Raises Head, Looks Around: The State of Elevated CPR

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Five years ago, when U.S. emergency docs first started talking about it, elevating the head as part of standard CPR was a tantalizingly simple possibility that looked like it might contribute to better outcomes. Five years later it's part of a fleshed-out resuscitation bundle that's been embraced in several major jurisdictions and may be starting to yield those hoped-for results.

There's a device for doing it and data around aspects like the best rate and moment in the resuscitation sequence at which to elevate, and excitement for the bundle—which optimally includes automated compressions, active compression-decompression (ACD), and an impedance threshold device (ITD)—is high and growing among many EMS docs.

"With head-up CPR with ACD and an ITD, we can restore cardiocerebral circulation to near-normal levels," says University of Minnesota cardiologist Keith Lurie, MD, who's spearheaded the idea in the U.S., led investigations into its benefit, and created a company (Advanced CPR Solutions) to produce a patient-positioning device (the EleGARD) for EMS to execute it. "We can reduce the potential for injuries associated with CPR in the flat position, and we may be able to improve long-term survival."

The goal is better blood flow to the brain: In conjunction with the other bundle components, elevation of the head and upper torso immediately reduces intracranial pressure and improves cerebral perfusion. That means better circulation and better outcomes.

There's a lot to do right—it's not as simple as the Pelican case under the head trialed by the early adopters of 2015. But when you do, the results hold reason for optimism.

Take Palm Beach County, Fla., whose EMS system was among those early adopters: Its package of head/torso elevation, high-quality CPR, ACD, ITD, and automated compressions raised resuscitation rates for all patients from 18% to 34%, and from 23% to

All the Way Down the Line

When Skogen's cardiac arrest struck last August 11th, her coworkers at Little Rock's Capital Hotel did everything right: They called 9-1-1 and started CPR. They got the hotel's AED and shocked her. It didn't work.

Metro EMS (MEMS) arrived in nine minutes. Its crew had a LUCAS device, a ResQPOD ITD, and an EleGARD—the service had implemented the care bundle just three weeks before. They applied all three, but Skogen's v-fib proved refractory. They kept at it. It took 29 minutes and more than 20 shocks, but they finally got her back to a stable rhythm that stuck.

At Baptist Health Medical Center, cardiac catheterization revealed dissection of her left anterior descending coronary artery. Skogen's care team decided against a risky repair, as blood flow had been sufficiently restored. They cooled her to 33°C for 24 hours, then after rewarming kept her sedated for a night. Once the sedation began to ebb, she awoke hemodynamically stable and back to neurological baseline.

"I remember looking over and seeing my 13-year-old daughter, and she'd had her nails done," recalls Skogen. "I started crying and said, 'Who took you to have your nails done?!' She'd been pestering me forever, and I'd told her she was too young. I didn't remember anything else."

Spontaneous dissection of the LAD leading to cardiac arrest is rare and usually fatal. A doctor at Baptist used the term "widow-maker," says Skogen's mother, Jean Fuentes. Refractory v-fib secondary to LAD occlusion also generally spells doom. Yet Skogen, 44, went home August 16th and is fine today, back at work and attending school.

Later Fuentes would call MEMS to update staff on the outcome and thank them for their part in Darlene's save. She left a message for the crew's supervisor, Mack Hutchison. "I told him had they not been able to do what they did, I wouldn't have my daughter anymore, and that I couldn't thank them enough," says Fuentes. Hutchison passed the message on to Skogen's crew and beyond; it's now been heard by prehospital providers across Little Rock, physicians at Baptist, and even made its way to Lurie.

“I know God had everybody in the right place at the right time with the right knowledge and right equipment that night, all the way down the line,” Fuentes adds. “From the person who started CPR until the EMTs got there, the EMS crew using the EleGARD, the LUCAS machine, and everything else, and they just kept shocking her.”

Drain the Brain

The benefit of head elevation during CPR is fairly straightforward. When you compress a supine patient’s chest, it forces blood from both sides of the heart, not just one, and bombards the brain with blood from both directions, including the venous side. It increases arterial and venous pressures simultaneously, reducing the possibility of a cerebral perfusion gradient. This increases intracranial pressure and potentially creates a risk of concussion with every compression.

With a slight elevation of the head, gravity helps offset that venous pressure and drain the brain, so to speak. Adding the ACD and ITD enhances flow further with pull on the venous side. With less resistance to forward flow, ICP and the risk of additional injury fall.

A 2013 trip to South Korea spawned the idea. There Lurie encountered a wheeled, foldable stretcher-cart designed to help bring patients down small elevators in high-rise apartments. It raised the legs straight up so rescuers could keep compressing the chest. That seemed the opposite of what they should have been doing—what they needed, Lurie realized, was “easy-chair” CPR. He and some colleagues began experimenting around the idea.

They verified in pigs that using a feet-up/head-down position produced an excessively high intracranial pressure and low cerebral perfusion pressure, but with a head-up/feet-down position, ICP dropped, cerebral perfusion pressures improved, and the pigs started to gasp spontaneously.

As it appeared safe, early versions of head elevation started coming to the field in the U.S. by 2015. Research continued to refine the details, and the next several years produced some important findings:

- Palm Beach County’s survival to hospital improved;[3]
- 30 degrees emerged as the optimal angle for elevation;[4]
- Hemodynamic benefits seen in pigs translated to human cadavers;[5]
- Controlled progressive elevation was shown to maximize cerebral perfusion pressure.[6]

A poster at the 2019 NAEMSP conference documented cerebral and coronary perfusion pressures of more than 70% of baseline during prolonged resuscitation with controlled elevation, ACD, and ITD in pigs—gains sustained for more than 19 minutes.[7] Another at the 2019 AHA Scientific Sessions reported a sixfold increase in 24-hour neurologically intact survival in pigs with head-up CPR.[8]

“It’s not just one thing that’s going to bring you back from cardiac arrest—it’s all these different things,” says Johanna Moore, MD, research director for Hennepin County Medical Center’s Department of Emergency Medicine. “I explain head-up CPR to people as like the sixth gear of resuscitation: You have to prove your system is capable of doing high-quality CPR; you have to be able to use an ITD effectively; ideally you’ll have mechanical CPR for transport. Then we can talk about whether you’re ready for head-up CPR. I think it’s for more advanced systems.”

The value of ACD and the ITD in CPR has been well established. Active compression-decompression CPR uses a suction device to pull up on the chest during recoil, increasing the intrathoracic vacuum and helping pull blood back into the heart. The ITD restricts air flow into the chest, limiting intrathoracic pressure toward the same end. The result is better preload and thus better output on subsequent compressions, contributing to better survival.[9]

Without those other interventions, elevating the head alone doesn’t show comparable benefit. A 2018 pig study of BLS CPR without ACD or ITD demonstrated improved cerebral perfusion pressure but not oxygenation;[10] in response Moore and Lurie elaborated that, “The benefit of [head-up] CPR is predicated on the fact that in order to pump blood ‘uphill’ to the brain, some sort of circulatory enhancement is needed above and beyond that achieved with standard CPR.”[11]

Importantly, you have to prime the system with CPR *before* raising the head/shoulders. “If you just put the head up right away and the system isn’t flowing, you basically stall out,” says Lurie. “You have to have a pressure head.”

There is an optimal elevation sequence and height. Raising too rapidly may be dangerous if gravity causes aortic pressure to drop. And inclining the whole body, rather than just the head and shoulders, may be problematic because blood eventually flows downhill to the feet.

Lurie, Moore, and other investigators have spent recent years honing in on the optimal degree of elevation, point at which to achieve it, and speed with which to get there. Those findings are reflected in the EleGARD, which hit the streets in 2019.

Elevation in Action

The EleGARD patient positioning system provides multilevel elevation over a timed sequence and is compatible with both ITD and ACD/automated compressions. Advanced CPR Solutions has a brand name, ElevatedCPR, for the package, and it's in use in more than half a dozen states.

With those additional interventions, the company notes, the ElevatedCPR method can double blood flow through the brain compared to today's best CPR;[12] raise cerebral perfusion pressure to more than 80% of normal; and, with two minutes of supine priming preceding a two-minute elevation, get coronary perfusion pressure back above 70% of normal.[6,7,13]

In July the EleGARD was part of ongoing postresuscitation research at Hennepin County Medical Center. A sedated pig underwent eight minutes of untreated ventricular fibrillation; had an EleGARD, ResQPOD, and LUCAS device applied; got two minutes of supine CPR and then was raised over two minutes to the EleGARD's highest level (22–24 cm for the head, 9 cm for the heart); and received compressions in that position for 12 more minutes before shock.

As the pig was raised, its CPP increased and ICP fell as expected. Cerebral oximetry returned to near normal. The pig gasped at 3½ minutes—a positive sign[14]—and was resuscitated with one shock and no drugs.

"Over time we maintained a terrific coronary perfusion pressure and cerebral perfusion pressure relative to what we usually see with a pair of hands," says Lurie. "Normally, even with perfect manual CPR, everything degrades over time. By 15 minutes you typically can't get a pig or a person back. But even in the absence of drugs, by optimizing the physics of CPR and blood flow to the brain, we were able to reach and maintain very high levels of cerebral perfusion. And after one shock, within two minutes the level of oxygen in the brain was back to normal."

Then the research team lowered the pig back to the EleGARD's lowest position, and then to flat. The last step produced a striking rise in intracranial pressure (from 20 to 30 mmHg) and decrease in cerebral perfusion pressure (from about 70 to 60 mmHg). Cerebral oximetry fell 7%–10% but then rebounded.

Conclusion

It's true that the elevation research to date is based largely on cadavers and pigs, and we'll need to see more Darlene Skogens—human patients surviving extreme resuscitation efforts neurologically intact in numbers that constitute data, not anecdote. But with preliminary data that's good against a problem so intractably bad, it seems worth more scrutiny and some judicious trialing in systems already delivering high-quality CPR and resuscitation care.

cardiopulmonary resuscitation involving a head-up/torso-up chest compression technique. *Resuscitation,* 2019 Mar; 47(3): 449–55.

2. Grayson ST. Leading the Way to Cardiac Arrest Survival. Take Heart America, 2018; https://takeheartamerica.org/wp-content/uploads/2018/10/Sat1040amGrayson.pdf.

3. Pepe P, Scheppke K, Antevy P, et al. Impact of head/torso-up chest compressions and flow-oriented CPR adjuncts on survival [abstract]. *Resuscitation,* 2016; 44(12 Supp): 284.

4. Kim T, Shin SD, Song KJ, et al. The effect of resuscitation position on cerebral and coronary perfusion pressure during mechanical cardiopulmonary resuscitation in porcine cardiac arrest model. *Resuscitation,* 2017; 113: 101–7.

5. Moore J, Holley J, Segal N, Lick M. et al. Consistent head up cardiopulmonary resuscitation haemodynamics are observed across porcine and human cadaver translational models. *Resuscitation,* 2018; 132: 133–9.

6. Moore J, Salveda B, Lick M, et al. Controlled progressive elevation maximizes cerebral perfusion pressure during head up CPR in swine model of cardiac arrest [abstract]. *Circulation,* 2018; 138(Suppl 2): A17.

7. Rojas-Salvador C, Moore J, Salverda B, et al. Controlled head and upper thorax elevation improves cerebral perfusion pressure during active compression-decompression cardiopulmonary resuscitation with an impedance threshold device in a porcine model of cardiac arrest. Poster presentation, NAEMSP annual meeting, 2019.

8. Moore JC, Salverda B, Lick M. Contolled Sequential Elevation of the Head and Thorax Combined with Active Compression Decompression Cardiopulmonary Resuscitation and an Impedance Threshold Device Improves Neurological Survival in a Swine Model of Cardiac Arrest. Poster presentation, Resuscitation Science Symposium, 2019.

9. Aufderheide TP, Frascone RJ, Wayne MA, et al. Comparative effectiveness of standard CPR versus active compression decompression CPR with augmentation of negative intrathoracic pressure for treatment of out-of-hospital cardiac arrest: Results from a randomized prospective study. *Lancet,* 2011 Jan 22; 377(9,762): 301–11.

10. Putzer G, Braun P, Marini J, et al. Effects of head-up vs. supine CPR on cerebral oxygenation and cerebral metabolism—a prospective, randomized porcine study. *Resuscitation,* 2018 Jul; 128: 51–5.

11. Moore JC, Segal N, Debaty G, Lurie KG. The “do’s and don’ts” of head up CPR: Lessons learned from the animal laboratory. *Resuscitation,* 2018 Aug; 129: e6–e7.

12. Moore J, Segal N, Lick M, Dodd K, et al. Head and thorax elevation during active compression decompression cardiopulmonary resuscitation with an impedance threshold device improves cerebral perfusion in a swine model of prolonged cardiac arrest. *Resuscitation,* 2017; 2017(121): 195–200.

13. Frascone RJ. “…and the dead shall rise again.”: Head Up CPR. EMS State of the Sciences Conference, 2019.

14. Debaty G, Labarere J, Frascone RJ, et al. Long-term prognostic value of gasping during out-of-hospital cardiac arrest. *J Am Coll Cardiol,* 2017 Sep 19; 70(12): 1,467–76.

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