Fifteen-minute consultation: Drowning in children

Jordan Evans ,[1] Assim Ali Javaid ,[1] Eleanor Scarrott,[2] Andrew R Bamber,[2] Jeff Morgan[1]

[1]Paediatric Emergency Department, University Hospital of Wales, Cardiff and Vale University Health Board, Cardiff, UK
[2]Cellular Pathology Department, Southmead Hospital, Bristol, UK

Correspondence to
Dr Jordan Evans, Paediatric Emergency Department, University Hospital of Wales, Cardiff and Vale University Health Board, Cardiff, CF14 4XW, UK; jordan.evans@wales.nhs.uk

Received 14 April 2020
Revised 16 June 2020
Accepted 17 June 2020

To cite: Evans J, Javaid AA, Scarrott E, *et al*. *Arch Dis Child Educ Pract Ed* Epub ahead of print: [please include Day Month Year]. doi:10.1136/archdischild-2020-318823

ABSTRACT

Drowning is a significant cause of childhood morbidity and mortality globally. The underlying mechanisms vary with child development and most are modifiable to public health promotion strategies. This article serves to highlight some of the specific considerations for the clinical management of drowning in children, both prehospital and by the in-hospital paediatric resuscitation team. This includes changes to standard advanced paediatric life support in the presence of hypothermia.

CASE VIGNETTE

You receive an alert that a 3-year-old boy is being brought into the paediatric emergency department with cardiopulmonary resuscitation in progress; he was recovered from a pond where he was found face down and unresponsive. The child's temperature is 35.1°C. A junior colleague, keen to lead the resuscitation, asks what are the specific aspects of managing a drowning incident that should be considered in addition to standard high-quality advanced paediatric life support (APLS).

INTRODUCTION AND EPIDEMIOLOGY

The term 'drowning' refers to the process of respiratory impairment caused by submersion or immersion in a liquid medium irrespective of whether the incident is fatal or not.[1] Drowning is a major cause of morbidity and mortality in young people, with more than 40 deaths occurring every hour worldwide.[2] However, the majority of drowning incidents are largely preventable in all populations.[3] Children who survive drowning are often left with long-term consequences, typically in terms of neurological deficits.

The circumstances leading to drowning vary by age. In infancy, drowning is often a result of inadequate supervision near or in water (eg, baths). In early childhood, an inquisitive nature and lack of appreciation for danger result in children wandering away from caregivers to a nearby body of water (eg, garden ponds). Late childhood and adolescence bring about increased risk-taking behaviours (eg, tombstoning). In 2018, out of 20 drowning deaths in the UK among 15–19 year-olds, eight involved alcohol or recreational drug use.[4]

PATHOPHYSIOLOGY OF DROWNING

The pathology encountered in victims of drowning varies considerably depending on the circumstances of the incident. Obtaining a clear history, including a bystander account, is essential with safeguarding considerations of paramount importance. Box 1 highlights key clinical questions that should be explored.

In many cases, the sequence of events will be purely mechanical, for example, an infant left unattended in a bath slips under the water and is unable to save themselves.

Some individuals may die from injury before drowning has occurred or may drown as a consequence of the injury.[5] Cervical spine injury is of particular consideration with specific mechanisms (eg, diving) and in specific age groups. This is also true for medical illness, the classical example being a child with epilepsy suffering a seizure then falling into water. However, drowning may be the first presentation of an underlying cardiac disease. Diagnosis of such conditions is important for the management of the patients themselves, and for managing risk in family members. Cardiomyopathy should be considered in athletic young persons who drown despite being able to swim proficiently. Channelopathies such as catecholaminergic polymorphic ventricular tachycardia and long QT syndrome may be unmasked by an apparent drowning episode. In one study of 35 drowning victims, channelopathy-causing mutations were identified in 28.6% of cases.[6]

Box 1 Questions to consider in a drowning history

How did they enter the water?

1. Deliberately entered themselves.
   - Jumped or climbed in.
2. Accidentally entered themselves.
   - Mechanical fall.
   - Became unwell outside the water and fell in.
   - Injured outside the water and fell in.
   - Suffered cardiac arrest outside the water and fell in.
3. Introduced to the water by a third party.
   - Placed there by a caregiver (eg, bath).
   - Pushed in (accidentally or deliberately).
   - Incapacitated and fell or pushed in (eg, assault).

How did they get into difficulty?

1. Mechanical (eg, could not swim).
2. Injured in the water.
3. Already unwell; unconscious or incapacitated on entry.
4. Became unwell in the water.

Why did they not extricate themselves from the situation?

1. Unable to do so.
   - Mechanical (eg, could not swim).
   - Incapacitated before or after entry into water.
2. Prevented from doing so by a third party (eg, held under).

Any given drowning may involve a combination of many of the above factors.

What is the likely prognosis?

1. What was the water temperature?
2. How long were they submerged?
3. How long was it until basic life support was commenced?
4. How long was it until return of spontaneous circulation (ROSC)?

While many individuals appear to die as a consequence of water entering the lungs, it has long been suggested that this is not always the case, with potential alternative mechanisms including cardiac arrhythmia and laryngospasm. This remains subject to significant debate.

It has been suggested that severe clinical deterioration may occur some time following a drowning event as a consequence of worsening pulmonary oedema. This was previously referred to by some as 'delayed' or 'secondary' drowning. A recent review concluded there has never been a case in the literature of a patient who was asymptomatic within 8 hours of being in the water who has subsequently gone on to deteriorate and die. Patients with mild symptoms will declare their prognostic direction of travel within this time frame and this is usually one of improvement.[7] There is expert consensus that these historical, inaccurate and poorly defined terms are best avoided. This is also true for 'dry drowning' and 'wet drowning', which relate to the absence or presence of aspirated liquid in the lungs and 'near drowning' which may be inconsistently used for those who have survived or those who have subsequently died of complications secondary to the drowning event.

Box 2 Common pathology encountered in victims of drowning

Immediate/early

- Cardiac arrest/arrhythmia.
- Electrolyte disturbance.
- Pulmonary oedema.
- Intra-alveolar haemorrhage.
- Vomiting (water swallowing).
- Hypothermia.

Medium term

- Hypoxic ischaemic encephalopathy.
- Ischaemic damage to other organs (eg, heart).
- Bronchopneumonia/pneumonitis.
- Acute respiratory distress syndrome/acute lung injury.

Long-term survivors

- Long-term effects of ischaemia (eg, poor neurological outcome, ischaemic cardiomyopathy).
- Psychological effects.

The evidence exploring the influence of fresh water versus salt water on clinical outcome is of low quality and should not influence any change in management.

A wide range of pathology may be encountered in victims of drowning; a summary of common findings is given in box 2.

MANAGEMENT

Prehospital management

- At drownings outside of the home, for example, quarries, open water, it is paramount that the victim should be removed from the water only after ensuring it is safe for the rescuer to do so. All possible ways to rescue the victim without entering the water should be considered. This is to avoid the rescuer becoming a second victim.
- Early effective basic life support (BLS) is likely to be the most important factor for survival. In the majority of circumstances, a standard ABC approach should be followed.
- Rescue breaths can begin in shallow water, delivering mouth to nose breaths may be easiest in this situation.
- Record a temperature and begin the process of maintaining or re-establishing normothermia. This can begin on the scene by removing wet clothes, drying the victim and covering them with blankets or dry clothes.
- There is no evidence to support the use of positioning manoeuvres or abdominal thrusts to remove aspirated water from the lungs.[8]
- Immobilisation of the cervical spine should be performed where appropriate, specifically in the adolescent age group or with a history of traumatic injury. Cervical spine injuries are rarely associated with drownings in younger children. Hwang *et al* looked at 10 years of drowning presentations to a tertiary paediatric centre and determined that out of 143 patients, only seven had cervical spine injuries. The youngest child was 9 years old. All injuries occurred in a swimming pool, six having a history of diving.[5]

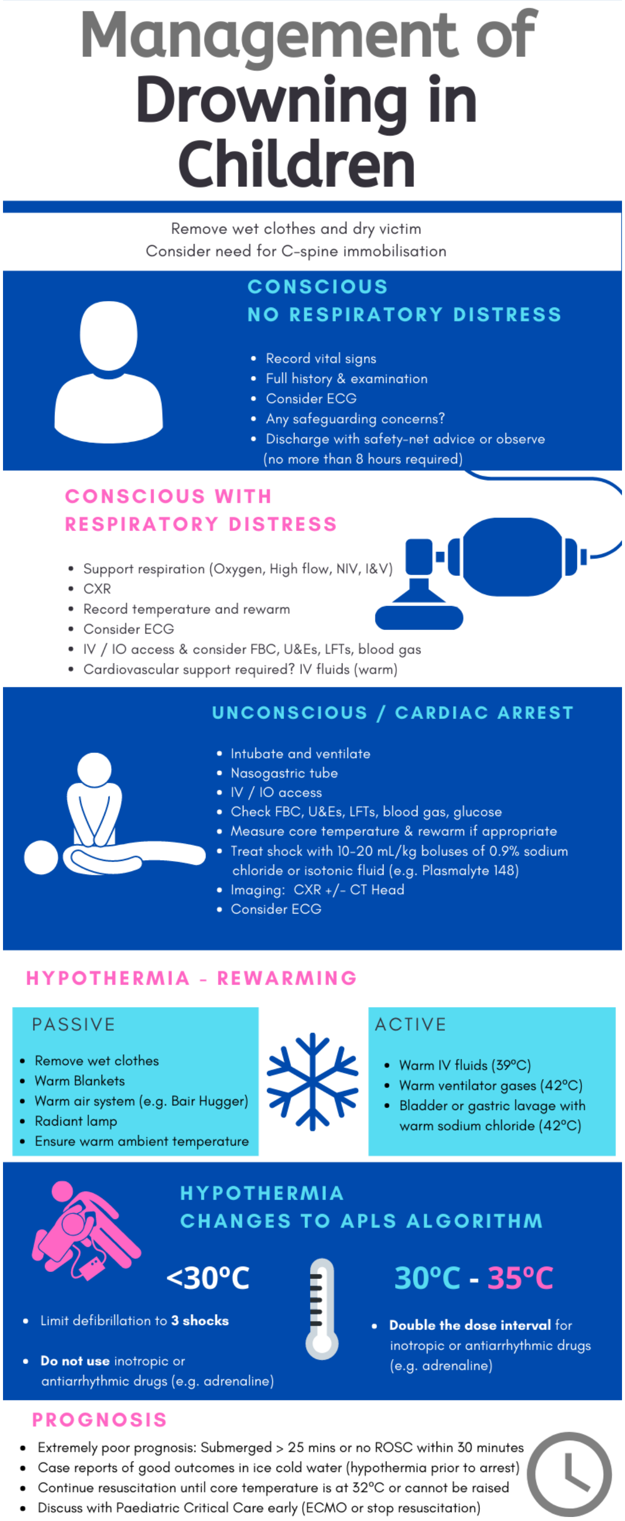

Figure 1 An approach to the management of drowning in children. APLS, advanced paediatric life support; CXR, chest X-ray; ECMO, extracorporeal membrane oxygenation; FBC, full blood count; I&V, Intubate and ventilate; IO, intraosseous; IV, intravenous; LFT, liver function test; NIV, non-invasive ventilation; ROSC, return of spontaneous circulation; U&E, urea and electrolytes.

- A nasogastric or orogastric tube should be inserted and definitive airway established early to minimise the risk of vomiting and aspiration.[9]

Table 1 Hypothermia: methods of rewarming (passive and active) and specific changes to the standard APLS algorithm

Passive rewarming	Active rewarming (Use if core temperature <30°C)
Remove wet clothes	Warm intravenous fluids (39°C)
Warm blankets	Warm ventilator gases (42°C)
Warm air system (eg, Bair Hugger)	Bladder or gastric lavage with warm saline (42°C)
Ensure warm ambient temperature	
Hypothermia—changes to standard APLS algorithm	
Below 30°C, limit defibrillation to 3 shocks as arrhythmia may be refractory.	
Below 30°C, do not use inotropic or antiarrhythmic drugs such as epinephrine.	
The dose interval for resuscitation drugs (including epinephrine) is doubled between 30°C and 35°C.	
Continue resuscitation until core temperature is at least 32°C or cannot be raised (not required if there is clear evidence the patient has died, this may be from history or examination).	

APLS, advanced paediatric life support.

- The victim's chest should be dried prior to applying defibrillator pads.[9]

Hospital management

In most cases routine APLS practice should be followed, prioritising resuscitation with correction of hypoxia and acidosis. However, for the hypothermic patient, there are a small number of changes to the standard algorithm (figure 1). Defibrillation is less effective for the hypothermic myocardium and the metabolism of drugs, such as adrenaline, is reduced.

Hypothermia

Core temperature should be recorded (usually rectally). Marked hypothermia has been associated with a greater chance of survival and improved neurological outcome in numerous case reports, but this remains controversial with no association found in a systematic review and meta-analysis.[10] When outcomes of minimal long-term neurological impairments have been reported, this has typically been associated with water temperatures <6°C.[11] One proposed mechanism for this therapeutic hypothermia is rapid cooling of cerebral blood flow as inhaled cold water cools the lungs, heart and carotid arteries protecting the brain early from hypoxic injury. Younger children have a greater body surface to weight ratio and therefore theoretically best suited anatomically to enable rapid cerebral cooling.

Sea temperatures surrounding the UK rarely fall below 6°C, but inland waters can be lower. Establishing a clear history may help distinguish between the patient who is hypothermic with a reversible cause of cardiac arrest and those hypothermic because they are deceased.

Figure 2 Prevention strategies.

Irrespective of the prognostic role water temperatures may play in drowning victims, management strategies should focus on rewarming and effective APLS. For rewarming methods, see table 1.

Investigations

First-line investigations: conscious patient

- Pulse oximetry—to determine presence of hypoxaemia.
- ECG—to identify arrhythmias either as a potential cause of the drowning incident (eg, long QT syndrome) or which may have occurred secondary to hypoxia or hypothermia.
- Radiology imaging—request according to mechanism of drowning event and secondary injuries sustained.

First-line investigations: unconscious patient

- Pulse oximetry—to determine presence of hypoxaemia.
- Blood gas—to identify acidosis which may aid prognostication.
- Blood glucose—to identify hypoglycaemia. Maintaining normoglycaemia is required for neuroprotection.
- Full blood count—to establish a baseline haemoglobin level in view of the risk of evolving acute lung injury.
- Electrolytes—significant electrolyte imbalance is generally rare. Acute renal failure can evolve from acute tubular necrosis associated with prolonged period of hypoxia.
- ECG—to identify arrhythmias either as a potential cause of the drowning incident (eg, long QT syndrome) or which may have occurred secondary to hypoxia or hypothermia.
- Chest X-ray—to confirm endotracheal tube position (if intubated) and serve as a baseline for evolving acute lung injury.
- CT head—to identify hypoxic brain injury.
- CT cervical spine—may be required depending on mechanism of drowning/suspicion of injury.

Antibiotics, surfactant and steroids

- Evidence does not support the routine use of prophylactic antibiotics.[12]
- Evidence does not support the routine use of corticosteroids.[13]
- Despite case reports, there is no significant high-level evidence to support surfactant use.[14]

FURTHER MANAGEMENT

Ventilation strategies

Standard acute lung injury strategies, such as low tidal volume ventilation (lung protective ventilation), should be employed. High positive end-expiratory pressures may be required (10–15 cmH_2O). Expert advice from a paediatric intensivist should be sought.

Extracorporeal membrane oxygenation

- Multiple case reports describe the successful use of extracorporeal membrane oxygenation (ECMO) in patients with hypothermic cardiac arrest including children with prolonged periods of cardiac compression.[15]
- The European Resuscitation Council recommends ECMO as the preferred method for rewarming in hypothermic cardiac arrests.[16]
- ECMO should be initiated early. Prehospital teams should consider beginning discussions with the regional centre in cases of hypothermia and cardiac instability.

Concomitant injuries

Assessment and treatment of associated injuries will be required once initial resuscitation measures are complete and the patient's condition stabilised. A full secondary survey should be performed as soon as possible. In some cases, as previously discussed, it may include ongoing investigation and management of possible cervical spine injury.

Well-being and safeguarding

Drowning deaths are unexpected and therefore appropriate support should be offered to the family and staff. As in all aspects of paediatric practice safeguarding must be considered carefully and local procedures for raising concerns followed: Was there adequate supervision of the young child? Was the event a suicide attempt in the adolescent?

PROGNOSIS

Conscious

Non-fatal drowning occurs far more frequently than fatal drownings. The prognosis is excellent in children who are conscious at presentation. The duration of observation should be assessed on a case-specific basis, but is required for no more than 8 hours.[7]

Unconscious/cardiac arrest

It is difficult to draw conclusions on prognostication for the child who is unconscious or in cardiac arrest as the studies are heterogeneous with small numbers, inconsistent outcome measures and widely varying results.[17] The greatest evidence appears to be for the following:

- Time submerged: good outcomes are associated with <6 min submersion. Risk of mortality or poor neurological outcome is reported as 100% for submersion more than 25 min.[10 18]

- Duration of cardiac arrest: extremely poor outcomes associated with delayed delivery of BLS and no return of spontaneous circulation within 30 min of APLS.[18,19]

Without hypothermia

In most cases, where there is no history of significant and rapid-onset hypothermia, decisions to stop resuscitation should be made in the usual manner. That is to say, stopping resuscitation can be considered when there is no return of spontaneous circulation with 20 min of high-quality cardiopulmonary resuscitation in the absence of a shockable cardiac rhythm.[9]

With hypothermia

A Dutch study of drowned hypothermic children in cardiac arrest found poor neurological outcomes were associated with failure to restore spontaneous circulation within 30 min of advanced life support.[18] The longest paediatric submersion time with good neurological recovery, however, is reported to be greater than 1 hour.[15]

When assessing neurological status healthcare professionals should be aware that hypothermia may result in poorly responsive pupillary reflexes.

Cardiopulmonary resuscitation should be continued until core temperature is at least 32°C or cannot be raised. (This is not required if there is clear evidence from the history or examination that the patient has died.) Early discussions with a paediatric critical care service should act to either facilitate arrangements for ECMO or provide consensus for cessation of resuscitation.

PREVENTION

Several recent reports have focused on prevention: the WHO's Global Report on Drowning and the National Water Safety Forum's UK National Drowning Prevention Strategy.[2,20] Key messages focus on: education of the public on risks of water to children and of associated risk factors (eg, epilepsy, alcohol misuse), the use of safety barriers around bodies of water, the provision of swimming lessons for children and the provision of lessons in safe rescue and resuscitation for children and the public (figure 2).

CONCLUSION

Drowning in infants, children and young people is uncommon in the UK, but large paediatric units are likely to see cases. Globally, it is a significant cause of morbidity and mortality. Conscious children do extremely well and require limited observation. In unconscious children initial management should follow APLS principles. History is important to tailor the management; was hypothermia present prior to the arrest? It is only in this situation that prolonged resuscitation may be appropriate. Collectively, we should advocate for improved preventative strategies on the local, national and global stage.

Test your knowledge

1. In infancy, what circumstances most commonly lead to drownings?
   A. A combination of increased mobility, an inquisitive nature and lack of appreciation for danger.
   B. Being left alone, or unsupervised, near or in water.
   C. Reduced supervision and risk-taking behaviour.
2. In prehospital management, what is likely to be the most important factor in increasing the likelihood of survival?
   A. Initiation of early basic life support.
   B. Insertion of a nasogastric or orogastric tube due to the high risk of vomiting and aspiration.
   C. The use of abdominal thrusts to remove aspirated water from the lungs.
3. In the hospital setting, what investigation should be a priority for a conscious child with no symptoms or signs suggesting respiratory compromise?
   A. Bloods sent for a full blood count, electrolytes and liver function.
   B. Chest X-ray.
   C. Investigations are unlikely to be of use in this circumstance.
4. Which of the following is associated with a poor prognostic outcome?
   A. A conscious child at presentation.
   B. A submersion time of 5 min.
   C. No return of spontaneous circulation at 30 min.
5. Which of the following is a key change to the APLS algorithm in the context of drowning?
   A. Below 30°C, limit defibrillation to 1 shock.
   B. Below 30°C, use of inotropic or antiarrhythmic drugs is preferred to defibrillation.
   C. The dose interval for resuscitation drugs is doubled between 30°C and 35°C.

Answers to the quiz are at the end of the references.

Twitter Assim Ali Javaid @assimjavaid

Contributors JE conceived the idea for the article. JE, AAJ and ES undertook the literature review and drafted the manuscript. JE, AAJ, AB and JM contributed to its revision. JE and JM take responsibility for the paper as a whole.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient consent for publication Not required.

Provenance and peer review Commissioned; externally peer reviewed.

Data availability statement There are no data in this work

ORCID iDs
Jordan Evans http://orcid.org/0000-0002-8873-7343
Assim Ali Javaid http://orcid.org/0000-0003-4636-0688

REFERENCES

1 International Liaison Committee on Resuscitation (ILCOR) advisory Statements, "Recommended Guidelines for

Uniform Reporting of Data From Drowning". *Circulation* 2003;108:2565–74.
2 World Health Organization. *Global report on drowning: preventing a leading killer*. Geneva: World Health Organization, 2014.
3 Peden M, Oyegbite K, Ozanne-Smith J, *et al*. *World report on child injury prevention*. Unicef & World Health Organisation, 2008.
4 National Water Safety Forum. Uk water related fatalities 2010: water incident database report. National water safety forum; 2010-2018. Available: https://www.nationalwatersafety.org.uk/waid/reports-and-data/ [Accessed 9 Jul 2019].
5 Hwang V, Shofer FS, Durbin DR, *et al*. Prevalence of traumatic injuries in drowning and near drowning in children and adolescents. *Arch Pediatr Adolesc Med* 2003;157:50–3.
6 Tester DJ, Medeiros-Domingo A, Will ML, *et al*. Unexplained drownings and the cardiac channelopathies: a molecular autopsy series. *Mayo Clin Proc* 2011;86:941–7.
7 Szpilman D, Sempsrott J, Webber J, *et al*. 'Dry drowning' and other myths. *Cleve Clin J Med* 2018;85:529–35.
8 Rosen P, Stoto M, Harley J. The use of the Heimlich maneuver in near drowning: Institute of medicine report. *J Emerg Med* 1995;13:397–405.
9 Advanced Life Support Group. *Advanced paediatric life support*. 6th edn. West Sussex, UK: Wiley / BMJ, 2016.
10 Quan L, Bierens JJLM, Lis R, *et al*. Predicting outcome of drowning at the scene: a systematic review and meta-analyses. *Resuscitation* 2016;104:63–75.
11 Tipton MJ, Golden FSC. A proposed decision-making guide for the search, rescue and resuscitation of submersion (head under) victims based on expert opinion. *Resuscitation* 2011;82:819–24.
12 Wood C. Towards evidence based emergency medicine: best BETs from the Manchester Royal Infirmary. BET 1: prophylactic antibiotics in near-drowning. *Emerg Med J* 2010;27:393–4.
13 Foex BA, Boyd R. Towards evidence based emergency medicine: best BETs from the Manchester Royal Infirmary. Corticosteroids in the management of near-drowning. *Emerg Med J* 2001;18:465–6.
14 Cubattoli L, Franchi F, Coratti G. Surfactant therapy for acute respiratory failure after drowning: two children victim of cardiac arrest. *Resuscitation* 2009;80:1088–9.
15 Bolte RG, Black PG, Bowers RS, *et al*. The use of extracorporeal rewarming in a child submerged for 66 minutes. *JAMA* 1988;260:377–9.
16 Soar J, Perkins GD, Abbas G, *et al*. European resuscitation Council guidelines for resuscitation 2010 section 8. cardiac arrest in special circumstances: electrolyte abnormalities, poisoning, drowning, accidental hypothermia, hyperthermia, asthma, anaphylaxis, cardiac surgery, trauma, pregnancy, electrocution. *Resuscitation* 2010;81:1400–33.
17 Suominen PK, Vähätalo R. Neurologic long term outcome after drowning in children. *Scand J Trauma Resusc Emerg Med* 2012;20:55.
18 Kieboom JK, Verkade HJ, Burgerhof JG, *et al*. Outcome after resuscitation beyond 30 minutes in drowned children with cardiac arrest and hypothermia: Dutch nationwide retrospective cohort study. *BMJ* 2015;350:h418.
19 Marchant J, Cheng NG, Lam LT, *et al*. Bystander basic life support: an important link in the chain of survival for children suffering a drowning or near-drowning episode. *Med J Aust* 2008;188:484–5.
20 Rawlinson G, Glenn J, Hartley-Kite V, *et al*. *A future without drowning: the UK national drowning prevention strategy 2016-2026*. National Water Safety Forum, 2015.

Answers to the multiple choice questions

1. B. In this age group, infants left alone and unsupervised near or in water (eg, in the bath) is the most common cause of drowning.
2. A. Initiation of early basic life support.
3. C. Investigations are unlikely to be of use in this circumstance. An ECG could be considered to investigate an underlying cause of loss of consciousness if the history suggests this as a possibility.
4. C. Cases with no return of spontaneous circulation within 30 min of advanced paediatric life support are associated with extremely poor outcomes.
5. C. The dose interval for resuscitation drugs is doubled between 30°C and 35°C. Specifically, the key changes are:
   - Below 30°C, limit defibrillation to 3 shocks.
   - Below 30°C, do not use inotropic or antiarrhythmic drugs.
   - The dose interval for resuscitation drugs is doubled between 30°C and 35°C.
   - Continue resuscitation until core temperature is at least 32°C or cannot be raised.