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The Race to Reinvent CPR

A new, high-tech approach called ECPR can restart more hearts and save more lives. Why aren't more hospitals embracing it?

By Helen Ouyang
Helen Ouyang is a physician and contributing writer for the magazine. For this article, she visited an ECPR program in Minnesota that is one of the best in the world.

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Greg Hayes, an emergency first responder in Chanhassen, Minn., was picking up takeout sushi when a 911 call came in: A 61-year-old had stopped breathing at home. Hayes and his team jumped in their ambulance and were soon pulling up in front of a suburban two-story house, where paramedics and other first responders were also arriving. All of them grabbed their equipment and raced through the open garage to find a man, gray and still, on the living-room floor with his wife and stepdaughter nearby.

Until that Thursday in August 2022, John Sauer's most pressing health concern had been his seasonal allergies. After a routine day — desk job in front of a computer, a three-mile walk with his wife, some yardwork — he was sitting on the couch in front of the television with his wife, Kristen Waters. But when a commercial came on, he didn't mute it as he usually did. Then, when his stepdaughter asked him a question about her car, he didn't answer — he rolled his eyes at her instead. And he kept rolling them.

Waters, a nurse, checked for his pulse. His heart had stopped beating. She told her daughter to call 911, and the two women struggled to get Sauer, who is very tall and rather bulky, onto the ground to start CPR. Waters pushed up his sweaty T-shirt to expose his chest and began briskly pushing on his breastbone. She had taught CPR classes, but she had never done it on a real person. Up and down, up and down, her

fingers interlocked, hand over hand. Sauer's head bobbled limply around. Here I am doing chest compressions, she thought, and this CPR is never going to wake him up.

When Hayes arrived, he, too, didn't think there was anything that he or the medics — or even a hospital — could do to save Sauer. Not that he wouldn't give it, in his words, the "100 percent college try." But having been an emergency medical technician for more than three decades, he knew how sudden cardiac arrests usually end: Sauer would probably die.

As the clock ticked toward 30 minutes from when Sauer's heart stopped, the chance of his survival was dwindling rapidly to zero. Hayes began rehearsing in his head what he would say to Waters. He stared at a photo on the wall of Sauer white-water rafting with his family. "It was gut-wrenching," he says.

Worldwide, cardiac arrest — when the heart suddenly stops beating — strikes some five million people a year outside a hospital setting. In the United States, that figure is nearly 400,000. And in 2021, of those who were fortunate enough to have a bystander call 911 and have emergency medical services come to their assistance, only around 9 percent survived long enough to be discharged from a hospital — a dismal number that has barely budged in decades.

Waters was right: She was not going to revive her husband through chest compressions alone. But the chance of survival decreases by 10 percent for every minute that passes without any CPR at all. And while bystander CPR by itself is unlikely to save anyone, other advanced interventions won't work without it. That's because chest compressions keep blood flowing — however sluggishly, however minimally — to the brain.

The defibrillator, a machine that delivers a powerful jolt of electricity to a person's heart, is one of the few 20th-century inventions that have helped improve survival rates. Automated defibrillators are sometimes found in places like airports and gyms, and they can be incredibly effective when deployed immediately. Even so, bystanders seldom use them, because they don't know how or because they can't

find one. Nor can every type of cardiac arrest be helped with a defibrillator; the victim must have what's called a "shockable rhythm" — and even that may not respond to a shock.

A medical team transports a cardiac arrest patient to the M Health Fairview University of Minnesota Medical Center. Mark Peterson/Redux, for The New York Times

In the family's living room, the medics had immediately slapped defibrillator pads onto Sauer's chest. The machine's monitor displayed a green chaotic scribble — which meant his heart was quivering but not pumping blood — instead of the regular, organized pattern that normal hearts produce. Sauer was shocked twice. He didn't wake up.

Hayes remembered that some cases of cardiac arrest were supposed to prompt a call to the doctors at M Health Fairview University of Minnesota Medical Center, instead of being taken directly to the closest hospital. The specialist on call there,

Jason Bartos, confirmed that Sauer was a candidate for a procedure called extracorporeal CPR, or ECPR. Soon after that, a clunky machine that performs automatic chest compressions, called a LUCAS device, was strapped around Sauer's torso for the ambulance ride. By then his feet had turned a dusky blue.

Because the half-hour drive to the medical center would have been too long, the ambulance met an enormous ECPR truck at a midway point. Bartos arrived separately in a hospital-owned S.U.V.; he was already wearing blue scrubs and a University of Minnesota scrub cap. After Sauer was lifted into the truck, Bartos and several health workers got in as well. Hayes, eager to watch the ECPR procedure for the first time, joined them.

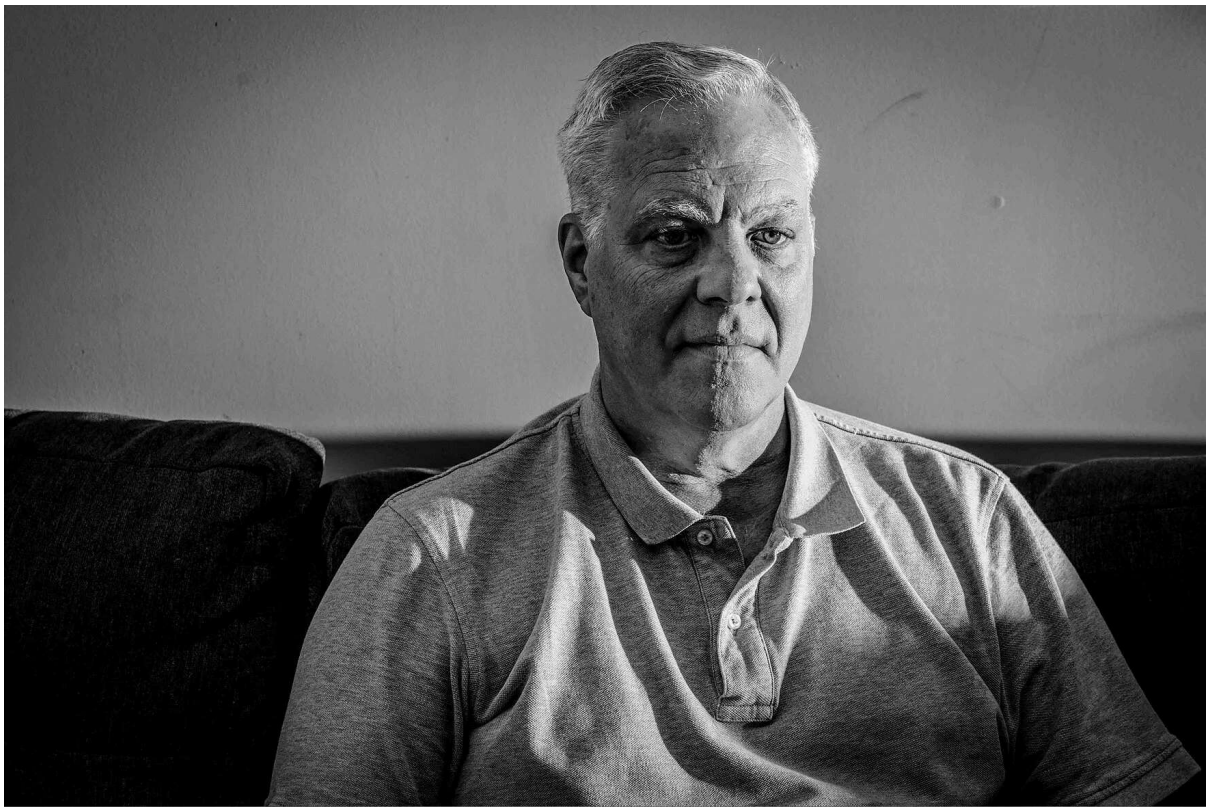
Bartos used an ultrasound machine to find the large vein and artery in Sauer's right groin, which appeared as black circles on the screen. He placed a needle in each blood vessel, then fed guide wires through the needles. He threaded one long wire into the vein and pushed it up into Sauer's abdomen and chest — with the help of X-rays to see the wire's path — until he had maneuvered it into and through Sauer's heart to reach a big vessel just above it. Another wire was placed in Sauer's artery. A dilator was temporarily inserted over one wire to create a tunnel. The dilator was then removed, and a thick cannula was inserted over the guide wire. This was repeated in the other vessel.

Once the cannulas were in place — one in the vein and one in the artery — tubes that looked like garden hoses connected them to a machine that began sucking out Sauer's blood. Inside that device, the blood passed through a membrane that functioned like an artificial lung, and then it was pumped, freshly oxygenated, back into Sauer's artery to perfuse his body — and most important, his brain.

The next day, in the intensive-care unit, Sauer looked bad, as though he were still dead. He had no color, and his toes were still blue. "I hope I did the right thing" by agreeing to the ECPR procedure, Waters recalls thinking while standing at his bedside. "Because what if he doesn't come out of it? What if he's stuck on these machines?"

But over the next few days, Sauer's eyes started fluttering, half open. When the doctor told him to squeeze his hand, he did. By the fourth day, he really wanted a frozen Coke, because the tubes in his mouth made it feel terribly dry.

Sauer spent about a week in the I.C.U., then left the hospital 12 days after his cardiac arrest. Two months after his heart stopped, he was back at work, though he had been so bored at home, he wanted to return earlier. Sometimes people didn't grasp that he died that day. "No," he would tell them, "I really did."



John Sauer suffered cardiac arrest from a "widow maker" heart attack at 61. He was met by the ECPR truck and a specialist, and eventually recovered and went back to work two months later. Mark Peterson/Redux, for The New York Times

ECPR, Hayes told his colleagues afterward, "is the most badass thing I've ever seen in my life." He calls it "the highest note" of his long career, a treatment for a condition that he had almost always seen end in death. "It changed my perspective," he says.

When I was a medical student, every so often I would find myself riveted by a television or movie scene in which a tenacious doctor tries one last time to resuscitate a patient, after everyone else has given up. Miraculously, the patient, receiving CPR, gets his heartbeat back. Sometimes he would even sit up or start talking. Of course, I knew the scenes were exaggerated — is there any greater drama than seeing a beloved character come back to life? — but still, a tiny part of me imagined myself as that emergency doctor, the one who kept doing CPR, administered that final shock, injected the drug that made *the* difference.

As I went through residency training, and eventually as an emergency doctor, I wasn't surprised to see that cardiac arrests don't follow the same narrative in real life as they do on film. Yet I *was* astonished, through the years, to discover how spectacularly rare it is for standard resuscitation in the emergency room — with its crew of physicians and nurses, in a facility full of equipment and drugs — to revive someone. Unlike those dramatic fictional scenes, in which one last action changes everything, the opposite is true offscreen: If an intervention doesn't work immediately during standard resuscitation, it's probably never going to work.

In reality, by the time a patient without a pulse arrives in the E.R., we know what the outcome is going to be. We continue CPR and shock the patient if we can. We insert a breathing tube and connect it to a ventilator. We inject medications: adrenaline, heart-rhythm drugs. But these treatments almost always fail. Occasionally, a thready pulse comes back, then it vanishes again.

By this point, the chest compressions may have caved in the patient's sternum, his ribs shattered. His lungs also might start hemorrhaging, blood and mucus filling his breathing tube. We continue the cycle — compressions, drugs, maybe shock — checking for a pulse every two minutes. Family members wait with hope and despair, sitting in plastic chairs in bustling hallways outside the resuscitation room. In more recent years, I've been escorting loved ones into the room after a while, so they can witness the resuscitation attempt. In every instance that I can recall, they asked us to stop — the futility obvious, the suffering too immense. The few times we coax the heart to beat again, the patient almost inevitably dies in the hospital later.

Demetris Yannopoulos, an interventional cardiologist and professor at the University of Minnesota Medical School who created its Center for Resuscitation Medicine, refused to accept that this was the best doctors could do. In 2014, he began performing ECPR, a treatment that was starting to catch on in a few places, mostly in Asia and Europe. To his surprise, patients he didn't expect to survive ended up doing well. The following year, he started the first comprehensive ECPR program in the United States, which diverted many cardiac arrests in the Twin Cities area to his facility, where, instead of getting only conventional resuscitation methods, they immediately received ECPR.

When a patient in cardiac arrest is placed on an extracorporeal membrane oxygenation (ECMO) machine, as Sauer was, the treatment is called ECPR. The type of ECMO intervention used in ECPR provides full life support, which means it does the work of both lungs and heart. (Another type of ECMO, used on Covid-19 patients, helps just with breathing.) ECMO evolved from the heart-lung machines that started being used during heart surgery in the 1950s. Patients could be on them for only an hour or so, because the technology delivering oxygen to the blood would also damage it.

Yannopoulos placing a venous cannula in a patient's leg during ECPR. Mark Peterson/Redux, for The New York Times

In the late 1960s, Robert Bartlett, a surgical resident in Boston, and others started to develop a solution: a membrane that infuses oxygen into the blood and filters carbon dioxide out of it. This became the basis of today's ECMO machine. Later, to treat newborns struggling to breathe, Bartlett used the machine — their last hope — and 80 percent mortality rates soon flipped to 80 percent survival rates. Now a professor emeritus at the University of Michigan and known as "the father of ECMO," Bartlett also was the first to use ECMO for its heartlike function, for a child experiencing difficulties after cardiac surgery.

But when a multicenter trial funded by the National Institutes of Health tested ECMO on adults suffering from respiratory failure, the treatment didn't save more lives than conventional care did. Afterward, critics pointed out the trial's poor design: Different centers relied on different protocols, and some had no ECMO

experience. Yet the results, published in a prominent medical journal, discouraged doctors from trying the intervention. “That set aside ECMO for adult patients for the next 30 years,” Bartlett, who helped design the study, told me. But he and others continued using the treatment with babies and then, in time, with older children as well.

The eventual adoption of ECMO for adults was driven, in part, by pandemics. In 2009, doctors, desperate to save patients dangerously ill with H1N1, or swine flu, put some of them on ECMO. Many of these patients survived. A decade later, Covid-19 thrust ECMO into the public consciousness. By then, a multicenter study testing ECMO on adults in Britain had shown promising results. Doctors also were successfully using ECMO for certain cardiac cases.

ECPR by itself doesn’t actually cure anything. But by providing fresh blood flow to the brain and other organs, it lets the body rest and gives doctors time to fix the underlying problem, if it’s fixable. Patients whose hearts are in a rhythm that’s conducive to being shocked with a defibrillator, like Sauer’s chaotic pattern, fare much better. That’s because they usually have a primary heart problem that can be repaired. After patients are hooked up to ECMO, angiograms of their hearts are typically performed to determine whether they have clogged arteries — as about 85 percent do. In Sauer’s case, Yannopoulos found a blockage in his largest heart vessel, the left anterior descending artery, also known as “the widow maker.” He inserted a stent to open it back up.

For others, whose hearts have some electrical signals but are not able to beat sufficiently — what’s called pulseless electrical activity — or worse, asystole, which is seen as a flat line, the underlying problem may not be found. Or if it is found, it’s often too late to fix. The reason ECPR must begin so quickly is to try to keep the brain perfused with oxygen, and the most common reason people still die afterward is that their brains couldn’t recover from the initial reduction in blood flow. “ECPR really should be called ECBR,” Bartlett says.

Complications during the procedure itself are not uncommon. A lot can go wrong when running big cannulas into people's blood vessels from their groins all the way up to their hearts. Vital vessels can be ruptured, causing catastrophic bleeding; the liver can be lacerated; the heart can be perforated. Or the procedure can simply fail. After a patient is on ECMO, a special catheter needs to be placed in the patient's leg to maintain its blood flow, or it, too, can die. ECMO machines can cause clots, so a powerful blood thinner is used, which in turn can also cause life-threatening bleeding.

Yannopoulos and his team treating a patient. Mark Peterson/Redux, for The New York Times

But the greatest enemy of ECPR — of the brain, really — is the clock. And unlike a stroke, whose treatment window is measured in hours from the start of symptoms, cardiac arrest stops blood flow to the brain, bringing a person closer to death with each passing minute. In Yannopoulos's program, if patients with a shockable

rhythm are started on ECMO within 30 minutes of collapse, there is a nearly 100 percent chance of reviving them, with their brain function intact. After 40 minutes, the survival rate falls to about half, and then to around 20 percent after one hour. By contrast, patients receiving standard resuscitation measures have essentially no chance of survival after 40 minutes. “Big picture, ECPR is the most effective intervention for cardiac arrest since CPR,” Joseph Tonna, an emergency critical-care doctor at the University of Utah Health who researches ECPR, told me. “Without a doubt.” But he acknowledges adversities: “It’s actually pretty hard to implement.”

The biggest obstacle for Yannopoulos in the beginning was proving to his colleagues that patients in cardiac arrest were “a population worth fighting for,” he says. “The nursing staff thought I was experimenting.” Marita Sanders, the nurse manager of the cardiovascular I.C.U. at his hospital, told me that when she heard about the program, “first thing I thought was, Oh, my, I got to figure out who’s running this and shut this down.” Sanders pictured the I.C.U. filling up with profoundly-brain-injured people who would stay for months before eventually being moved to nursing homes.

But then, she recalls, a patient — a middle-aged man whose heart stopped while he was at a pub nearby — woke up after several days in the I.C.U. with “all his faculties totally intact.” Her mind was changed. Compared with standard resuscitation practice, she says, “it’s like, ‘Wow, we’ve arrived.’”

Several years after the program started, Yannopoulos, Bartos and their team conducted the first randomized, controlled trial of ECPR. The results were published in The Lancet in 2020 as the ARREST trial. The study included only patients who had been given bystander CPR (so their brains received some blood flow) and had a shockable rhythm (signaling a treatable cause) — and only patients who did not wake up from standard E.M.S. resuscitation before they arrived at the hospital. Patients like Damar Hamlin, the Buffalo Bills safety, or Christian Eriksen, the midfielder who plays for Denmark and Manchester United — each of whom collapsed on the field of play and was shocked back to life — didn’t need ECPR because a defibrillator did its job.

After enrolling just 30 patients, the ARREST trial was stopped early by an N.I.H. board because the patients who got ECPR did so much better than the control-group subjects who received standard resuscitation, and it would have been unethical to continue the study. After six months, 43 percent of the 14 patients who got ECPR were alive with good brain function, compared with zero in the control group. (One ECPR patient woke up and decided he didn't want to be in the study, so he was excluded from the final count, although he obviously fared well.)

Walter Panzirer, a trustee of the Helmsley Charitable Trust, had already learned about the program before the ARREST study came out. "It sounded way too good to be true," Panzirer says, and he arranged to meet with Yannopoulos. The night before the meeting, Yannopoulos sat down in front of his fireplace with a glass of Lagavulin 16 Scotch and asked himself, "What would I do if I had all the money in the world?"

What he sketched out, on a napkin, was the next step in his ECPR revolution: making it mobile. That is, his team would meet patients at local hospitals and perform ECPR there; once they were connected to the ECMO machine — the countdown clock now stopped — patients would be driven to the university hospital to receive specialized I.C.U. care. For people who lived too far away from a participating hospital, an ECPR truck fully outfitted like "a superduper cath lab" — a state-of-the-art cardiac-catheterization facility — would converge with the team at rendezvous sites.

The Helmsley Trust gave Yannopoulos grants totaling $19.4 million, which enabled him to add this "hub and spoke" mobile component to his program: The university hospital would be the hub, and a truck and some local hospitals would be the spokes. "It was a real big bet," Panzirer told me.

Jason Bartos during rounds at the I.C.U. at the M Health Fairview University of Minnesota Medical Center. Mark Peterson/Redux, for The New York Times

To reach patients in areas that were more suburban and rural, Yannopoulos first had to team up with surrounding health systems. Competition is more often the norm among health systems, rather than collaboration, but he persuaded his chief executive, James Hereford, to gather his counterparts from other institutions. Eventually, they were willing to work together. But they had to sort out a lot more than simply agreeing to collaborate. How would insurers pay for what they were doing? Would the initial hospital get the money, or would the university hospital? Would malpractice coverage protect doctors outside their own institutions? What about transport?

Every question could be turned into a reason for hospital administrators and lawyers to say no. But Yannopoulos “would just not let this rest,” Hereford says, and an umbrella organization called the Minnesota Mobile Resuscitation

Consortium was created to address such questions; Bartos became its first president.

To make the program's expansion possible, Yannopoulos and Bartos had to train other doctors to perform what can be a very difficult procedure. Yannopoulos is known as an ECPR wizard; when I watched him at work on a cardiac-arrest patient recently, his fingers danced between needles and wires and dilators and cannulas with such grace and speed that they were a blur. But what he and Bartos can do in under five minutes can take other teams 20 minutes or longer, while also increasing the risk of complications. As Charles Bruen, an emergency critical-care doctor who joined the mobile team, explains, "Where the training really becomes necessary is the thousands of microskills that have to be done exactly right — where you place your hands, what that feel is and how you're specifically doing all those things." And this is happening as the chest compressions from the LUCAS device are bouncing the patient's body around.

About a dozen doctors started to learn the procedure, but in part because of its difficulty and also because of pandemic disruptions, all but two ended up dropping out. To assist with the procedure and with setting up the ECMO machine, flight paramedics and nurses — already familiar with ECMO — were recruited to train for the program.

One of Yannopoulos's most important tasks was teaching and coordinating all the E.M.T.s and paramedics who are first at the scene of a cardiac arrest. Before the Minnesota program was in place, first responders there would often remain where patients collapsed and try to resuscitate them on site; this is known as "stay and play." Once ECPR became available, they were encouraged to "load and go" — to deliver a patient to a specific facility as quickly as possible.

To meet them there, the mobile team drives special S.U.V.s equipped with lights and sirens. "We go very fast," says Yannopoulos, who also owns a Ducati motorcycle. "It's like a state trooper going crazy down the roads. And I'm even more crazy."

The ECPR truck debuted in the summer of 2022. Sauer was the first survivor treated in it. To accommodate all the equipment and ensure that everything had at least one backup — so that the care provided in it wouldn't be inferior to that in the hospital — the truck and its modifications cost $1.8 million; $50,000 a year is spent on its maintenance. Taller than most fire trucks, it has over seven miles of wiring and enough electrical supply to power a house. Its use has helped shorten the times between cardiac arrest and treatment, but not as much as doctors had hoped, in part because patients started coming from farther away. For now, with the protocol in its initial incarnation, the truck parks outside local hospitals to treat patients; eventually, the team hopes to clear enough bureaucratic and logistical hurdles to be able to rendezvous with it at nonmedical facilities — schools, retail parking lots — so that treatment can begin even earlier.

Taller than most fire trucks, the ECPR truck has over seven miles of wiring and enough electrical supply to power a house. Mark Peterson/Redux, for The New York Times

The economics of ECPR are in line with those of other established lifesaving interventions, like dialysis and heart transplants. And if patients don't survive, ECPR may perfuse their bodies with enough oxygen to keep their organs eligible for donation. The program in Minnesota costs about $3.2 million a year to operate, which is covered by its revenue. This doesn't include the start-up funding from the Helmsley Trust, however, or the significant groundwork Yannopoulos laid before that — or his personal sacrifices. "When I started, I had hair and my beard was black," says Yannopoulos, who is mostly bald and gray. For seven years, he was not paid for his ECPR work; some years, he was on call every day. Today, he still spends about 6,500 hours on call annually. "It's the force of his will more than anything," Hereford says when explaining why the program has succeeded.

Many larger institutions are equipped to provide ECMO, yet effectively reviving people who are not in a hospital when they suffer cardiac arrest — that is, consistently saving lives through ECPR — requires a comprehensive, systemic approach. "Just because you have an ECMO machine doesn't mean you have an ECPR program," Yannopoulos says. "That's like saying I have a scalpel, and I went into the forest to cut someone's brain, so now I have a neurosurgery program."

Yannopoulos has invited physicians from all over to visit his program; afterward, he often hears from them that replicating his work at their home institutions — getting health and E.M.S. systems to collaborate, finding institutional support and start-up funding, coordinating 24/7 staffing — seems too daunting. For these reasons, Yannopoulos regards his ECPR program as "an administrative and political achievement, rather than a scientific or technological one."

Currently, "there's no federally mandated standard of what a new ECPR program should look like," says Joseph Tonna, the University of Utah doctor and researcher. "So people do what works for them." Unlike the care for certain strokes and heart attacks, which have designated treatment centers that require accreditation, ECPR programs for out-of-hospital cardiac arrest are not officially tracked in the United States. This makes it difficult to know what facilities are offering this care and, if they do, what it consists of exactly and what the outcomes are. At least a dozen programs have emerged. So far, progress seems uneven; some, like an effort in Los

Angeles County, have seen modest early success, while others have struggled — a result of limited operational hours, perhaps, or trouble performing the procedure. A couple have already sputtered out.

There are also hospitals that may offer ECPR ad hoc, without a program in place: If, say, a cardiothoracic surgeon is on site and not occupied with surgery, he may be willing to do ECPR for someone who shows up at the E.R. in cardiac arrest. Several places have emergency doctors who can initiate ECPR; one hospital in San Diego has relied on this model for years. For now, though, the Minnesota program remains unparalleled in the country, if not the world, with survival rates and patient numbers that set it apart as the most advanced of its kind.

To achieve survival statistics similar to Yannopoulos's, programs need coordinated expertise, which is inherently constrained by geography and logistics. But the answer isn't as simple as adding more teams or sites, because that could dilute the volume of cases that medical personnel need to see in order to gain proficiency. This reality was demonstrated in a study whose results were published in The New England Journal of Medicine last year. The trial, called INCEPTION, compared ECPR with standard care across 10 medical centers in the Netherlands. It was the first randomized, controlled trial to look at ECPR across multiple facilities, and unlike the ARREST trial, it found that ECPR resulted in similar survival as standard treatments. The disappointing results could dampen the willingness to establish new ECPR programs, the way the first multicenter ECMO trial in adults nearly a half-century ago delayed the treatment's spread.

In ECPR, tubes carry a patient's blood to be oxygenated outside the body before it is pumped back in again. Mark Peterson/Redux, for The New York Times

Yet there are reasons to interpret the study as saying more about the real-world challenges of developing and implementing ECPR programs than it does about the treatment itself. In the INCEPTION trial, it took roughly a half-hour longer for patients to get on an ECMO machine once they arrived at the hospital than it did in the ARREST study. Of the patients who got ECPR, 12 percent were not successfully connected to the machines, compared with zero in ARREST. Several Dutch hospitals handled only a couple of ECPR cases a year, which means they hadn't yet acquired the right skills. "I think they were destined for failure because of that rollout, with no experience up front," Bartos says.

Experience matters profoundly: According to a 2022 paper based on data from the Extracorporeal Life Support Organization, an international nonprofit that Robert Bartlett founded, patients treated at centers that perform fewer than 10 ECPR procedures yearly have 64 percent lower odds of survival; for every 10-case increase, the odds go up 11 percent. (The Minnesota program treats about 150 every year.)

Not only does the procedure itself require mastery, but so, too, does the care in the I.C.U. afterward — an ineffable art as much as a precise science. The first 48 hours can be especially tenuous, requiring meticulous bedside adjustment of machines and medications, as the patient teeters between life and death.

Bartos, who also directs the cardiovascular I.C.U., refuses to offer early prognostications for ECPR patients, because some have taken more than three weeks to wake up. "You need people who are willing to wait," he says, referring to the I.C.U. staff. Across the INCEPTION sites, the median time patients spent on the ECMO machine before being disconnected was 26 hours. So it's not much of a surprise to hear Yannopoulos ask, "What does INCEPTION have to do with what we're doing?" His program was carefully developed, with deep expertise, over years, to achieve the best outcomes; INCEPTION studied what would happen if a lot of hospitals started doing ECPR tomorrow.

Engineering the ideal ECPR program can feel like a maddening calculus involving experience, availability and distance — all to beat time. To treat patients faster, maybe doctors should go directly to the scene. For more than a decade, doctors in France have been doing just that, performing ECPR on the streets of Paris, in Métro stations, even on the oak parquet floors of the Louvre. Early on, Lionel Lamhaut, the head of Paris's ECMO team, was told that he was "a cowboy to try to do something outside the hospital." But as he and his colleagues persisted, they "started a new way of thinking." Their survival rates are not as high as those in Minnesota, but the Paris undertaking demonstrates that ECPR can be taken to the patient — not just performed inside a hospital.

In 2019, emergency physicians from the University of New Mexico began performing ECPR outside the hospital setting for the first time in the United States. In contrast to the giant, expensive truck that the Minnesota group would build, a regular ambulance was outfitted with an ECMO machine that is powered by a hand crank; part of an ultrasound was attached by bungee cord to the truck's ceiling. But their outcomes so far underscore the harsh reality of doing ECPR outside the hospital: No patient has survived long enough to be discharged.

If roads can't deliver expert teams to cardiac-arrest patients in time, perhaps the skies can. Despite the INCEPTION trial's disappointing results, a helicopter-based system is being tested in the Netherlands. Dinis Reis Miranda, who is leading this effort, was not deterred by the findings from INCEPTION, with which he was also involved: "I am convinced that ECPR works," he says — if teams can get there fast enough. By training a small network of doctors to deliver ECPR by helicopter, any patient in the Netherlands, which is about two-thirds the area of West Virginia, can be reached within a half-hour. The Dutch trial, called ON-SCENE, is still running, but Miranda says, "I'll eat my shoe if it isn't positive."

In December 2015, Audrey Baumtrog, who was 55, felt like any other mom preparing for Christmas. She had just finished her holiday shopping in Maple Grove, northwest of Minneapolis. While driving home, she called her daughter to

say she would be there soon. But a few minutes later, her heart abruptly stopped, and her car crashed into the back of a pickup truck. Its driver found her slumped over her steering wheel and immediately called 911.

Yannopoulos started ECPR as soon as Baumtrog arrived at his hospital. She was one of the first patients treated in the program, and almost nine years later, she is still working at her job in customer service — and making sure she travels a lot. “I make decisions more based off of adventures now, in this second life that I feel like I get to live,” she says. On occasion, while driving, she has seen the truck or the S.U.V.s marked with “ECMO” in yellow and red, a startling reminder of her death experience. “But I have so much confidence in who’s in those vehicles,” she told me. “And I think they’re going to save some lucky person.”

Audrey Baumtrog’s heart stopped beating while she was driving in 2015. She was 55 and one of the first patients treated in Yannopoulos’s ECPR program. Mark Peterson/Redux, for The New York Times

Yet if someone today suffers cardiac arrest close to the university hospital — instead of where Baumtrog was, at an intersection 20 miles away — that person may not be as lucky as she was. For all of Yannopoulos's efforts, there is a patch, not even two miles from his hospital, from which patients will not be brought to him because that area's health system did not join the consortium. Its hospital offers no similarly comprehensive ECPR program for the patients who end up there after suffering cardiac arrest.

And as much money as the Helmsley Trust has given, it is not enough to overcome some of the structural limitations in the American health care system. The organization funded a multimillion-dollar expansion of the cardiovascular I.C.U. at Yannopoulos's hospital to add 12 more spacious rooms specifically designed to accommodate patients on ECMO. But on a weekend in January when I visited, the I.C.U. was closed to new ECPR patients: Not enough nurses were available to work, so four beds in the unit were kept empty.

Even as Yannopoulos and his team hit administrative roadblocks like these, they are still trying to redefine what is medically possible. Recently, a 74-year-old man collapsed on the streets of St. Paul and went into cardiac arrest. Forty-two minutes after the first 911 call, the man was already on ECMO and had regained his pulse. Yannopoulos was optimistic about the case, given how quickly ECMO was started, even though the patient had not been shocked with a defibrillator — which meant he technically fell outside the protocol and should not have received ECPR at all. (After a week in the I.C.U., the man died when his family decided to stop all treatment.)

The man's heart was almost certainly in pulseless electrical activity (P.E.A.), which many experts think should not be treated with ECPR. Of the three published ECPR randomized, controlled trials, only one did not limit the intervention to people with shockable rhythms. That ambitious trial, in Prague, included patients whose hearts were in the same P.E.A. pattern as the St. Paul man's. The study was stopped early when it appeared that ECPR wasn't saving significantly more people than standard

care was. These enigmatic cases that lack shockable rhythms are vexing: When the Prague data was reanalyzed without these patients, the findings were favorable for ECPR.

Yannopoulos is undeterred by the Prague results. “You have to decide what’s more important: your survival rate” — what is often used in studies and by institutions to justify support for a program — “or the number of patients you actually save.” Because its program is now well established, Yannopoulos’s team is starting to treat patients with less promising rhythms, even though that may drive down its overall survival rate. Jan Belohlavek, who led the Prague study, will also continue to push the application of ECPR. “We’ve reached a roof with the interventions we do have for cardiac arrest at the moment,” he says. “Except for ECPR.”

The biggest obstacle for Yannopoulos in the beginning was proving to his colleagues that patients in cardiac arrest were “a population worth fighting for,” he says. Mark Peterson/Redux, for The New York Times

Yannopoulos wonders if, in a decade or perhaps less, ECPR science will still require the same specially trained teams using the same high-tech equipment — at least before patients get to the hospital. Instead, he imagines small cannulas that will be easy to place in the patient's neck and attached to compact, simple machines that provide some blood flow to the brain. In his vision, which he is currently working to realize, medics could be trained to start people on this, and then doctors could transition them to regular ECMO once they reach the hospital. If the brain is protected, the rest of the body can eventually recover.

In the meantime, for much of Minnesota's population, ECPR is becoming the standard treatment for cardiac arrest. And sooner or later, protocols elsewhere will evolve, too.

"There is this idea that people in cardiac arrest, you cannot harm them," Yannopoulos says. For some doctors, that means cycling relentlessly through chest compressions and medications, so they feel as if they did everything they could. For others, it means briefly going through the motions, so they feel as if they did something. And for still others, it has always seemed kindest to do nothing at all, to let their patients die peacefully. Because almost none of them lived — no matter what the doctors did. "But now we know what is possible," Yannopoulos says. "So if you're not achieving that, then you are harming them in a way, right?"

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