Near-Drowning: Prognoses and Prevention

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ABSTRACT

Drowning is a significant and preventable cause of death in children across the world. Early indicators for 2001-2 suggest that at least 251 incidents occurred in Australia, with 44 of these being children under five years old (The Royal Life Saving Society Australia, 2002). This figure is down by 25% from the previous five-year average. However, the loss of 44 young children in preventable water related incidents is 44 too many.

Seventy-five percent of paediatric drowning deaths in the 0-5 year age group were due to the child falling or wandering into the water (Langley, 2001). Because children of this age are curious, the message to all is that children need to be kept under constant supervision when near water.

KEY WORDS

near drowning, childhood drowning, near death incidents, preventable deaths, Australia, United States, emergency department

It is estimated that each year there are over 150,000 drowning deaths worldwide, 68,000 in the United States (US), of which 2,000 are children (Vaughn, 2002; DeNicola, 1997). In Australia, New Zealand and the US, drowning is the first or second cause of injury death in children, tragically with most being under four years old (Stevenson, 2003; Mackie, 1999; Fenner, 2000; Langley, 2001). For every paediatric drowning death in the 0-5 year age group, there were approximately 3-4 children admitted to hospital as a result of an immersion incident. For each hospitalised child four are seen for treatment in the emergency department (ED) (Vaughn, 2002). Every one of these incidents presents as a potential death.

On the receiving end of such devastating incidents, emergency nurses feel the lament of dealing with a potential child's death that could have been prevented. The outcome of paediatric cardiac arrest is abysmal (Young & Seidel, 1999).

Once a child is resuscitated and transferred to the appropriate centre, the question remains "What will be the outcome?" This article is a review of the literature on neurological outcomes of paediatric patients following a near-drowning event and it provides proven prevention strategies to minimise these tragedies.

Over the years clinicians have developed a reasonable sense about who is going to live and who is going to die, they do however continue to struggle with the grey area between life and death. When resuscitating a patient after a near-drowning event no-one wishes to withhold life saving interventions. However, the possibility of the child suffering neurological damage after their life has been saved is always present in the resuscitator's minds and ethicists struggle with and debate the fate worse than death. The parents of a child saved from a near-drowning event want to know the answer to two questions. Firstly, is their child going to live and, secondly, will they be the same the same as before the incident? In other words, they want to know realistically the neurological outcome. Providing parents with reasonably foreseeable answers to these questions is imperative because these answers will form the parent's decisions about the aggressiveness of further invasive procedures and treatment management. To help us answer these questions, researchers have studied prehospital, ED and intensive care unit (ICU) assessment findings in an attempt to be able to predict a patient's neurological outcome. However, because patients continue to surprise us with unexpected outcomes, particularly recovery, there are always excepnons.

One of the first studies detailing the prognoses of near-drowning victims was published by Hasan in 1971. Since then several researchers have trialed various criteria to determine a child's neurological outcome. Most research focuses on neurological assessments performed either upon the initial presentation to prehospital providers, the ED, the ICU, or those performed at repeated intervals throughout the hospitalisation. The complexity of the examinations range from those commonly performed, such as the Glasgow Coma Scale (GCS), to invasive measurements of intracranial pressure (ICP) and cross-brain oxygen content. The neurological prognoses chart (Appendix 1 on page 33) summarizes the published literature on neurological outcomes after a near-drowning event. It details the correlations between prehospital and medical centre assessment findings and eventual neurological status. However, none of the studies have consistently achieved the desired 100o/o predictive value as to life in a persistent vegetative state (PVS) versus being discharged neurologically intact. In summary, research findings support the statement that if a patient presents to the ED, or especially to the ICU, and they are doing anything – moving, breathing, posturing, or their pupils are reactive – and they are considered to be improving, they have a remarkable chance of being discharged neurologically intact.

Like burns, near-drowning, is better prevented than treated. In a recent US study on drowning prevention, paediatricians indicated that it was less important to counsel parents about drowning prevention than other issues, such as gun safety (Barkin, 1999). However, statistically more injury deaths, especially in the young, are attributable to drowning than firearms and toxic ingestions (Barkin, 1999). From an international perspective this is not just an issue for the young. Although the peak age for near drowning is 0-5 years, there is a econd peak in the US at 15-24 years when the Three Ds – drinking, drugs and dares – come into play.

Children can and do drown. All sources of liquid are potential hazards for children, however swimming pools are the place of many drowning incidents. Studies place the percentage of drowning in swimming pools between 17% and 90%, depending on the child's age (Mackie, 1999; Vaughn, 2002; Cass, 1996). In Australia there is also a disturbing increase in the number of children drowning in rural lakes and dams and a large increase from the previous five-year average in rivers, oceans and harbours (RLSSA, 2002).

Pools are not the only area of concern for near-drowning incidents. Bathtubs are the site of just as many incidents in those under one year. Infants have the ability to sit upright, but lack the ability to right themselves once they topple over (O'Fiaherty, 1997; Mackie, 1999; Pearn & Nixon, 1977; Vaughn, 2002; Cass, 1996; Byard, 2001). Bathtubs are not only a common place for drowning, but also of abuse, 56% of all inflicted drownings occurred in bathtubs (Byard, 2001; Gillinwater, 1995). In all cases ofbathtub drowning, lack of adult supervision played a role with the majority of children being unattended, sometimes only momentarily. Parents and caregivers left a child unsupervised for activities such as fetching a forgotten towel, retrieving washing off the line, making phone calls or doing the dishes (RLSSA, 2002).

In Australia, tourists are frequently the victims of drowning with 87% of drowning incidents occurring in the ocean. However, on beaches patrolled by the Surf Lifesaving Association (SLSA), none of these incidents involved under 5-years olds (Fenner, 2000; Mangolios, 1998). Buckets, toilets, oceans, ponds and rivers are other areas where drowning occurs; conversely, in the young, pools, bathtubs and buckets are the key areas (Mackie, 1999; Fenner, 2000; Langley, 2001; Byard, 2001; Pearn & Nixon, 1977; Cass, 1996).

The layers of protection concept is a key to understanding drowning. It commences with preventing the child from entering the pool and continues with knowing that the child has entered the pool. However, simply having a fence is not enough. A functioning, self-latching gate is just as crucial. Several studies have demonstrated that up to 80% of paediatric drownings could be prevented with proper fencing which involves at least 2.4 m (five-foot), non-chain link, four-sided fence with a maximum of 10em (four inches) between the slats (Milliner, 1980; Pitt, 2001; Stevenson, 2003). Three-sided fences with the house being the fourth side have been shown to allow a 78% higher chance of drowning compared with four-sided pool isolation fencing (Stevenson, 2003). In Australia, a study showed that in the ten years following enforcement of mandatory fencing laws, there were no drownings in domestic swimming pools (Miliner, 1980). Similar studies show atleast a 50% reduction in drownings if proper barriers are in place (Blum, 2000; Pitt, 2001; Stevenson, 2003). However, several studies have found that where fences are in place, few of them comply with mandatory specifications and many have non-functioning gates or even worse, gates which had been propped open (Stevenson, 2003; Blum, 2000; Pearn & Nixon, 1977).

If a child proceeds past the first level of prevention, the fence and closed gate, it is important to know at what point they enter the water. Supervision is essential however it does fail. Parents need to be aware that supervising a child excludes activities such as playing cards, reading, chatting over a drink and talking on the phone. Countless drownings have occurred where children were supposedly being supervised by their parents or caregivers (O'Flaherty, 1997; Vaughn, 2002). Several years back, floating pool alarms were introduced in the US and Canada. The idea was, and continues to be, a very feasible one. These devices floated on the water and the wave vibration caused by a child falling into the pool would activate the alarm (see Figure 1).

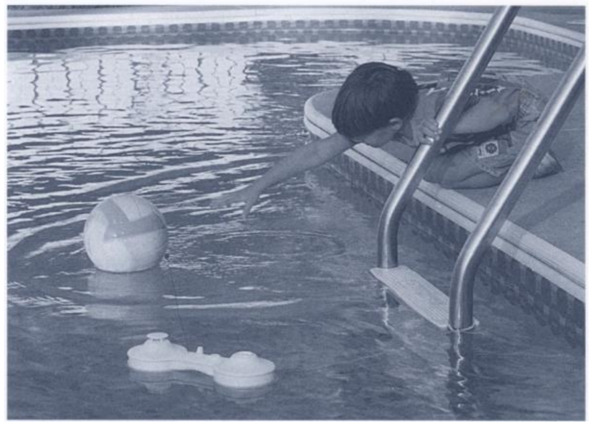

Figure 1. 505 pool alarm, Boucherville, Quebec, Canada

However, because they can be activated by rain or wind, parents may decrease their sensitivity to prevent false alarms. This defeats the purpose of having the detector (Harborview Injury Prevention and Research Center, 2001).

Another device, the Safety Turtle watch (see Figure 2 over page) is key locked on the child's wrist. The watches, which are available in several colours, are cute little turtles. Most importantly, if the watch is submerged (not just in contact with a liquid), the base alarm sounds instantly alerting those nearby that a child has entered the pool (Harborview Injury Prevention and Research Center, 2001).

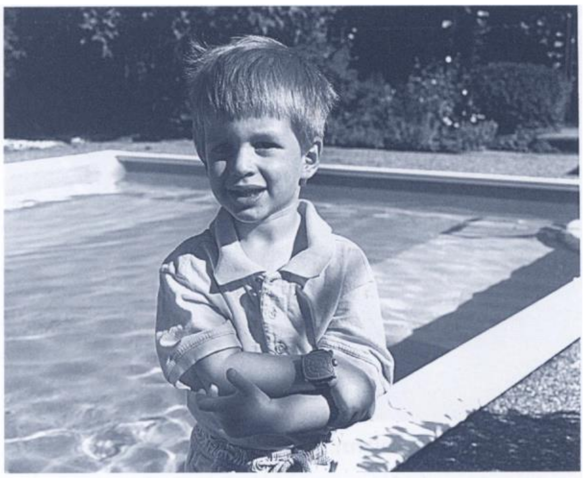

Figure 2. The safety turtle, Terrapin Communications, Ottawa, Ontario, Canada

Figure 3. Loop-loc cover & elephant, Loop-Loc Ltd, Hauppauge, NY, USA

Hard, non-submersible pool covers (see Figure 3), lifejackets whose usage is now being promoted in teen fashion shows, CPR training and swimming lessons especially after the age of four, are vital assets in the prevention of drowning (Committee on Sports Medicine & Fitness and Committee On Injury & Poison Prevention, 2000; Committee on Injury, Violence & Poison Prevention, 2003; Harborview Injury Prevention & Research Center, 2001; Wintemute, 1990). Fencing a pool to the Australian Standard (AS 1926) may prevent a child from drowning if the self- closing gate and latches are in good working order but fencing, swimming lessons, floaties and pool alarms are no substitute for adult supervision (RLSSA, 2002; Thompson, 2000).

In an effort to prevent drowning in Australia, the national RLSSA runs an excellent public awareness campaign, Keep Watch. The organisation is volunteer based and focuses on public education to prevent aquatic related injury and death. Supervising your child is one of the key messages in the campaign and in this context, supervision means a continuous process of watching, not the occasional glance. Another key message is water familiarisation, it is strongly encouraged. RLSSAhave approved infant and parent water programs and swim and survive courses at local swimming pools. A third key message is to encourage parents and caregivers to undertake an approved course in basic life support.

Emergency nurses play a vital role in health promotion and injury prevention. It is evident from the review of the literature that causal patterns leading to drowning, especially in the 0-5 year old cohort, involve little or no adult supervision as a primary factor. Education and behavioural change are imperative and when combined with the layers of protection concept, are the keys to preventing these unnecessary tragedies.

References

Allman, F., Nelson, W., Pacentine, G. & McComb, G. (1986) Outcome following cardiopulmonary resuscitation in severe pediatric *near-drowning.American journal ofDiseases ofChildhood 140(6)* 571-5

Ashwal, S., Schneider, S., Tomasi, L. & Thompson, J. (1990) Prognostic implications of hyperglycemia & reduced cerebral blood flow in childhood near-drowning. *Neurology. 40(5)* 820-3

Barkin, S. & Gelberg, L. (1999) Sink or swim: Clinicians don't often counsel on drowning prevention. *Pediatrics. 104(5)* 117-21

Bell, T., Ellenberg, L. &McComb,]. (1985) Neuropsychological outcome after severe pediatric near-drowning. *Neurosurgery. 17(4)* 604-8

Bierens,J., VanderVelde, E., Berkel, M. &VanZanten,]. (1990) Submersion in the Netherlands: Prognostic indicators & results of resuscitation.*Annals ofEmergency Medicine. 19(12)* 1390-5

Biggart, M. & Bohn, D. (1990) Effect of hypothermia & cardiac arrest on outcome of near-drowningaccidents in children.*journal ofPediatrics. 117(2)* Pt 1, 179-83

Blum, C. & Shield, J. (2000) Toddler drowning in domestic swimming pools. *Injury Prevention*. 6(4) 288-90

Bratton, S. Jardine, D. & Morray,]. (1994) Serial neurologic examinations after near drowning and outcome. *Archives of Pediatrics and Adolescent Medicine. 148(2)* 167-70

Byard, R., de Koning, C., Blackbourne, B., Nadeau, J. & Kraus, H. (2001) Shared bathing & drowning considerations in infants & young children. *journal of Paediatrics & Child Health. 37(6)* 542-4

Cass, D., Ross, F. & Lam, L. (1996) Childhood drowning in New South Wales 1990-1995: A population-based study. *MjA.* 165(11-12) 6102

Causey, A., Tilelli,]. & Swanson, M. (2000) Predicting discharge inuncomplicatednear-drowning.*AmericanjournalofEmergency Medicine. 18(1)* 9-11

Committee on Sports Medicine & Fitness Committee on Injury & Poison Prevention. (2000) Swimming programs for infants & toddlers. *Pediatrics. 105(4)* 868-70

Committee on Injury, Violence, & Poison Prevention. (2003) Prevention of drowning in infants, children, & adolescents. *Pediatrics. 112(2)* 437-9

Conn,A,Edmonds,]. &Barker, G. (1979) Cerebral resuscitation in near-drowning. *Pediatric Clinics of North America. 26(3)* 691-701

Conn, A., Montes, J.,Barker, G. & Edmonds, J. (1980) Cerebral salvage in near-drowning following neurological classification by triage. *Canadian Anesthetists Society journal. 27(3)* 201-9

Connors, R., Frewen, C., Kissoon, N., Kronick,]., Sommerauer,]., Lee, R., Singh, N., Tiffin, N. &Brown, T. (1992) Relationship of cross-brain oxygen content difference, cerebral blood flow, and merabolic rate to neurologic outcome after near-drowning. *The journal ofPediatrics. 121(6)* 839-44

Cristensen, D., Jansen, P. & Perkin, R. (1997) Outcome & acute hospital costs after warm water near-drowning in children. *Pediatrics. 99(5)* 715-21

Dean,]. (1981) Prognostic indicators in pediatric near-drowning: The Glasgow coma scale. *Critical Care Medicine. 9(7)* 536-9

Dean,J. & McComb, J. (1981) Intracranial pressure monitoring in severe pediatric near-drowning. *Neurosurgery. 9(6)* 627-30

DeNicola, L. (1997) Submersion injuries in children & adults. *Critical Care Clinics of North America. 13(3)* 477-502

Dul:iowitz, D., Blum!, S., Arcinue, E. & Dietrich, R. (1998) MR of hypoxic encephalopathy in children after near drowning: Correlation with quantitative proton MRspectroscopy & clinical outcome. *American journal of Neuroradiology. 19(9)* 1617-27

Fenner, P. (2000) Drowning awareness. Prevention & treatment. *Australian Family Physician. 29(11)* 1045-9

Fisher, B. (1992) Use of brainstem auditory-evoked response testing to assess neurologic outcome following near-drowning in children. *Critical Care Medicine. 20(5)* 578-85

Frates, R. (1981) Analysis of predictive factors in the assessment of warm-water near-drowning in children. *American journal of Diseases of Childhood 135(11)* 1006-8

Gillenwater, J., Quan, L. & Feldman, W. (1995) Inflicted submersion in childhood. *Archives of Pediatrics & Adolescent Medicine. 150(3)* 298-303

Gonzalez-Luis, G. (2001) Use of the Pediatric Risk of Mortality Score as predictor of death & serious neurologic damage in children after submersion. *Pediatric Emergency Care. 17(6)* 405-9

Gooden, B. (1992) Why some people do not drown: Hypothermia versus the diving response. *MjA. 157(9)* 629-32

Graf, W., Cummings, P., Quan, L. & Brutocao, D. (1995) Predicting outcome in pediatric submersion victims. *Annals of Emergency Medicine. 26(3)* 312-9

Harborview Injury Prevention & Research Center. (2001) Systematic reviews of childhood injury prevention interventions. *http:lldepts. washington.edulhiprclchildinjuryl* Accessed January, 2004

Hasan, S., Avery, W., Fabian, C. & Sackner, M. (1971) Near drowning in humans: A report of 36 patients. *Chest. 59(2)* 191-7

Jacobsen, W., Mason, L., Briggs, B., Schneider, S. &Thompson, J. (1983) Correlation of spontaneous respiration & neurologic damage in near-drowning. *Critical Care Medicine. 11(7)* 487-9

Langley, J., Warner, M., Smith, G. & Wright, C. (2001) Drowning-related dearhs in New Zealand, 1980-1994. *Australian & New Zealand journal of Public Health. 25(5)* 451-7

Lavelle, J. & Shaw, K. (1993) Near drowning: Is emergency deparrmem cardiopulmonary resuscitation or intensive care unit cerebral resuscitation indicated? *Critical Care Medicine. 21(3)* 368-73

Mackie, I. (1999) Patterns of drowning in Australia, 1992-1997. *M]A.* 171(11-12) 587-90

Manolios, N. & Mackie, I. (1988) Drowning & near-drowning on Australian beaches patrolled by life-savers: A 10-year study, 1973-1983. *MJA. 148(4)* 165-7,170-1

Milliner, N., Pearn, J. & Guard, R. (1980) Will fenced pools save lives? A 10-year study from Mulgrave Shire, Queensland. *M]A. 2(9)* 510-1

Modell,]., Graves, S. & Ketover, A. (1976) Clinical course of 91 consecutive near-drowning victims. *Chest. 70(2)* 231-8

Modell, J., Graves, S. & Kuck, E. (1980) Near-drowning: Correlation of level of consciousness & survival. *Canadian Anaesthetists Society Journal. 27(3)* 211-5

Noonan, L., Howrey, R. & Ginsburg, C. (1996) Freshwater submersion injuries in children: A retrospective review of seventy-five hospitalized patients. *Pediatrics. 98(3)* 368-71

Nussbaum, E. & Galant, S. (1983) Intracranial pressure monitoring as a guide to prognosis in the nearly drowned, severely comatose child. *journal of Pediatrics. 102(2)* 215-8

Nussbaum, E. (1985) Prognostic variables in nearly-drowned, comatose children. *American journal of Diseases of Children. 139(10)* 1058-9

Oakes, D. (1982) Prognosis & management of victims of near-drowning. *journal of Trauma. 22(7)* 544-9

O'Flaherty, J. & Pirie, P. (1997) Prevention of pediatric drowning & near-drowning: A survey of members of the American Academy of rediatrics. *Pediatrics. 99(2)* 169-74

Orlowski, J. (1979) Prognostic factors m pediatric cases of drowning & near-drowning. *journal of the College of Emergency Physicians. 8(5)* 176-9

Orlowski,]. (1987) Drowning, near-drowning, & ice water submersion. *Pediatric Clinics of North America. 34(*1) 75-92

Pearn, J. (1977) Neurological & psychometric studies in children surviving freshwater immersion accidents. *The Lancet. 1(8001)* 7-9

Pearn, J. & Nixon, J. (1977) Swimming pool immersion accidents: An analysis from the Brisbane drowning study. *Medical journal of Australia.* 1(13) 432-7

Pearn, J., Bart, R. & Yamaoka, R. (1979) Neurologic sequelae after childhood near-drowning: A total population study from Hawaii. *Pediatrics. 64(2)* 187-91

Pitt, W. & Cass, D. (2001) Preventing children drowning in Australia. *M]A.* 175(11-12) 603-4

Quan, L. & Kinder, D. (1992) Pediatric submersions: Prehospital predictors of ourcome. *Pediatrics. 90(*6) 909-13

Sarnaik, A., Preston, G., Lieh-Lai, M. & Eisenbrey, A. (1985) Intracranial pressure & cerebral perfusion pressure m near-drowning. *Critical Care Medicine. 13(4)* 224-7

Stevenson, M., Rimajova, M., Edgecombe, D. & Vickery, K. (2003) Childhood drowning: Barriers surrounding private swimming pools. *'l>ediatrics. 111*(2) E115-9

Suominen, P. (2002) Impact of age, submersion time, & water temperature on outcome in near-drowning. *Resuscitation. 52(3)* 247-54

Szpilman, D. (1997) Near-drowning & drowning classification: A proposal to stratifY morrality based on the analysis of 1,831 cases. *Chest. 112(3)* 660-5

The Royal Life Saving Society Australia. (2002) National Drowning Report 2002. *www.rlssa.org.au* Accessed January, 2004

Thompson, D. & Rivara, F. (2000) *Pool fencing for preventing drowning in children*. Cochrane Database of Systematic Reviews. (2) CD001047.

Vaughn, B. (2002). Pediatric drowning: An old nemesis, ever presenr. Kansas City, MO. *Association of Air-Medical Services Transport Medicine Conference*, October 5, 2002

Waugh,]., O'Callaghan, M. & Pitt, W. (1994) Prognostic factors & long-term outcomes for children who have nearly drowned. *M]A. 161(10)* 594-5, 598-9

Wintemute, G. (1990) Swimming pool owners' opinions of strategies for prevention of drowning. *Pediatrics. 85(1)* 63-9

Young, K. & Seidel, J. (1999) Pediatric cardiopulmonary arrest: A collective review. *Annals of Emergency Medicine. 33(2)* 195-205

Zuckerman, G., Gregory, P. & Santos-Damiani, S. (1998) Predictors of death & neurologic impairment in pediatric submersion injuries: The pediatric risk of mortality *score. Archives of Pediatrics & Adolescent Medicine. 152(2)* 134-40

Appendix 1

Authors	n	Patients	Water Temperature	Place Assessments Performed	Clinical Indicators Used	Findings
Hasan (1971) Chest, 59, 191-7	36	Peds & adults	Warm water	ED assessments	Survival rates Neurological status ABG's	25% of patients were unconscious upon arrival 92% of patients survived to discharge Baseline ABG's should be done on all near-drowning patients to look for significant acidosis & hypoxemia that is not always clinically apparent
Modell (1976) Chest, 70, 231-8	91	Peds & adults	Warm water	ED assessments	Neurological status ABG's CXR	89% of patients survived to discharge Patients arriving at the ED alert were discharged intact Patients arriving at the ED comatose with fixed/dilated pupils died All patients with a normal ED CXR survived
Pearn (1977) The Lancet, 1, 7-9	56	Peds	Warm & cold water	ICU & post-discharge long-term neurological status	Psychometric testing I.Q. tests Age	96% of children were neurologically intact several months after an immersion incident 4% of children had severe neurological sequelae Median IQ of survivors was higher than that of the general population!
Conn (1979) Pediatric Clinics of North America, 26, 691-701	30	Peds	Warm water	ICU admission assessments	Modified GCS	Good outcomes with spontaneous respiration's & purposeful response to pain 70% had full neurological recovery if displaying abnormal extension/flexion posturing & abnormal breathing patterns Poor outcomes if flaccid, unresponsive, or history of cardiac arrest
Pearn (1979) Pediatrics, 64, 187-91	104	Peds	Warm water	EMS, ER, & ICU assessments	Neurological status Presence of spontaneous respirations	100% of children who were not apneic or completely comatose upon extraction from the water were neurologically intact upon discharge 7% of children who were apneic & comatose upon extraction from the water died within 7 days of admission 93% of children who were apneic & comatose were neurologically intact upon discharge "If a child does not gasp spontaneously within one hour of rescue (with a normal body temp), then neurologic complications are inevitable..." (p. 190)
Conn (1980) Canadian Anaesthetists Society Journal, 27, 201-10	96	Peds	Warm & cold water	ER & ICU assessments	Neurological status Creation of ABC classification	(A)wake, (B)lunted, & (C)omatose 100% of class A & B patients were discharged neurologically intact C1 (decorticate) - 11% died, 22% damaged & 66% neurologically intact C2 (decerebrate) - 13% died, 31% damaged & 56% neurologically intact C3 (flaccid) - 72% died, 14% damaged & 14% neurologically intact

Authors	n	Patients	Water Temperature	Place Assessments Performed	Clinical Indicators Used	Findings
Modell (1980) Canadian Anaesthetists Society Journal 27, 211-5	121	Peds& adults	Warm water	ED assessments	ModifiedGCS	87% of all patients survived neurologically intact 2% of all patients had severe neurological deficits 11% of all patients died All awake patients (Category A) & 90% of blunted (Category B) patients were discharged intact 44% (peds) & 73% (adults) comatose (Category C) patients were discharged intact
Dean (1981)	20	Peds	Warm water	ICU assessments	ICP monitoring	All patients had GCS of 3 upon admission to PICU & underwent ICP monitoring Salvage rate for those with normaiiCP is significantly better than those with elevated ICP Sustained intracranial hypertension is associated with a uniformly bad outcome
Dean (1981) Critical Care Medicine, 20, 536-9	94	Peds	Warm water	ED assessments	Age,GCS	No differences in neurological complications based on age All patients with GCS 5 had full neurological recovery 3 patients with GCS 3-4 had full neurological recovery
Frates (1981) American Journal of Diseases of Childhood, 135,1006-8	42	Peds	Warm water	ED assessments	Age,sex,pH, temperature, neurological exam, arrest state	All patients with fixed & dilated pupils in the ED died or suffered severe brain damage All patients who died or with severe brain damage were comatose upon arrival to the ED All patients who died or had severe brain damage required CPR in the ED Reactive pupils in the ED was the key defining factor for an eventual good outcome
Oakes (1982) Journal of Trauma,22, 544-9	40	Peds& adults	Warm water	ED assessments	Modified GCS Vital signs/ neurological exam findings	All patients arriving in the ED with a spontaneous pulse were discharged neurologically intact ED neurological & hemodynamic assessment findings more prognostic than those done in critical care Devastating complications if cardiac arrest while hospitalized 19o/o of ED patients presenting in full arrest had full neurological recoveries
Jacobsen (1983) Critica I Care Medicine, 11, 487-9	26	Peds	Warm water	ICU assessments after ED arrest	GCS Apnea vs. spontaneous respirations	All children with spontaneous respirations after resuscitation had little or no neurological impairment All children who were apneic after resuscitation died or had severe neurological impairment

Authors	n	Patients	Water Temperature	Place Assessments Performed	Clinical Indicators Used	Findings
Nussbaum (1983) Journal of Pediatrics, 102,215-8	55	Peds	Warm water	ICU assessments	ICP& CPP monitoring	ICP monitoring in C3 (comatose/flaccid) patients 92% survival if ICP 5.20 & CPP L50 1OOo/o death if ICP >20 & CPP <50 ICP monitoring is useful to predict death or survival, but not residual brain damage
Bell {1985)	49	Peds	Warm water	ICU assessments	ICP monitoring Neurological exam findings	ICP monitoring in GCS 3-5 (post-arrest) patients High ICP/low CPP predicted death vs. survival. but not PVS vs. intact Pupil reactivity &/or any motor activity predicted death vs. survival, but not PVS vs. intact
Nussbaum (1985) American Journal of Diseases of Childhood, 139,1058-9	51	Peds	Warm water	ICU assessments	ICP monitoring, submersion time, age, pH, temperature	ICP monitoring in C3 (comatose/flaccid patients) Estimated submersion time & mean ICP/ CPP were prognostic for death vs. survival, but not severe deficits vs. intact Age, pH, & temperature were not helpful
Sarnaik (1985) Critical Care Medicine, 13, 224-227	11	Peds	Warm water	ICU assessments	ICP monitoring CPP management	All patients who awakened spontaneously did so within 3 days Several patients with initially normaiiCP, had critical increases at days 2-3 Management of ICP with CPP control did not ensure intact survival
Allman (1986) American Journal of Diseases of Children, 140, 571-5	66	Peds	Warm water	ICU assessments after ED arrest	GCS Pupil reactivity	24% of patients were discharged intact, 26% vegetative & 50% died No patient who presented to the ICU with a GCS of 3 was discharged intact All patients who were later discharged intact had reactive pupils on admission to the ICU
Orlowski (1987) Pediatric Clinics of North America, 34, 75-92		Peds	Warm water	ICU assessments	Neurological status & improving/not improving	Patients who remain profoundly comatose (posturing or flaccid) 2-6 hours after the event are brain dead or have moderate to severe neurological impairment Patients who are improving, but remain unresponsive have a 50% likelihood of a good outcome Patients who are definitely improving and are alert or obtunded, but respond to stimuli 2-6 hours after the event have normal or near-normal neurological outcomes
Ashwal (1990) Neurology, 40,820-3	20	Peds	Warm water	ED& ICU assessments	Initial & serial FBS Cerebral blood flow	An initial elevated FBS was highly predictive of death or PVS Cerebral blood flow measurements are predictive of eventual death, but cannot differentiate PVS from normal recovery

Authors	n	Patients	Water Temperature	Place Assessments Performed	Clinical Indicators Used	Findings
Biggart (1990) Pediatrics, 117,179-83	55	Peds	Warm&cold water	ED assessments	Temperature Arrest state	All patients with arriving with a spontaneous pulse in ED had no neurological complications Major factors for predicting intact vs. vegetative survivors were spontaneous heartbeat & hypothermia (<33C) upon presentation to the ED
Bierens (1990) Annals of Emergency Medicine, 19, 1390-5	87	Peds& adults	Warm&cold water	ICU assessments	Age, neurological status, core temperature, aspiration status, submersion time	Better survival potential with young age, <10 minutes of submersion, no aspiration, & core body temperature of <35C upon admission 33% of cardiac arrest & 100% of respiratory arrest patients were able to be discharged "No indicator at the rescue site & in the hospital is absolutely reliable with respect to death or survival" (p.1394)
Connors (1992)The Journal of Pediatrics, 121,839-44	12	Peds	Warm water	ICU assessments	Cross-brain oxygen content difference, cerebral blood flow, & cerebral metabolic rate	Neurologically intact children had a significantly higher cross-brain oxygen content difference compared with those who died or suffered severe brain damage No significant difference in cerebral blood flow, ICP. & cerebral perfusion pressure between intact & neurologically devastated groups
Quan (1992) Pediatrics, 90, 909-13	77	Peds	Warm water	Prehospital assessments & history	Submersion time Neurological exam Cardiac status	Only the extremes of submersion & resuscitation times reliably predict neurological outcome Prehospital ALS associated with better outcomes
Fisher (1992) Critical Care Medicine, 20, 578-585	89	Peds	Warm water	ICU assessments after prior arrest	BAER testing	BAER results from 6 & 24 hour exams most prognostic of neurological outcomes
Dubowitz (1998) American Journal of	22	Peds	Warm water	ICU assessment s	MRimaging& quantitative proton MR spectroscopy	Good outcomes with normal MR & cerebral metabolites PVS or death with cerebral edema & decreased cerebral metabolites MRI findings at 3-4 days after injury were 100% predictive for PVS or death MRI can't differentiate between outcome of PVS & death
Lavelle (1993) Critical Care Medicine, 21, 368-73	44	Peds	Warm water	ED&ICU assessments	GCS Pupil reactivity	Minimal neurological deficits with reactive pupils in ED or GCS >5 in the ICU 2 patients presenting to the ED in full arrest also had full neurological recoveries
Bratton (1994) Archives of Pediatrics & Adolescent Medicine, 148,167-70	40	Peds	Warm water	ICU assessments	Modified GCS Brainstem reflexes	Initial ED or ICU findings not sufficiently predictive of neurological outcome Assessment at 24 hours after injury carries a much better predictive value

Authors	n	Patients	Water Temperature	Place Assessments Performed	Clinical Indicators Used	Findings
Waugh (1994) MJA, 161,594-9	57	Peds	Warm& coldwater	ED&ICU assessments	Neurological assessments Length of resuscitation	32% of patients died greater than 24-hours post-immersion All patients presenting to the ED with any motor response to pain were discharged intact 20X higher chance of death or severe disability if C3-C4 (comatose/flaccid/ arrest) in ED No survivors in patients who required more than 25 minutes of resuscitation after warming
Graf (1995) Annals of Emergency Medicine,26, 312-9.	194	Peds	Warm water	ED assessments	GCS Pupil reactivity FBS Gender	Favorable neurological outcome if not comatose Unfavorable outcomes associated with not reactive pupils,elevated FBS,& male gender
Noonan (1996) Pediatrics,98, 368-71.	75	Peds	Warm water	ED assessments & admission/ discharge criteria	Symptomatic vs.non-symptomatic Observation time in ED	Sick kids in ED should be admitted Not sick kids should be observed for 8 hours, then discharged home if now asymptomatic Mildly symptomatic, but stable kids should be observed for 8 hours, then admitted if continue to be symptomatic or deteriorate
Cristensen (1997) Pediatrics, 99, 715-21.	274	Peds	Warm water	EMS,ED, & ICU assessments	Neurological status Good vs.poor outcomes	Good outcomes (intact/functional recovery) if demonstrated first purposeful movement within 48 hours of submersion Poor outcomes (vegetative state/death) -consider withdrawal of support if no improvement by 48 hours after submersion
Szpilman (1997) Chest, 112,660-5.		Peds& adults	Warm water	EMS& EMS-Physician assessments	Mortality Six grades of severity	Grade 1 - normal pulmonary exam with coughing - 0% mortality Grade 2 - abnormal pulmonary exam with some rales - 0.6% mortality Grade 3 - pulmonary edema without hypotension- S2% mortality Grade 4- pulmonary edema with hypotension - 19.4% mortality Grade 5 - isolated respiratory arrest - 44% mortality Grade 6 - cardiopulmonary arrest - 93% mortality
Zuckerman (1998) Archives of Pediatrics & Adolescent Medicine, 152,134-40.	50	Peds	Warm&cold water	ED&ICU assessments	Pediatric Risk of Mortality Score (PRISM)	PRISM scores done in the ED were better than those done in the PICU at predicting neurological complications or death

Authors	n	Patients	Water Temperature	Place Assessments Performed	Clinical Indicators Used	Findings
Causey (2000) American Journal of Emergency Medicine, 18, 9-11.	48	Peds	Warm water	ED assessments	Early ED discharge criteria ED GCS ≥13 & no ALS interventions prior to or ≤4 hours after ED presentation	Patients with a normal pulmonary exam & room air saturation of ≥95 by 4-6 hours after ED admission can be safely discharged home
Gonzalez-Luiz (2001) Pediatric Emergency Care, 17, 405-9.	60	Peds	Warm water	ICU or Short Stay Unit admission assessments	Pediatric Risk of Mortality Score (PRISM)	All patients admitted to the Short Stay Unit survived without impairments All ICU patients with PRISM scores ≥24 or with probability of death ≥42% either died or had serious neurological impairment 1/3 of ICU patients with PRISM scores between 17-23 &/or a probability of death between 16-42% either died or had serious neurological impairment Only extreme PRISM values accurately predict presence or absence of death or serious impairment Intermediate PRISM scores are not reliable to predict prognosis
Suominen (2002) Resuscitation, 52, 247-54.	61	Peds & adults	Cold & warm water	ER & ICU assessments	Survival rates & neurological status	Median submersion time for survivors was 10 minutes Median submersion time for survivors (intact or with mild neurological disability) was S minutes Median submersion time for non-survivors was 16 minutes Submersion time was the only independent predictor of survival Age, water temperature, or ED patient temperature were not accurate predictors of survival

Key

ABG's	Arterial blood gases
ALS	Advanced Life Support
BAER	Brainstem auditory-evoked response
CPP	Cerebral perfusion pressure
CXR	Chest X-ray
ED	Emergency department
EMS	Emergency Medical Services
FBS	Fasting Blood Sugar
PVS	Persistent vegetative state
GCS	Glasgow Coma Scale
ICP	Intracranial pressure
ICU	Intensive Care Unit
n	Number of patients in study
Peds	Pediatric
PICU	Pediatric ICU