which innate factors play a role may be in one’s willingness to engage in sustained training. He’s found, for example, that top performers dislike practicing just as much as others do. (That’s why, for example, athletes and musicians usually quit practicing when they retire.) But more than others, they have the will to keep at it anyway.

I wasn’t sure I did. What good was it, I wondered, to keep doing central lines when I wasn’t coming close to getting them in? If I had a clear idea of what I was doing wrong, then maybe I’d have something to focus on. But I didn’t. Everyone, of course, had suggestions. Go in with the bevel of the needle up. No, go in with the bevel down. Put a bend in the middle of the needle. No, curve the needle. For a while, I tried to avoid doing another line. Soon enough, however, a new case arose.

The circumstances were miserable. It was late in the day and I’d been up all the night before. The patient was morbidly obese, weighing more than three hundred pounds. He couldn’t tolerate lying flat because the weight of his chest and abdomen made it hard for him to breathe. Yet he absolutely needed a central line. He had a badly infected wound and needed intravenous antibiotics, and no one could find veins in his arms for a peripheral IV. I had little hope of succeeding. But a resident does what he is told, and I was told to try the line.

I went to his room. He looked scared and said he didn’t think he’d last more than a minute on his back. But he said he understood the situation and was willing to make his best effort. He and I decided that he’d be left sitting propped up in bed until the last possible minute. We’d see how far we got after that.

I went through my preparations: checking the labs, putting out the kit, placing the towel roll, and so on. I swabbed and draped his chest while he was still sitting up. S., the chief resident, was watching me this time, and when everything was ready I had her tip him back, an oxygen mask on his face. His flesh rolled up his chest like a wave. I couldn’t find his clavicle with my fingertips to line up the right point of entry. And already he was looking short of breath, his face red. I gave S. a “Do you want to take over?” look. Keep going, she signaled. I made a rough guess as to where the right spot was, numbed it with lidocaine, then pushed the big needle in. For a second, I thought it wouldn’t be long enough to reach through, but then I felt the tip slip underneath his clavicle. I pushed a little deeper and drew back on the syringe. Unbelievably, it filled with blood. I was in. I concentrated on anchoring the needle firmly in place, not moving it a millimeter as I pulled the syringe off and threaded the guidewire in. The wire fed in smoothly. He was struggling hard for air now. We sat him up and let him catch his breath. And then with one more lie-down, I got the entry dilated and slid the central line in.

“Nice job,” was all S. said, and then she left.

I still have no idea what I did differently that day. But from then on, my lines went in. Practice is funny that way. For days and days, you make out only the fragments of what to do. And then one day you’ve got the thing whole. Conscious learning becomes unconscious knowledge, and you cannot say precisely how.

I have now put in more than a hundred central lines. I am by no means infallible. Certainly, I have had my fair share of what we
prefer to call “adverse events.” I punctured a patient’s lung, for example—the right lung of a surgeon from another hospital, no less—and, given the odds, I’m sure such things will happen again. I still have the occasional case that should go easily, but doesn’t, no matter what I do. (We have a term for this. “How’d it go?” a colleague asks. “It was a total flog.” I reply. I don’t have to say anything more.)

But then there are the other times, when everything goes perfectly. You don’t think. You don’t concentrate. Every move unfolds effortlessly. You take the needle. You stick the chest. You feel the needle travel—a distinct glide through the fat, a slight catch in the dense muscle, then the subtle pop through the vein wall—and you’re in. At such moments, it is more than easy; it is beautiful.

Surgical training is the recapitulation of this process—the floundering followed by fragments, followed by knowledge and occasionally a moment of elegance—over and over again, for ever harder tasks with ever greater risks. At first, you work on the basics: how to glove and gown, how to drape patients, how to hold the knife, how to tie a square knot in a length of silk suture (not to mention how to dictate, work the computers, order drugs). But then the tasks become more daunting: how to cut through skin, handle the electrocautery, open the breast, tie off a bleeding vessel, excise the tumor, close up the wound—a breast lumpectomy. By the end of six months, I had done lines, appendectomies, skin grafts, hernia repairs, and mastectomies. At the end of a year, I was doing limb amputations, lymph node biopsies, and hemorrhoidectomies. At the end of two years, I was doing tracheotomies, a few small-bowel operations, and laparoscopic gallbladder operations.

I am in my seventh year of training. Only now has a simple slice through skin begun to seem like nothing, the mere start of a case. When I’m inside, the struggle remains. These days, I’m trying to learn how to fix abdominal aortic aneurysms, remove pancreatic cancers, open blocked carotid arteries. I am, I have found, neither gifted nor maladroit. With practice and more practice, I get the hang of it.

We find it hard, in medicine, to talk about this with patients. The moral burden of practicing on people is always with us, but for the most part unspoken. Before each operation, I go over to the pre-operative holding area in my scrubs and introduce myself to the patient. I do it the same way every time. “Hello, I’m Dr. Gawande. I’m one of the surgical residents, and I’ll be assisting your surgeon.” That is pretty much all I say on the subject. I extend my hand and give a smile. I ask the patient if everything is going OK so far. We chat. I answer questions. Very occasionally, patients are taken aback. “No resident is doing my surgery,” they say. I try to reassure. “Not to worry. I just assist,” I say. “The attending surgeon is always in charge.”

None of this is exactly a lie. The attending is in charge, and a resident knows better than to forget that. Consider the operation I did recently to remove a seventy-five-year-old woman’s colon cancer. The attending stood across from me from the start. And it was he, not I, who decided where to cut, how to isolate the cancer, how much colon to take.

Yet to say I just assisted remains a kind of subterfuge. I wasn’t merely an extra pair of hands, after all. Otherwise, why did I hold the knife? Why did I stand on the operator’s side of the table? Why was it raised to my six-feet-plus height? I was there to help, yes, but I was there to practice, too. This was clear when it came time to reconnect the colon. There are two ways of putting the ends together—by hand-sewing them or stapling them. Stapling is swifter and easier, but the attending suggested I hand-sew the ends—not because it was better for the patient but because I had done it few times before. When it’s performed correctly, the results are similar, but he needed to watch me like a hawk. My stitching was slow and imprecise. At one point, he caught me leaving the stitches too far apart and made me go back and put extras in between so the connection would not leak. At another point, he found I wasn’t taking deep enough bites of tissue with the needle to insure a strong closure. “Turn your wrist more,” he told me. “Like this?” I asked. “Uh, sort of,” he said. I was learning.
In medicine, we have long faced a conflict between the imperative to give patients the best possible care and the need to provide novices with experience. Residencies attempt to mitigate potential harm through supervision and graduated responsibility. And there is reason to think patients actually benefit from teaching. Studies generally find teaching hospitals have better outcomes than non-teaching hospitals. Residents may be amateurs, but having them around checking on patients, asking questions, and keeping faculty on their toes seems to help. But there is still no getting around those first few unsteady times a young physician tries to put in a central line, remove a breast cancer, or sew together two segments of colon. No matter how many protections we put in place, on average these cases go less well with the novice than with someone experienced.

We have no illusions about this. When an attending physician brings a sick family member in for surgery, people at the hospital think hard about how much to let trainees participate. Even when the attending insists that they participate as usual, a resident scrubbing in knows that it will be far from a teaching case. And if a central line must be put in, a first-timer is certainly not going to do it. Conversely, the ward services and clinics where residents have the most responsibility are populated by the poor, the uninsured, the drunk, and the demented. Residents have few opportunities nowadays to operate independently, without the attending docs scrubbed in, but when we do—as we must before graduating and going out to operate on our own—it is generally on these, the humblest of patients.

This is the uncomfortable truth about teaching. By traditional ethics and public insistence (not to mention court rulings), a patient’s right to the best care possible must trump the objective of training novices. We want perfection without practice. Yet everyone is harmed if no one is trained for the future. So learning is hidden, behind drapes and anesthesia and the elisions of language. Nor does the dilemma apply just to residents, physicians in training. In fact, the process of learning turns out to extend longer than most people know.

My sister and I grew up in the small town of Athens, Ohio, where our parents are both doctors. Long ago my mother chose to practice pediatrics part-time, only three half-days a week, and she was able to because my father’s urology practice became so busy and successful. He has now been at it for more than twenty-five years, and his office is cluttered with the evidence of it: an overflowing wall of patient files, gifts from people displayed everywhere (books, paintings, ceramics with biblical sayings, hand-painted paperweights, blown glass, and carved boxes, as well as a figurine of a boy who pees on you when you pull down his pants). In an acrylic case behind his oak desk there are a few dozen of the thousands of kidney stones he has removed from these patients.

Only now, as I get glimpses of the end of my training, have I begun to think hard about my father’s success. For most of residency, I thought of surgery as a more or less fixed body of knowledge and skill which is acquired in training and perfected in practice. There was, as I envisioned it, a smooth, upward-sloping arc of proficiency at some rarefied set of tasks (for me, taking out gallbladders, colon cancers, bullets, and appendices; for him, taking out kidney stones, testicular cancers, and swollen prostates). The arc would peak at, say, ten or fifteen years, plateau for a long time, and perhaps tail off a little in the final five years before retirement. The reality, however, turns out to be far messier. You do get good at certain things, my father tells me, but no sooner than you do, you find what you know is outdated. New technologies and operations emerge to supplant the old, and the learning curve starts all over again. “Three-quarters of what I do today I never learned in residency,” he says. On his own, fifty miles from his nearest colleague—let alone a doctor who could tell him anything like “You need to turn your wrist more when you do that”—he has had to learn to put in penile prostheses, to perform
microsurgery, to reverse vasectomies, to do nerve-sparing prostatectomies, to implant artificial urinary sphincters. He's had to learn to use shock-wave lithotripters, electrohydraulic lithotripters, and laser lithotripters (all instruments for breaking up kidney stones); to deploy Double J ureteral stents and Silicone Figure Four Coil stents and Retro-Inject Multi-Length stents (don't even ask); to maneuver fiber-optic ureteroscopes. All these technologies and techniques were introduced since he finished training. Some of the procedures built on previous skills. Many did not.

This is, in fact, the experience all surgeons have. The pace of medical innovation has been unceasing, and surgeons have no choice but to give the new new thing a try. To fail to adopt new techniques would mean denying patients meaningful medical advances. Yet the perils of the learning curve are inescapable—no less in practice than in residency.

For the established surgeon, inevitably, the opportunities for learning are far less structured than for a resident. When an important new device or procedure comes along, as they do every year, surgeons start out by taking a course about it—typically a day or two of lectures by some surgical grandees with a few film clips and step-by-step handouts. We take a video home to watch. Perhaps we pay a visit to observe a colleague perform the operation—my father often goes up to Ohio State or the Cleveland Clinic for this. But there's not much by way of hands-on training. Unlike a resident, a visitor cannot scrub in on cases, and opportunities to practice on animals or cadavers are few and far between. (Britain, being Britain, actually bans surgeons from practicing on animals.) When the pulsed-dye laser came out, the manufacturer set up a lab in Columbus where urologists from the area could gain experience. But when my father went, the main experience provided was destroying kidney stones in test tubes filled with a urinelike liquid and trying to penetrate the shell of an egg without hitting the membrane underneath. My surgery department recently purchased a robotic surgery device—a staggeringly sophisticated nine-hundred-and-eighty-thousand-dollar robot, with three arms, two wrists, and a camera, all millimeters in diameter, which, controlled from a console, allows a surgeon to do almost any operation with absolutely no hand tremor and with only tiny incisions. A team of two surgeons and two nurses flew out to the manufacturer's headquarters in San Jose for a full day of training on the machine. And they did get to practice on a pig and on a human cadaver. (The company apparently buys the cadavers from the city of San Francisco.) But even this, which is far more practice than one usually gets, was hardly thorough training. They learned enough to grasp the principles for operating the robot, to start getting a feel for using it, and to understand how to plan an operation. That was about it. Sooner or later, one just has to go home and give the thing a try.

Patients do eventually benefit—often enormously—but the first few patients may not and may even be harmed. Consider the experience reported by the pediatric-surgery unit of the renowned Great Ormond Street Hospital in London, as detailed in the British Medical Journal in the spring of 2000. The doctors described their results in operating on three hundred and twenty-five consecutive babies with a severe heart defect, known as transposition of the great arteries, over a period (from 1978 to 1998) when its surgeons changed from doing one operation for the condition to another. Such children are born with their heart's outflow vessels transposed: the aorta emerges from the right side of the heart instead of the left and the artery to the lungs emerges from the left instead of the right. As a result, blood coming in is pumped right back out to the body instead of first to the lungs, where it can be oxygenated. This is unsurvivable. The babies died blue, fatigued, never knowing what it was to get enough breath. For years, switching the vessels to their proper positions wasn't technically feasible. Instead, surgeons did something known as the Senning procedure: they created a passage inside the heart to let blood from the lungs cross backward to the right heart. The Senning procedure allowed children to live into adulthood. The weaker right heart, however, cannot sustain the body's entire blood flow as long as the left. Eventually, these patients' hearts failed,
and although most made it to adulthood, few lived to old age. Then, by the 1980s, a series of technological advancements made it possible to do a switch operation safely. It rapidly became the favored procedure. In 1986, the Great Ormond Street surgeons made the changeover, and their report shows that it was unquestionably a change for the better. The annual death rate after a successful switch procedure was less than a quarter that after the Senning, resulting in a life expectancy of sixty-three years instead of forty-seven. But the price of learning to do it was appalling. In their first seventy switch operations, the doctors had a 25 percent surgical death rate, compared with just 6 percent with the Senning procedure. (Eighteen babies died, more than twice the number of the entire Senning era.) Only with time did they master it: in their next hundred switch operations, just five babies died.

As patients, we want both expertise and progress. What nobody wants to face is that these are contradictory desires. In the words of one British public report, “There should be no learning curve as far as patient safety is concerned.” But that is entirely wishful thinking.

Recently, a group of Harvard Business School researchers who have made a specialty of studying learning curves in industry—in making semiconductors, building airplanes, and such—decided to examine learning curves among surgeons. They followed eighteen cardiac surgeons and their teams as they took on the new technique of minimally invasive cardiac surgery. This study, I was surprised to discover, is the first of its kind. Learning is ubiquitous in medicine, and yet no one had ever compared how well different clinicians actually do it.

The new heart operation—involving a small incision between the ribs instead of a chest split open down the middle—proved substantially more difficult than the conventional one. Because the incision is too small to admit the usual tubes and clamps for rerouting blood to the heart-bypass machine, surgeons had to learn a trickier method, which involved balloons and catheters placed through groin vessels.

They had to learn how to operate in a much reduced space. And the nurses, anesthesiologists, and perfusionists all had new roles to master, too. Everyone had new tasks, new instruments, new ways that things could go wrong, and new ways to fix them. As you’d expect, everyone was found to experience a substantial learning curve. Whereas a fully proficient team takes three to six hours for such operations, these teams took an average of three times longer for their early cases. The researchers could not track rates of morbidity in detail, but it would be foolish to imagine that these rates were not affected.

What’s more interesting is that researchers found striking disparities in the speed with which different teams learned. All teams received the same three-day training session and came from highly respected institutions with experience in adopting innovations. Yet, in the course of fifty cases, some teams managed to halve their operating time while others failed to improve at all. Practice, it turned out, did not necessarily make perfect. Whether it did, the researchers found, depended on how the surgeons and their teams practiced.

Richard Bohmer, the one physician among the Harvard researchers, made several visits to observe one of the quickest-learning teams and one of the slowest, and he was startled by the contrast. The surgeon on the fast-learning team was actually quite inexperienced compared with the one on the slow-learning team—he was only a couple of years out of training. But he made sure to pick team members with whom he had worked well before and to keep them together through the first fifteen cases before allowing any new members. He had the team go through a dry run before the first case, then deliberately scheduled six operations in the first week, so little would be forgotten in between. He convened the team before each case to discuss it in detail and afterward to debrief. He made sure results were tracked carefully. And as a person, Bohmer noticed, the surgeon was not the stereotypical Napoleon with a knife. Unbidden, he told Bohmer, “The surgeon needs to be willing to allow himself to become a partner [with the rest of the team] so he can accept
It would certainly be a graceful and happy solution. We'd ask patients—honestly, openly—and then they'd say yes. Hard to imagine, though. I noticed on the expert's desk a picture of his child, born just a few months before, and a completely unfair question popped into my mind. "So did you let the resident deliver?" I asked.

There was silence for a moment. "No," he admitted. "We didn't even allow residents in the room."

One reason I doubt that we could sustain a system of medical training that depended on people saying "Yes, you can practice upon me" is that I myself have said no. One Sunday morning, when my eldest child, Walker, was eleven days old, he suddenly went into congestive heart failure from what proved to be a severe cardiac defect. His aorta was not transposed, but a long segment of it had failed to grow at all. My wife and I were beside ourselves with fear—his kidneys and liver began failing, too—but he made it to surgery, the repair was a success, and although his recovery was erratic, after two and a half weeks he was ready to come home.

We were by no means home free, however. He was born a healthy six pounds plus but now, at a month of age, weighed only five, and would need strict monitoring to insure that he gained weight. He was on two cardiac medications from which he would have to be weaned. And in the longer term, the doctors warned us, his repair would eventually prove inadequate. As Walker grew, his aorta would require either dilation with a balloon or wholesale replacement in surgery. Precisely when and how many such procedures would be necessary over the years they could not say. A pediatric cardiologist would have to follow him closely and decide.

Nearing discharge, we had not chosen who that cardiologist would be. In the hospital, Walker had been cared for by a full team of cardiologists, ranging from fellows in specialty training to attendings who had practiced for decades. The day before discharge, one of the young fellows approached me, offering his card and a suggested
apptointment time to bring Walker to see him. Of those on the team, he was the one who had put in the most time caring for Walker. He was the one who saw Walker when we brought him in inexplicably short of breath, the one who made the diagnosis, who got Walker the drugs that stabilized him, who coordinated with the surgeons, and who came to see us each day to answer our questions. Moreover, I knew fellows always got their patients this way. Most families don’t know the subtle gradations among players, and after a team has saved their child’s life, they take whatever appointment they’re handed.

But I knew the differences. “I’m afraid we’re thinking of seeing Dr. Newburger,” I said. She was the hospital’s associate cardiologist-in-chief, and a published expert on conditions like Walker’s. The young physician looked crestfallen. It was nothing against him, I said. She just had more experience, that was all.

“You know, there is always an attending backing me up,” he said. I shook my head.

I know this was not fair. My son had an unusual problem. The fellow needed the experience. Of all people, I, a resident, should have understood. But I was not torn about the decision. This was my child. Given a choice, I will always choose the best care I can for him. How can anybody be expected to do otherwise? Certainly, the future of medicine should not rely on it.

In a sense, then, the physician’s dodge is inevitable. Learning must be stolen, taken as a kind of bodily eminent domain. And it was, during Walker’s stay—on many occasions, now that I think back on it. A resident intubated him. A surgical trainee scrubbed in for his operation. The cardiology fellow put in one of his central lines. None of them asked me if they could. If offered the option to have someone more experienced, I certainly would have taken it. But that was simply how the system worked—no such choices were offered—and so I went along. What else could I do?

The advantage of this coldhearted machinery is not merely that it gets the learning done. If learning is necessary but causes harm, then above all it ought to apply to everyone alike. Given a choice, people wriggle out, and those choices are not offered equally. They belong to the connected and the knowledgeable, to insiders over outsiders, to the doctor’s child but not the truck driver’s. If choice cannot go to everyone, maybe it is better when it is not allowed at all.

It is 2 P.M. I am in the intensive care unit. A nurse tells me Mr. G’s central line has clotted off. Mr. G has been with us for more than a month now. He is in his late sixties, from South Boston, emaciated, exhausted, holding on by a thread—or a line, to be precise. He has several holes in his small bowel that surgery has failed to close, and the bilious contents leak out onto his skin through two small reddened openings in the concavity of his abdomen. His only chance is to be fed by vein and wait for these fistulae to heal. He needs a new central line.

I could do it, I suppose. I am the experienced one now. But experience brings a new role: I am expected to teach the procedure instead. “See one, do one, teach one,” the saying goes, and it is only half in jest.

There is a junior resident on the service. She has done only one or two lines before. I tell her about Mr. G. I ask her if she is free to do a new line. She misinterprets this as a question. She says she still has patients to see and a case coming up later. Could I do the line? I tell her no. She is unable to hide a grimace. She is burdened, as I was burdened, and perhaps frightened, as I was frightened.

She begins to focus when I make her talk through the steps—a kind of dry run, I figure. She hits nearly all the steps, but crucially forgets about checking the labs and about Mr. G’s nasty allergy to heparin, which is in the flush for the line. I make sure she registers this, then tell her to get set up and page me.

I am still adjusting to this role. It is painful enough taking responsibility for one’s own failures. Being handmaiden to another’s is something else entirely. It occurs to me that I could have broken open a kit and had her do an actual dry run. Then again, maybe I can’t. The kits must be a couple of hundred dollars each. I’ll have to find out for next time.
Half an hour later, I get the page. The patient is draped. The resident is in her gown and gloves. She tells me she has saline to flush the line with and that his labs are fine.

"Have you got the towel roll?" I ask.

She forgot the towel roll. I roll up a towel and slip it beneath Mr. G's back. I look into his face and ask him if he's all right. He nods.

I see no fear. After all he's been through, there is only resignation.

The junior resident picks out a spot for the stick. The patient is so hauntingly thin. I see every rib and fear she will puncture his lung. She injects the numbing medication. Then she puts the big needle in, and the angle looks all wrong. I motion for her to reposition. This only makes her more uncertain. She pushes in deeper and I know she does not have it. She draws back on the syringe; no blood. She takes out the needle and tries again. And again, the angle looks wrong. This time Mr. G feels the jab and jerks up in pain. I hold his arm. She gives him more numbing medication. It is all I can do not to take over. But she cannot learn without doing, I tell myself. I decide to let her have one more try.
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
