Drowning: Emergency Management in Children

Purpose
This procedure provides clinical practice guidelines to inform health professionals in the emergency management of children following drowning.

Scope
This guideline applies to all staff involved in the emergency care and management of children with injury as a result of drowning.

Related documents
Policy and standard(s)
- Appendix 1: Flowchart: Emergency management of children after a drowning

Guideline
Introduction
Definitions and terminology
The World Congress on Drowning convened by the World Health Organisation in 2002 agreed on the international definition of drowning as:

“A process resulting in primary respiratory impairment from submersion/immersion in a liquid medium”.\(^1\)\(^,\)\(^2\)

Drowning injuries are referred to as “fatal drowning” or “non-fatal drowning”. These definitions should be universally adopted to avoid confusion in the literature and facilitate accurate reporting of drowning injuries and estimate of mortality and morbidity.\(^3\)\(^-\)\(^5\)
Epidemiology

Australia reports the highest rates of drowning deaths in children aged 0-4 years, with 67% being male. Pool drowning occurs most often between 4pm and 6pm during the summer months. Falls into water including pools, bath tubs, spas, dams, lakes, rivers and the ocean are the most common causes of drowning in the <5 year old group. Queensland experienced the second highest number of drowning deaths in Australia between 2011 and 2012, with deaths more common in summer (but occurring all year round). Approximately 80% of drownings are preventable by implementing strategies such as effective barriers/fencing to pools and bodies of water as well as provision of effective adult supervision.

Risk factors

Although drowning is the most commonly the primary event in children (e.g. an unsupervised young child who is unable to swim is found in a body of water), there are other factors that may contribute to drowning. It is therefore essential to take a detailed history of the event from someone who witnessed it, and other relevant past history from caregivers.

**ALERT**

It is important to consider whether an underlying medical condition has caused a drowning event.

### 1. Epilepsy

- The risk of drowning is increased by 4 to 14 fold in children with epilepsy.
- Children with epilepsy who have drowned tend to be older (age >5 years) than children without epilepsy.
- Children aged >5 years with epilepsy are at increased risk of bathtub drowning, although if supervised the risk of drowning is no greater than the background population risk.

### 2. Cardiac dysrhythmias

- Swimming can trigger certain dysrhythmias: congenital long QT syndrome, catecholaminergic polymorphic ventricular tachycardia and Brugada syndrome.
- Cardiac dysrhythmias should be considered in any unexplained drowning in older children or adolescents.
- A detailed family history of dysrhythmia and ECG should always be included in the work-up.

### 3. Hyperventilation

- Hyperventilation causes hypocapnia, which reduces the respiratory stimulus to breathe and can lead to syncope under water.

### 4. Hypoglycaemia
5. **Hypothermia**
   - Hypothermia resulting in body temperature under 35°C can cause poor muscular coordination and weakness, and interferes with swimming and self-rescue attempts.
   - Generally seen in children who fall through ice and a rare cause of drowning in Queensland.

6. **Alcohol and illicit drugs**
   - Generally less relevant in children but should be considered in adolescents.

**Pathophysiology**\(^3,5\)

The following flow diagram has been formulated using a combination of information from the Australian Resuscitation Council guideline and an article on paediatric submersion injuries by Semple-Hess et al.\(^3,5\)

**DROWNING - pathophysiology and sequence of events**

- **Initial struggle** – breathing takes priority therefore unable to cry/wave for help
- **Submersion** – airway below the surface of a liquid medium – water spat out or swallowed
- **Voluntary breath holding**
  - 20 to 30 seconds
  - 60 seconds maximum
- **Small amount of water aspirated triggering cough reflex and laryngospasm. Respiratory impairment leads to hypoxia, hypercarbia and acidosis.**
- **Cerebral hypoxaemia** leads to loss of consciousness and apnoea
- **Arterial oxygen tension decreases, laryngospasm abates and more water is aspirated.**
- **Cardiac deterioration with bradycardia and hypotension** secondary to hypoxia lead to a cardiac arrest.

**Management**

As with any emergency scenario, a structured approach should be used to assess and manage the patient with drowning. Clinical assessment (history and examination) should occur concurrently with patient management (paying particular attention to the optimisation of respiratory function).\(^5\)

A detailed history is essential, including details of the drowning event:

- circumstances leading to the drowning
- duration of immersion
- resuscitation (length of CPR and administration of drugs)
- past medical history and social circumstances.
Depending on the circumstances and severity, it may be appropriate to have a social worker with the caregivers, especially in the case of a cardiac arrest or in a post-arrest situation. Child protection issues should also be considered depending on the scenario.5

Previous classification systems such as those proposed by Szpilman (1997)18 and Conn (1980)19 are no longer used. For the purpose of this guideline we will categorise drowning events into

1. asymptomatic patients,
2. those with some respiratory compromise, and
3. those who are apnoeic or in cardiac arrest.

Most patients seen will be in the first two groups and managed in the Emergency Department (ED); those in the third category will be managed initially in the ED and then transferred to the Paediatric Intensive Care Unit (PICU). It is quoted that 5% will have a secondary deterioration. In Queensland, the ratio of non-fatal to fatal drowning is 10:1, and approximately two thirds of those in the non-fatal group are admitted to hospital.20

The following section will focus in detail on the management of all patient groups using a structured approach that is summarised in the algorithm.

**Airway and Breathing**

The primary focus of initial treatment is to reverse hypoxaemia by restoring adequate oxygenation and ventilation. Oxygen with or without mechanical ventilation support is the first line of therapy.5

Management of airway and breathing depends on the clinical situation

- **Patients breathing spontaneously** and able to maintain oxygen saturation > 90% (ideally 95%) with an FiO2 of 0.5 may require only supplemental oxygen therapy by mask or nasal prongs.5,21-23

- **Patients with an adequate conscious state** (GCS 13–15, who have some respiratory compromise and hypoxia (SpO2 < 95%), may be supported with non-invasive ventilation (NIV); either high flow nasal cannula (HFNC), CPAP or BiPAP. The increasing use of HFNC by emergency staff makes this the method of first choice.

- **Patients who are apnoeic or have severe respiratory compromise** require tracheal intubation (preferably with a cuffed tube) using a rapid sequence induction technique.

- **Intubated patients** require mechanical ventilation with lung protective measures and positive end-expiratory pressure.5,23

Investigations should include venous/arterial blood gas analysis and chest x-ray.

Acute Respiratory Distress Syndrome (ARDS) is common after a significant drowning event. Ventilation with lung protective measures reduces barotrauma and should aim for normocapnia or mild hypocapnia. FiO2 should be reduced to <0.5 as soon as possible to avoid pulmonary oxygen toxicity.

There is no evidence to support the use of corticosteroids.5,21-23

**Cervical spine protection**

Spinal injury occurring with drowning is rare; therefore, routine immobilisation of the cervical spine is not warranted based solely on the history of submersion. A study by Watson et al5,24 found that cervical spine
injuries occur in <0.5% of drowning events, and are unlikely in low-impact submersion (swimming or bathing).

Cervical spine injuries should be suspected in cases of trauma to the head and neck such as in diving, surfing or water skiing incidents, or in boat or motor vehicle collisions. In such cases spinal precautions should be used (jaw thrust manoeuvres for airway management, cervical immobilisation) and when the patient is stabilised, they should be investigated using first-line cervical spine x-rays.

See LCCH CHQ-GDL-62441 Assessment of possible cervical spine injury in children suffering blunt trauma for further information on the management of suspected cervical spine injury.

Circulation

The patient’s perfusion should be assessed and treated appropriately with fluid resuscitation using crystalloid solution (e.g. 0.9% NaCl 20 mL/kg) via either intravenous or intraosseous access.

Cardiac dysfunction with decreased cardiac output and high systemic and pulmonary vascular resistance may occur secondary to hypoxia associated with drowning. This may persist after adequate oxygenation, ventilation and perfusion have been re-established. Thus there may be a cardiogenic component to the pulmonary oedema, and inotropic agents (e.g. dobutamine) may be required to improve cardiac output and re-establish adequate tissue perfusion.

Disability

The greatest permanent harm in drowning is to the brain, and most late deaths and long-term sequelae are neurological. The brain is highly sensitive to hypoxia, which can cause irreversible injury within 4–10 minutes. This sensitivity to hypoxia and the inability to predict outcome at the point of rescue (due to delayed neuronal death and the impact of water temperature) creates a challenge in patients who fail to sustain or recover consciousness following a drowning event.

Little can be done to change the damage caused by the primary hypoxic event. The best hope is to prevent secondary injury. Measures to achieve this goal include the prevention of hypoxia, hypercapnia and hyperthermia, and maintenance of normoglycaemia.

Seizures following hypoxic brain injury are common, and evaluation of seizures allows for treatment and will inform prognosis. This will usually be in the PICU where commonly an EEG (looking for subclinical seizures) and neurological consultation will be obtained. There is no evidence for prophylactic anticonvulsant medications.

Head CT imaging: whether a head CT is required remains a contentious issue. Targeted CT is therefore recommended. The non-intubated, conscious patients does not need a CT head. For patients who are intubated and ventilated and may or may not have had a cardiac arrest a CT MAY be necessary, but is not mandatory. Toddlers who have drowned in public pools will not need a CT whereas any patient with a history suspicious of traumatic brain injury/intracranial bleed should have a CT on admission. Where the indication for a head CT remains unclear it should be discussed with a SMO (ED or PICU) at the respective paediatric referral centre.

Exposure and electrolytes

A secondary survey should be completed, avoiding prolonged exposure to limit hypothermia, to assess for other injuries and signs of non-accidental injury.
Electrolyte and haematocrit levels are rarely abnormal regardless of water type (freshwater or saltwater). Baseline potassium, renal and haematologic functions should be measured in patients who have sustained a significant hypoxic event or are hypothermic. Consider coagulation studies and creatinine kinase in a severely hypothermic or critically-ill child.

Routine laboratory studies such as electrolytes and full blood count are not indicated in asymptomatic drowning victims.

**Gastrointestinal and genitourinary**

Nasogastric tube insertion is important to prevent aspiration due to vomiting in any child with a depressed level of consciousness.

In the critically unwell patient, a urinary catheter should be inserted to measure urine output and facilitate a strict fluid balance.

**Hypothermia**

Core temperature should be assessed and further cooling prevented. Hypothermia is common after drowning but hypothermia induced dysrhythmias are rare. Rewarming should almost always occur slowly, and in Queensland active rewarming is indicated only in very few cases. The following rewarming strategies are recommended by Advanced Paediatric Life Support (APLS). 25

<table>
<thead>
<tr>
<th>External rewarming (Temperature above 30 °C)</th>
<th>Core rewarming</th>
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<tbody>
<tr>
<td>• Remove wet clothes</td>
<td>• Warm intravenous fluids to 39°C</td>
</tr>
<tr>
<td>• Apply warm blankets</td>
<td>• Warm ventilator gases to 42°C</td>
</tr>
<tr>
<td>• Warm air system</td>
<td>• Gastric or bladder lavage with 0.9% NaCl to 42°C</td>
</tr>
<tr>
<td>• Heating blanket</td>
<td>• Pleural or pericardial lavage</td>
</tr>
<tr>
<td>• Infrared radiant lamp</td>
<td>• Endovascular warming</td>
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If temperature is not actively managed after OHCA the majority of patients will develop fevers. There is evidence that suggests that fevers after OHCA are detrimental to outcome. Emergency department management should focus on preventing a further drop in core temperature by removing wet clothes and applying warm blankets. Active rewarming with heating blankets, warm air blowers and radiant lamps should only be employed cautiously, and be reserved for patients with a core temperature below 33 to 34 degrees, or where hypothermia has led to arrhythmias/haemodynamic instability. Any of these devices will lead to a rapid “overshoot” of the core temperature. Most patients will increase their core temperature slowly when further cold exposure is removed.

The THAPCA study, a randomised controlled trial of targeted hypothermia (33°C) versus normothermia (36.8°C), measured survival and functional outcomes in children at 12 months following out-of-hospital cardiac arrest (OOHCA). There was no benefit in the therapeutic hypothermia group. Maintaining normothermia (rewarming as above and avoiding hyperthermia) is therefore recommended in comatose children following OOHCA.26 Similarly in adults following out-of-hospital cardiac arrest the latest large randomized study (TTM trial) shows that therapeutic hypothermia does not improves outcomes.26
Infection

Prophylactic antibiotics have not been shown to be of benefit and are not recommended for every drowning case.\textsuperscript{28-30} Children who have drowned in stagnant or contaminated water, water with a high amount of particulate matter or warm water have specific infection risks. Water dwelling organisms may cause infection, (particularly \textit{Aeromonas} species) in fresh or brackish water or mud. In these patients, take sputum for culture early in the admission.

If pneumonia occurs, it typically develops after the first 24 hours at which point it should be managed early with empiric broad-spectrum antibiotics.

- piperacillin/tazobactam 100mg/kg (maximum 4gram Piperacillin component) IV every 6 hourly
  (<1 month: every 8 hourly dosing).

If antimicrobials are continued then treat according to cultured sensitivities

Seek specialist advice when specific waterborne organisms are suspected.

Reference: CHQ-GDL-63000 \textit{Management of Water-related Wound Infections in Children}

\textit{Pseudallescheria boydii} is a fungus found worldwide that has been reported to cause late pneumonia in drowning victims as late as 4 to 6 months after the event. \textit{P.boydii} pneumonia and meningitis therefore should be considered in the differential diagnosis of patients who develop new respiratory or CNS symptoms after a drowning event.\textsuperscript{5,27}

Outcomes & predictors of outcomes

The strongest predictors for outcome are submersion time and CPR duration.

Combining the findings from two studies from the University of Washington, the following predictors were recognised.\textsuperscript{5}

<table>
<thead>
<tr>
<th>Predictors of children with \textbf{mild or no neurologic impairment include:}</th>
<th>Indicators of \textbf{death and severe neurologic impairment are:}</th>
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<tbody>
<tr>
<td>• A submersion time &lt; 5 minutes (91%),</td>
<td>• Resuscitation duration &gt; 25 minutes (100% risk)</td>
</tr>
<tr>
<td>• Resuscitation duration &lt; 10 minutes (87%)</td>
<td>• Submersion time &gt; 25 minutes (100% risk)</td>
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</tbody>
</table>

The grey area is:

- Resuscitation duration between 11 and 25 minutes (68% risk death or poor outcome)
- Submersion time between 10 and 25 minutes (90% risk death or poor outcome)

A study from Southern California reviewing charts of paediatric drowning patients found that three variables predicted most of those with a poor outcome (93%):

1) CPR in the ED;
2) apnoea and coma in the ED; and
3) pH < 7.0 $^{5,31-33}$

**Disposition**

In critically ill patients, who are post-cardiac arrest or intubated and ventilated, referral to the PICU is mandatory.

Moderate to severely symptomatic children should be stabilised in the ED and admitted to either a PICU or inpatient unit.

In children who are asymptomatic or mildly symptomatic, routine admission is unnecessary, but they should receive a full medical evaluation and be observed for 4-8 hour to observe for “secondary drowning” (respiratory and clinical deterioration in a patient initially deemed well). Consider discharge home in daylight hours with a responsible caregiver after a period of observation.

**Key learning points**

- Important to consider non-accidental injury (NAI) or neglect in patients presenting with incongruent histories, an obvious lapse in supervision, a delay in seeking care for submersion or other injuries suggestive of NAI (bruises, old fractures).
- Patients should be observed for 4–8 hours following a drowning even if asymptomatic.
- It is important to check core temperature on all drowning victims if temperature cannot be measured using a conventional thermometer. Hypothermia should be corrected during resuscitation.
- Consider underlying conditions (such as epilepsy, cardiac dysrhythmias, hypoglycaemia) when assessing drowning victims.
- Consider traumatic injuries sustained to the cervical spine in high-impact submersions (diving or motor vehicle collision). If suspected, immobilise the cervical spine but note that routine immobilisation and radiographs are not warranted on history of drowning only.
- There is no evidence for the use of corticosteroids in drowning. Their use is potentially harmful.
- Drowning in stagnant or contaminated water results in higher risk for pneumonia in the first few days but also late-onset pneumonia and meningitis caused by *P. boydii*. There is no evidence for routine use of prophylactic antibiotics.
- It is important to advocate for safety measures around pools and when participating in water sports.
Consultation

Key stakeholders who reviewed this version:

- Dr Laura Sumners, Paediatric Emergency Fellow, Lady Cilento Children’s Hospital
- Suzanne Williams, Nurse Practitioner, Lady Cilento Children’s Hospital
- Dr Mark Coulthard, Staff Specialist, PICU, Lady Cilento Children’s Hospital
- Dr Claire Nourse, Staff Specialist, Infectious Disease, Lady Cilento Children’s Hospital
- CHQ Medicines Advisory Committee

Definition of terms

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<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tr>
<td>Fatal drowning</td>
<td>Any death related to drowning</td>
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<tr>
<td>Near fatal drowning</td>
<td>Survivor from drowning injury</td>
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References and suggested reading

The main article used for the development of this guideline was the article by Hess & Semple - Paediatric submersion injuries: Emergency Care and Resuscitation (June 2014, Vol 11, No 6). For those seeking further information on the topic this article is definitely worth reading.


Guideline revision and approval history

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<tr>
<th>Version No.</th>
<th>Modified by</th>
<th>Amendments authorised by</th>
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<tr>
<td>1.0</td>
<td>Natalie Deuble, Senior</td>
<td>Julie McEnery, Divisional</td>
<td>Executive Director</td>
</tr>
<tr>
<td></td>
<td>Emergency Consultant, CHQ</td>
<td>Director Critical Care</td>
<td>Medical Services</td>
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Keywords

Drowning, emergency, management, fatal drowning, airway, breathing, 00718

Accreditation references

NSQHS Standards (1-10): 1
EQuIP National Standards (11-15): 11, 12

Appendices

Appendix 1: Drowning Algorithm Flowchart

Appendix 2: Paediatric Life Support Flowchart
Appendix 1: Drowning Algorithm

Assess ABC
C-Spine Precautions if trauma

Apolnoea or Cardiac Arrest
Follow Paediatric Advanced Life Support Algorithms
Intube & Ventilate (Cuffed Tube, NGT & PEEP)
ABG, Glucose

Respiratory compromise
Hypoxia
Sats <95%

High Flow O₂
+/- HFNC / NIV
CXR +/- ECG
FBC, UES, Glucose
Cardiorespiratory Monitoring

Normal respiratory status
Spontaneously breathing
GCS 15
Sats >95%

Cardiorespiratory Monitoring with continuous pulse oximetry
CXR

Assess response
Consider intubation and ventilation if worsening hypoxia, respiratory distress or decreased conscious level

Abnormal CXR +/- O₂ Requirement
Refer for admission

Normal CXR & Vitals
Observe 4-8 hrs then discharge home with follow up

Admit PICU
If intubated mechanical ventilation with lung protective measures
Empirical antibiotics if contaminated water
Neuroprotective measures (Normothermia, Normoglycaemia)

Consider cessation of life support in consultation with PICU and patient’s family

RETURN OF SPONTANEOUS CIRCULATION

YES

NO

HYPOTHERMIA MANAGEMENT

- Mild (32-35°C)
  - Passive rewarming

- Moderate (28-32°C)
  - Active external rewarming

- Severe (<28°C)
  - Active external rewarming +/- Internal rewarming
Appendix 2: Paediatric Life Support Flowchart

Paediatric Advanced Life Support

Start CPR

Attach defibrillator/monitor

Assess rhythm

Shockable VT / pulseless VT

Non-shockable PEA/asystole

Shock (4 J/kg)

Adrenalin 10 mcg/kg after 2nd shock (then every 2nd loop)
Amiodarone 5 mg/kg after 3rd shock

CPR for 2 minutes

Return of spontaneous circulation

Adrenalin 10 mcg/kg (immediately then every 2nd loop)

CPR for 2 minutes

Post-resuscitation care

During CPR
- Airway adjuncts (LMA/ETT)
- Oxygen
- Wavelength capnography
- IV/IO access
- Plan actions before interrupting compressions (e.g. charge manual defibrillator to 6 J/kg)

Consider and correct
- Hypoxia
- Hypovolaemia
- Hyper/hypokalaemia/metabolic disorders
- Hypothermia/hyperthermia
- Tension pneumothorax
- Tamponade
- Trauma
- Thromboembolism (pulmonary/coronary)

Post-resuscitation care
- Re-evaluate ABCDE
- 12 lead ECG
- Treat precipitating causes
- Re-evaluate oxygenation and ventilation
- Temperature control (cool)

Post-resuscitation care