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A "Drowning Miracle," Case Study of a 2-Year-Old with Laryngospasms and Full Neurological Recovery. (Input from Video Surveillance and Clinician Bystander)

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Abstract

Drowning, as defined by the World Health Organization, is the process of experiencing respiratory impairment due to submersion or immersion in liquid. Despite global efforts to prevent drowning, it remains the primary driver of deaths for children under 5 in the United States, and the third leading cause of accidental death worldwide, disproportionately affecting rural and low-to-middle-income areas [1-4].

Drowning outcomes range from mild respiratory impairment to severe neurological damage and death, known as fatal drowning. Immediate bystander intervention is essential in these cases, yet data on pre-hospital interventions are scarce. In 2-10% of drowning cases, laryngospasm occurs; a protective reflex in which the body forcibly closes the airways to prevent aspirate from entering the lungs [5]. While the primary injury from drowning is due to hypoxia, the extent to which laryngospasms contribute to this remains understudied, with limited literature on physiology or effective interventions [6,7].

One leading question from this case is whether there are clinical benefits of manual gastric decompression, also known as the Heimlich maneuver, during cardiopulmonary resuscitation (CPR) in a drowned victim with laryngospasms. This hypothesis was peripherally raised by Dr. Heimlich, who collected cases of drowning victims benefitting from the Heimlich maneuver. His theory that it cleared aspirate from the lungs was invalidated; however, this case proposes an alternative explanation. The Heimlich maneuver may benefit certain drowning victims by ejecting fluid and vomitus from the stomach, and decompressing the gastric space. In gastric distention, elevated abdominal pressure can impair ventilation and cardiac output by restricting lung expansion and decreasing venous return and cardiac output. Thus, safely decompressing the stomach may allow the vagus nerve to signal the superior laryngeal nerve to clear the laryngospasm and improve ventilation [5,7]. In emergencies where airway and perfusion are priorities, this approach could be lifesaving, especially when the risk of decompression aspiration is minimal by the completely closed airway in cases of laryngospasm [8].

In an emergency where optimal intervention focuses on airway and perfusion, could safely decompressing the stomach by inducing vomitus save lives? This case study aims to contribute to the ongoing discussion and research on this critical issue, which has profound social implications for families and communities.

Introduction

Case Study

On a hot June Saturday afternoon, a 33-month-old, 10 kg female was found submerged in the shallow end of a residential pool. The pool, prepared for pediatric swim lessons, was freshly cleaned and maintained at 30°C, with active water filtration and heating, creating a gentle current.

Security footage revealed the child was unconscious for eight minutes before intervention. In the minutes leading up to this, she is seen in a sleeved rash guard swimsuit with neck coverage, opening the front door, a newly acquired skill, and firmly closing it behind her. She proceeded to the garage, attempting but failing to open the heavy child-proof door leading to the pool. Undeterred, she exited the garage and accessed the pool area through a side entry gate of a 5.5 feet fence. A bell had been attached to the latch to notify opening and closing, but this prevented the door latch from fully closing.

The child cautiously walked by the deep end of the pool, stepped over a garden hose, and approached the shallow end. She placed one foot on the first stair, five inches below the water's surface, followed by the other foot while holding the pool's cement rim. She splashed with one hand. Then, as she placed both hands into the water, she floated up and pulled away from the steps. After 20 seconds, her face submerged, and within a minute, she ceased movement.

She remained submerged for eight minutes before being pulled out and CPR initiated. Another adult assisted and called 911, notifying the emergency room team to prepare for her arrival at a regional trauma center, five minutes away.

After two rounds of 30 compressions to 2 breaths, the 2-year-old was moved to the floor of a van and transported to the Emergency Department (ED) with continued CPR delivery. No foam was noted at any point during CPR.

The clinician bystander performing CPR observed that airway management was initially ineffective. Despite tilting the head back, clasping the nostrils closed, and delivering breaths through a tight

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seal over the mouth, there was no chest rise. The breaths felt "like blowing on a brick wall."

After two more rounds of ineffective large forceful breaths, but strong compressions, the bystander delivered a prolonged breath, accidentally inducing vomiting. The subsequent breath "felt effective," and had some minimal chest rise. After another round of compressions, they repeated the prolonged large breath, turned the child to the left, concurrently pushing up on the stomach, and manually induced the expulsion of a large bolus of water and food remnants.

The bystander repeated this process while adjusting CPR to a 15:2 compression-to-breath ratio for the remainder of the drive (approximately 4 minutes). At this point, each breath resulted in chest rise without resistance.

Upon arrival at the ED, the child was found to be in normal sinus rhythm with agonal breathing. She was immediately intubated, placed on a cervical collar and transferred to the local Children's Hospital Pediatric Intensive Care Unit (PICU). The results of initial hematologic laboratory tests are shown in (Table 1).

Within two hours of her initial labs, her lactate improved to 4.63 mmol/L, and within 5 hours dropped to a normal of 0.96 mmol/L.

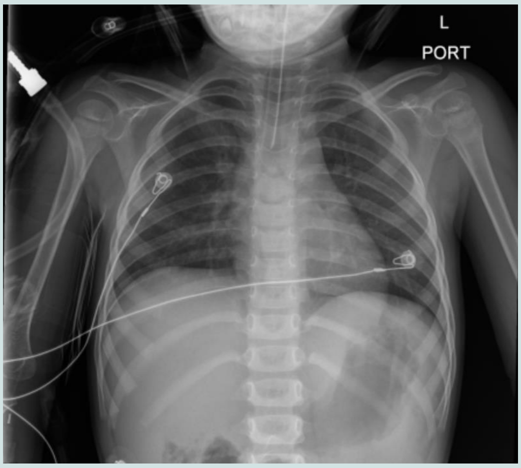

Figure 1: Initial chest X-ray after intubation at Children's Hospital.

Table 1: Lab values approximately 1 hour from initial submersion

Variable	Children's Hospital initial labs (normal):
Lactate	9.03 (0.36-1.25 mmol/L)
Creatinine	0.3 (0.1-0.7 mg/dL)
Glucose	320 (70-99 mg/dL)
Na	137 (135-145 mmol/L)
K	2.9 (3.5-5.3 mmol/L)
pH	6.96 (7.32-7.42)
pCO2	77 (41-51 mmHg)
pO2	100 (34-40 mmHg)
aPTT	29.3 (28.6 -37.2 sec)
ALT / AST	572/871 (0-33 / 8-50 U/L)
PT	13.6 (12.1 -14.5 sec)
INR	1.0 (0.8-1.2)

Initial chest X-ray was unremarkable with minimal atelectasis and gaseous distention (Figure 1). Her CT scan was benign.

She was enrolled in the Pediatric ICECAP study and randomized to 72 hours of induced hypothermia at 33°C [9]. She was placed on delirium prevention and infection prevention measures, including maintaining her sleep and nap schedules. Team members entering her room were asked to wear masks as the induced hypothermia dropped her WBC to 1.6 thousand/mm3 (normal 5-14 thousand/mm3).

Her PICU course was uncomplicated. There were no seizures, delirium, infection or pneumonitis.

After 72 hours, she was rewarmed and underwent a normal magnetic resonance imaging (MRI). She was successfully extubated on the first attempt, remarked 'I'm so silly,' and proceeded to eat three ice pops.

She then awaited transfer to inpatient pediatric rehabilitation. Within 48 hours, she was walking with assistance, communicating in two languages, eating solid foods, and maintaining her sleep schedule. The child was discharged home with continued monitoring from physical, speech, and occupational therapy. At 12 weeks, she was classified as Level 1 on the Pediatric Overall Performance Category Scale, indicating 'Good overall performance: healthy, alert, and capable of normal activities of daily life[10].'

Discussion

Drownings are currently the leading cause of mortality in young children in the United States [1-4] (Figure 2). Since 1995, drowning has surpassed fires and burns as the primary source of death for children aged 4 and under, largely because rates of deaths from fires have declined. However, since 2020, there has been a marked increase in pediatric drowning cases. For every fatal drowning, it is estimated that 4 non-fatal victims seek care [11]. Adult supervision, early swimming lessons, pool fencing, and pool covers are effective measures to prevent drowning incidents [3]. When drowning cannot be prevented, factors such as submersion time, bystander intervention, the need for and initiation of advanced life support, the duration of CPR, and the return of spontaneous breathing are crucially correlated with survival and neurological outcomes [12].

The drowning victim may have multi-factorial elements for causing physiological dysfunction including cardiopulmonary response to both temperature and hypoxia. Despite the victim attempting to hold their breath, coughing and involuntary laryngospasms occur. Recent studies have shown that laryngospasms resulting from drowning are always complete[8]. With the closure of the vocal cords, water enters the gastrointestinal tract. This protective mechanism is thought to last for approximately one minute. However, in 20% of cases, laryngospasms continue even after cardiac arrest. Laryngospasms are also 2-3x more common in younger children [13]. When the laryngospasms cease, water then enters the respiratory tract causing bronchospasms. This often causes foam from cellular damage to alveolar walls and surfactant washout. This foam may be beneficial and can be bagged back into the lungs. Cardiac dysfunction can occur at any of these points, and it follows a predictable hypoxic

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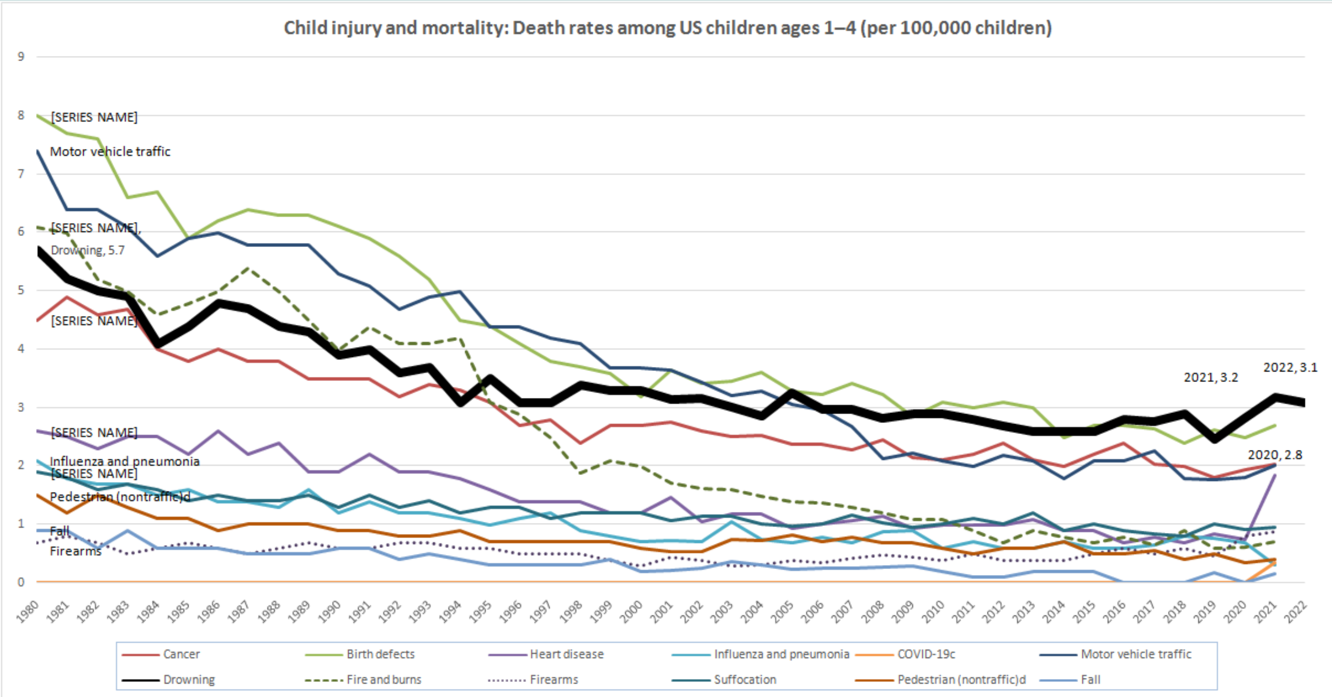

Figure 2: Death rates among US children ages 1–4 (per 100,000 children)

pattern: sinus tachycardia, bradycardia, pulseless electrical activity then asystole. While any organ can see injury, the most susceptible areas to ischemic injury are vascular end zones. In the brain, these are often the hippocampus, insular cortex, and basal ganglia. More severe hypoxic-ischemic events result in more extensive and global neocortical injury [14,15].

Drowning may cause a significant amount of water to enter the stomach (approximately 500 mL in a 2-year-old and up to 4 liters in adults). In many cases where CPR is administered, CPR can also induce vomiting. However, the drowned victim that does not respond needs airway, breathing and circulation (ABC) management as quickly as possible, as opposed to the typically practiced circulation-airway-breathing (CAB) pathway per the 2024 American Heart Association, American Academy of Pediatrics Focused Update and International Guidelines [15-21]. If CPR induces vomiting, sweeping the vomitus away, and continuing CPR is prioritized.

Conclusion

The pathophysiology of drowning is complex, and there is a significant need for more research in this field. We do not fully understand how the body responds to submersion and immersion, including why some victims have laryngospasms, and other do not. We also neither have physiological data on laryngospasms, nor do we have clear epidemiological data on outcomes of resuscitation in this population. This lends to a gap in our understanding of the most appropriate resuscitation mechanism for these victims [7,16,22].

The field of Anesthesia has published the most on laryngospasms in the field of post-surgical risks and complications, and gives us our biggest window of exploring other options. In post-op cases, young children have thrice the risk of laryngospasms as older children. Laryngospams are managed by medications, through jaw thrusts or using Larson's maneuver [13]. Jaw thrusts pull the vocal cords apart, and may be easily taught to bystanders. Larson's maneuver, while effective, may be more difficult to perform in the field by untrained persons. In using medications to manage laryngospasms, there is a preference to quickly deepen anesthesia using Propofol and Succinylcholine, and perform gastric decompression to maintain the open airway [23].

81% of fatal drownings involving US children under age 15 occurred in a residential setting, including at the victim's home, the home of a family member, friend, or neighbor[20]. Even in the United States, where Emergency Medical Services are available, it can take an average of 7-14 minutes for EMS to arrive on scene at a life-threatening emergency. And if EMS then decides to intubate, field intubation only has a 60% success rate, with no data available on successful intubation rates for laryngospasms[21,24,26]. In many of these cases, intubation at the scene will be difficult, or futile (in the case of laryngospasms). Any resources we can provide to bystanders and first responders in these dire situations can have meaningful impact.

Dr. Henry Heimlich collected intervention stories when the Heimlich maneuver was used, and inadvertently found cases where drowning victims potentially benefitted. He hypothesized that sub-diaphragmatic thrusts, or the Heimlich maneuver, could help clear liquid from the esophagus and lungs in drowning victims. Though a 1993 review by the Institute of Medicine found no evidence that the maneuver could clear aspirate from the lungs to improve ventilation

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and oxygenation, it is possible that Dr. Heimlich's observations may still hold value [5].

This case proposes an alternative explanation: the Heimlich maneuver, or gastric decompression, may benefit certain drowning victims by ejecting fluid and vomitus from the stomach and decompressing the gastric space. In gastric distention, elevated abdominal pressure can impair ventilation and cardiac output by restricting lung expansion and decreasing venous return and cardiac output. Thus, safely decompressing the stomach might allow the laryngospasm to clear and improve ventilation. In emergencies where airway and perfusion are priorities, this approach could be lifesaving, especially when the risk of aspiration is minimal by the completely closed airway in cases of laryngospasm [9].Perhaps, intentional gastric decompression in the recovery position can even reduce the likelihood of aspiration pneumonia in post-drowning laryngospasms.

This drowning miracle case, suggests that laryngospasm may have been alleviated through forced gastric emptying, facilitating diaphragmatic relaxation and airway opening. Perhaps this can be an additional tool in CPR to increase the window of opportunity in airway management, in one of the most devastating international public health challenges we face.

Acknowledgements

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