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Childhood drowning: morbidity and mortality from a Johannesburg paediatric ICU, 2003 to 2013

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Childhood drowning:

Morbidity and mortality from a Johannesburg Paediatric ICU, 2003 to 2013

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A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of

Masters of Science in Medicine *(Child Neurodevelopment)*

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Abstract

Drowning is a worldwide significant but preventable public health problem. South Africa has one of the highest rates in the world of unintentional drowning mortality in the under five year age group. The aim of this study was to describe the population of patients admitted to a Johannesburg PICU with the diagnosis of drowning and to investigate potential prognostic factors recorded within the first 12 hours after admission. A retrospective record review of all the children between zero and 14 years admitted to PICU between January 2003 and December 2013, with a diagnosis of "drowning" or "near-drowning" was conducted*. Of the 215 children admitted into the unit in the 11 year period, 11 did not meet inclusion criteria. Seventy-two percent of the population were male and the mean age was two years and seven months, with the majority of patients under the age of three years (76.5%). There were 71.6% discharged with a good neurological outcome while 10.3% died in hospital and 24% were classified as having a poor outcome with neurological sequelae. These results, similar to those found in previous hospital based studies, showed that more boys are likely to drown than girls and that the largest number of victims fall in the one to four year age group. Univariate analysis found 15 physiological variables (all recorded in the first 12 hours after admission) to be significantly associated with outcome. When a forward stepwise multivariate discriminant analysis was used six variables were found to be significant predictors of outcome, GCS (≤6) and sodium (>148mmol/L) having the strongest association, but no one factor was found to accurately predict outcome. It is therefore recommended that every patient who has drowned be treated aggressively, no matter their presentation or history.*

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- The hospital's research group: for permission to conduct the study
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    - Graham and Janine Edwards
    - Christopher Swanepoel

Declaration

I, **Tamsen Peta Edwards**, declare that this research report is my own unaided work except for the help given by the persons listed under the acknowledgements. It is being submitted in partial fulfilment of the requirements of the degree of Master of Science in Medicine (Child Neurodevelopment option) at the University of the Witwatersrand.

It has not been submitted before for any other degree or examination in any other university.

Signed on this 28th day of September, 2015, in Johannesburg,



T.P. Edwards

List of Abbreviations

ARDS	Acute Respiratory Distress Syndrome
ATP	Adenosine Triphosphate
CPP	Cerebral perfusion pressure
CPR	Cardiopulmonary resuscitation
CT	Computed tomography
ER	Emergency room
GCS	Glasgow Coma Scale
Hb	Haemoglobin
HIE	Hypoxic ischaemic encephalopathy
ICP	Intracranial pressure
PICU	Paediatric intensive care unit
PICUE	Paediatic Intensive Care Unit Evalutator
pm	Per minute
POPC	Pediatric Overall Performance Category
PRISM	Pediatric Risk of Mortality Score
RCCH	Red Cross Children's Hospital
TBI	Traumatic brain injury
WHO	World Health Organisation
WBC	White blood cells

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CHAPTER 1: Introduction

Drowning is defined as the “process of experiencing respiratory impairment from submersion/immersion in liquid” and drowning outcomes should be classified as death, morbidity, or no morbidity (Van Beeck, Branche, Spizilman, *et al.*, 2005). Previously, terms such as near-drowning and wet/dry/active/passive drowning were used but, in 2002, at the World Congress in Amsterdam, Netherlands, it was recommended these be avoided to eliminate confusion (Szpilman, Bierans, Handley, *et al*., 2012). Drowning is the third leading cause of accidental injury death worldwide. In South Africa, the highest rates of drowning occur between zero and four years of age (Donson and Van Niekerk, 2012).

Drowning is a process that begins with the victim’s airway being submerged in water (or other liquid). Then follows breath-holding, laryngospasm, and finally aspiration of the liquid. This results in hypercapnia and acidosis (Layon and Modell, 2009). Further pulmonary insult includes surfactant washout, atelectasis, and shunting of blood. This causes cardiopulmonary failure which decreases cerebral blood flow causing ischaemic injury to the brain (Koo, Boxerman, and Murphy, 2001). Hypertension, acidosis, and hypercapnia can increase the insult to the brain and, if the hypoxic ischaemic injury is severe, there can be global neocortical damage (Macnab, 1995). Drowning can result in varying degrees of neurological impairment with ten to 24 percent of children who have drowned never recovering normal neurological functioning and, in severely affected cases, a permanent vegetative state can occur. (DeBoer, 1997; Macnab, 1995; Habib, Tecklenburg, Webb, *et al.*, 1996; Pearn, *et al.,* 1979). Drowning victims can have deficits in memory, executive function, attention and language. Often motor function is affected and disorders such as spasticity, dystonia, chorea and rigidity are found (Abrams, and Mubarak, 1991).

However, victims can be rescued at any time during the drowning process leading to variable outcomes (Layon and Modell, 2009). Several studies have tried to determine predictive factors of survival versus mortality so as to guide triage decisions, reduce unnecessary interventions and guide withdrawal of support (Christensen, Jansen and Perkin, 1997). Factors such as submersion time, cardiopulmonary resuscitation (CPR) lasting more than 25 minutes, low Glasgow Coma scale (GCS) scores, low pH on admission to hospital and unreactive pupils have been found to significantly correlate with poor outcome but results have been varied with no consensus among studies (Christensen, Jansen and Perkin, 1997; Nagel, Kibel & Beatty, 1990; Spack *et al.,* 1997; Graf *et al.*, 1995). There is minimal research published on drowning populations and their outcomes in Southern Africa and, of those studies that have been published, most have been based in Cape Town at the Red Cross Children's Hospital (RCCH) (Joanknecht, Argent, van Dijk, *et al.,* 2015).

Long-term outcome after drowning has also been poorly researched with very few studies available (Suominen and Vahatalo, 2012). These studies suggest that drowning, even if the child is discharged as "fully recovered", can cause neurological sequelae, which may only manifest later in life. When considering that drowning can cause hypoxic ischaemic injury to the brain (diffuse damage) and that the majority of children who drown fall in the under five year age group, long term follow-up studies are much needed in this high-risk group (Anderson, Morse and Catroppa, 2004).

The emotional and financial suffering experienced by the families and the social and public health costs placed on society by a child surviving drowning with a poor neurological

outcome is immense (Suominen& Vahatalo, 2012). Therefore the saying that “prevention is better than cure” is most pertinent when considering drowning. The World Health Organisation (WHO) call drowning a highly preventable public health threat and advises that there needs to be a focussed plan of action to decrease mortality rates (WHO, 2014). This includes community action such as barriers around swimming pools, education of school-aged children about water safety and rescue, public awareness campaigns and bystander CPR. The WHO also recommends effective policies and legislations be implemented in each country, especially those in the low to middle income brackets, to help coordinate drowning prevention efforts and to develop national water safety plans (WHO, 2014).

1.1 Study Aims

This study aims to provide a statistical description of the morbidity and mortality of the children who have drowned and been admitted to a private hospital paediatric intensive care unit (PICU) in Johannesburg, South Africa.

1.2 Study Objectives

- To provide a statistical description of the population using the available PICU database.
- To categorise children who were admitted into the unit due to drowning into the following two outcome groups for further analysis using the Paediatric overall performance categories (POPC):
    - Good (normal neurological functioning)

    - Poor (neurologically impaired or dead)
- To determine the mortality rate of patients admitted to the unit due to drowning
- To determine if time of year when drowning occurs has an effect on outcome.
- To determine if there was a significant difference in outcome results in the first five years of study compared to the last six years
- To determine if there are differences between the means or medians of each variable recorded for each outcome group
- To determine if Paediatric Risk of Mortality (PRISM) scores are significantly associated with outcome
- To determine if certain physiological variables, measured in the first 12 hours after admission to PICU (as recorded in the available database) are associated with outcome by univariate and multivariate analysis.

1.3 Motivation for and significance of the study

The unit's patient data had been collected and stored on the Pediatric Intensive Care Unit Evaluator (PICUE) database program for many years but it had not been analysed. It is important for this data to be analysed to see the trend over the eleven years since the drowning protocol of the unit had been implemented and to determine if any factors were specifically associated with outcome. This unit is known to have expertise in dealing with children who have drowned and is the private referral centre for these cases in Gauteng. There is a scarcity of research about drowning in Southern Africa and there are very few hospital based studies completed on South Africa's drowning populations. These have mainly been based in Cape Town, at the Red Cross Children's Hospital. There has not been any analysis completed on this particular private hospital PICU's drowning population

data. As it treats a large number of victims of drowning, it is important to analyse its populations and trends.

CHAPTER 2: Literature Review

2.1 Definition

The definition of drowning has varied widely over the years the subject has been researched. “Drowning” was defined as death secondary to asphyxia due immersion in a liquid and this could occur up to 24 hours after the event. “Near-drowning” was survival after drowning. Terms such as “wet versus dry drowning” (to differentiate between cases which show liquid aspiration in the lungs and those that did not) and “active versus passive or silent drowning” (to differentiate between those victims who are seen to drown or make some motion while drowning and those cases where the event was not witnessed or there was no struggle) were also frequently used (Idris, Berg, Bierans, *et al.,* 2003). “Secondary drowning” was used to describe drowning occurring due to an unrelated event, such as a seizure. It can also be used to describe the onset of acute respiratory distress syndrome (ARDS) after the victim seems to have recovered from the submersion event. These complicated and varied terms made it difficult to compare and analyse studies on the topic. In 2002, at the World Congress of Drowning in Amsterdam, The Netherlands, it was recommended that all these terms be avoided as to eliminate confusion and to facilitate research (Van Beeck, Branche, Spizilman, *et al.*, 2005; Szpilman, Bierans, Handley, *et al*., 2012). The Utstein guidelines were then published that recommended drowning be defined as the “process resulting in primary respiratory impairment from submersion/ immersion in a liquid medium” (Idris, Berg, Bierans, *et al.,* 2003). According to Idris, Berg, Bierans, *et al., (*2003) implicit in this definition is that the liquid/air interface present at the entrance of the victim’s airway is what prevents the victim from inhaling air. Whatever the outcome, be it death or survival, the victim has been involved in a drowning incident.

2.2 Epidemiology and aetiology of drowning

Drowning is among the ten leading causes of death in children all over the world, and is, as such, a significant public health problem (WHO, 2014; Maconochie, 2015). Drowning is estimated to cause around 372 000 deaths every year in all age groups. Males are more likely to drown than females, with a ratio of 4:1 (Topjian, Berg, Bierans, *et al.,* 2012). According to Zuckerman and Saladino (2005), the aetiology of drowning is complex and due to many factors such as geographical location and age but, when looking at childhood drowning, is often due to poor supervision around the home and by bodies of water. In most countries, drowning is one of the top three causes of accidental death in children younger than five years of age.

In a study looking at worldwide unintentional drowning mortality, South Africa had one of the lowest rates of adult mortality but one of the highest rates of mortality in the zero to four years age group (Lin, Wang, Lu *et al.,* 2014). Donson and van Niekerk (2012), used the South African National Injury Mortality Surveillance Register data from 2001 to 2005 to determine that drowning occurs at rates of between 1.4 to 2.7 per 100 000 people in South Africa. In the zero to four years age group, the highest rate of drowning (seven per eight per 100 000) occurred in Johannesburg. Males had an overall drowning rate of 8.7 per 100 000 while females had a rate of 3.8 per 100 000 in this age group. A study done in Cape Town, found that most of the children (77%) who were admitted due to drowning were under five years old, and there were twice as many boys as girls (Kibel, Nagel, Myers, *et al.*, 1990).

In the USA, most drowning incidents occur in fresh water, such as swimming pools and rivers. In children, this can also include baths and washing buckets and drowning can occur in water only five centimetres deep (Burford *et al.,* 2005). Large buckets are a threat to toddlers at the "pull-to-stand" developmental stage. They will often use buckets to pull themselves up however, due to their high centre of gravity, they can easily fall head first into the bucket without being able to extract themselves from it (Burford *et al.,* 2005). Swimming pools are the most common site of drowning in children of this age group (Burford *et al.,* 2005). This is true for South Africa, where children most often drowned around the home in swimming pools, bathtubs and buckets, rather than in dams, rivers or seas (Donson and van Niekerk, 2012). The summer months, November, December, and January, recorded the highest number of drowning incidents due to increased time spent outdoors and near bodies of water. This is similar to a 1985 four year retrospective study of drowning victims in Cape Town which found that the majority of childhood drownings occurred in swimming pools and buckets of water and the highest number of drowning occurred over the summer holiday months (Davis and Smith, 1985).

2.3 Pathophysiology of drowning

2.3.1 Pulmonary

Pulmonary complications are normally the primary pathology in a drowning event. Drowning is a process and occurs in a continuum (Layon and Modell, 2009). During the initial stages of drowning, there might be struggle, breath holding, and panic (Burford *et al.,* 2005). However, some reports show that children may drown silently, without struggle. Laryngospasm can be triggered with a small aspiration of fluid and in some cases, no water is found in the lungs. After an extended period of hypoxia and as the oxygen levels drop in

the body but before inspiratory efforts cease, the laryngospasm relaxes, which increases the likelihood of aspiration of water and/or gastric contents (Topjian, Berg, Bierans, *et al.,* 2012; Burford, Ryan and Stone*,* 2005; Zuckerman and Saladino, 2005).

Aspiration causes surfactant wash-out and results in impaired gaseous exchange, atelectasis, and pulmonary oedema (Zuckerman and Saladino, 2005). Fresh water aspiration causes surfactant destruction while salt water causes the surfactant to be washed out by osmosis extracting fluid from the alveoli (Scott and Nelson, 2011). In poorly ventilated areas of lung, intrapulmonary shunting can occur and can result in inadequate oxygenation and ventilation. Aspiration can also lead bronchospasm, acute lung injury or acute respiratory distress syndrome (ARDS) (Topjian, Berg, Bierans, *et al.,* 2012; Burford *et al.,* 2005). The consequence of these events is progressive hypoxia and acidosis (Zuckerman and Saladino, 2005). Depending on how severe these are, there may be electrical instability and the resulting cardiac dysfunction may lead to cardiac arrest (Zuckerman and Saladino, 2005).

2.3.2 Neurological

Prolonged hypoxia can have a severe impact on the central nervous system (Lieh-Lai, Sarnaik and Sarnaik, 2011). The brain is sensitive to the “timing, duration, and intensity of the hypoxaemic event” (Topjian, Berg, Bierans, *et al.,* 2012). During the drowning process, aspiration causes cardiopulmonary failure which decreases cerebral blood flow causing ischaemic brain injury (Koo, Boxerman, and Murphy, 2001). The duration and severity of the initial insult is the main determinant of outcome. However, hypertension, acidosis, hypercapnia, and cerebral oedema can further increase the insult to the brain (Macnab,

1995). The most susceptible areas are usually the vascular end zones (the “watershed areas”) as well as the hippocampus, insular cortex and basal ganglia (Topjian, Berg, Bierans, *et al.,* 2012). If the hypoxic ischaemic injury is severe, there can be extensive global neocortical damage (Suominen and Vähätalo, 2012; Koo, Boxerman, and Murphy, 2001).

While the initial hypoxia can cause brain cell damage there is also a secondary apoptosis which is the body’s complex response to the hypoxia which can cause further neuronal death and impacting the neurological outcome of the patient (Topjian, Berg, Bierans, *et al.,* 2012). Therefore neurological assessment immediately after drowning may not predict the full extent of the neurological insult, which may only be apparent months to years later. However, neurological indicators, such as GCS scores and pupillary response, have been found to be significantly associated with outcome in children who have drowned. On presentation to the ER, those patients who have suffered a severed insult will show poor neurological responses (Joanknecht, Argent, van Dijk, *et al.,* 2015; Christensen, Jansen and Perkin, 1997; Graf, Cummings, Quan, *et al.*, 1995; Quan, Wentz, Gore, *et al.*, 1990).

2.3.3 Cardiovascular

Cardiac failure is rare in successfully resuscitated drowning victims (Topjian, Berg, Bierans, *et al.,* 2012). However, when it does occur, cardiac dysfunction is usually as a result of factors such as hypothermia, acidosis, and/or hypoxaemia (Buford *et al.,* 2005). Hypoxia causes decreasing levels of arterial blood oxygen which in turn decreases cardiac output due to a decrease in myocardial oxygen supply resulting in myocardial ischaemia

(Zuckerman and Saladino, 2005). Peripheral vasoconstriction caused by the hypoxia can further reduce the cardiac output and decrease blood pressure. If the hypoxia is not quickly reversed, organs such as the heart, kidneys and brain are affected by the decreased blood oxygen content and reduced cardiac output. Severe bradycardia and circulatory arrest may result (Zuckerman and Saladino, 2005). The ventilation-perfusion mismatch of hypoxaemia can cause ventricular tachycardia, ventricular fibrillation and even asystole. If there is a metabolic acidosis present (which is common in drownings) there might be further myocardial impairment (Lieh-Lai, Sarnaik and Sarnaik, 2011).

In hypoxic states (low O2 supply) such as in strenuous muscle activity (seizure) or in low tissue perfusion states from circulatory failure, lactic acid is also produced anaerobically during glycolysis

2.3.4 Acid-Base balance, fluids and electrolytes

Drowning causes significant respiratory and/or metabolic acidosis (Salomez and Vincent, 2004). Respiratory acidosis is due to a build-up of carbon dioxide in the blood while the metabolic acidosis. Metabolic acidosis is caused by hypoxaemic related glycolysis where lactic acid is produced anaerobically (Salomez and Vincent, 2004). A review of laboratory results from 31 drowning victims showed that pH was lowered in the majority of cases, indicating a state of hypoxic acidosis (Oehmichen, Hennig and Meissner, 2008). In a study of 58 drowned children, Vähätalo, Lunetta, Olkkola, *et al.* (2014) found that those children with a poor outcome had significantly lower levels of pH than those that survived neurologically intact.

Rarely is enough water aspirated to cause any electrolyte imbalance which is only found in about 15% of drowning cases (Burford *et al.,* 2005; Zuckerman and Saladino, 2005). Studies have shown that very large amounts of fresh or salt water have to be aspirated before a fluid shift occurs which does not often happen in human submersion victims, even in water with high salinity. A study of 31 drowning cases showed that 47.5% of those who died had decreased potassium levels (Oehmichen, Hennig and Meissner, 2008).

Severe glucose abnormalities can result post drowning and hypothermia can decrease the amount of insulin produced and the body's sensitivity to it (Topjian, Berg, Bierans *et al,* 2013). The brain is very sensitive to changes in glucose levels when it is damaged. A study of 58 children who had drowned showed that those who did not survive had significantly higher blood glucose levels on arrival in ER than those who did survive (Vähätalo, Lunetta, Olkkola, *et al.*, 2014). Increased blood glucose concentrations after ischaemic brain injury could result in poor neurological outcomes (Salomez and Vincent, 2004).

2.3.5 Haematological

Usually drowning does not affect haemoglobin and haemocrit values. If changes do occur, this is may be due to significant blood loss from injury/trauma inflicted during the incident (Burford *et al.,* 2005). Oehmichen, Hennig and Meissner (2008) found that haemoglobin was reduced in only 17% of drowning victims and thought that this may be due to a slight haemolysis or haemodilution.

2.3.6 Temperature

Hypothermia is often found in drowning victims on presentation to the ER (Scott and Nelson, 2011). This may be caused by submersion in icy water which causes rapid cooling or it may be indicative of a prolonged time spent submerged in warmer water, which has negative implications on the outcome. In those cases where hypothermia is beneficial, it has been found to have the positive effects such as a decrease in cerebral metabolic rate, intracranial pressure and cytotoxic oedema (Lieh-Lai, Sarnaik and Sarnaik, 2011). Hypothermia decreases the amount of oxygen needed by the brain which will delay the onset of cell death and slow down the rate of adenosine triphosphate (ATP) depletion (Szpilman, Bierans, Handley, *et al*., 2012). The reduced activity (metabolic and electrical) will protect the brain from further damage. Hypothermia causes peripheral vasoconstriction, thereby preserving blood flow to central organs. However, conversely, hypothermia also has direct effects on cardiac function which may decrease the chances of a good outcome (Lieh-Lai, Sarnaik and Sarnaik, 2011).

2.3.7 Other

The other consequences of severe asphyxia due to drowning can include acute tubular necrosis and disseminated intravascular coagulation (Burford, *et al.,* 2005).

2.4 Management

Drowning with good neurological outcome depends on a management chain that begins at the scene and continues through to emergency room and in-hospital care (Topjian, Berg, Bierans, *et al.,* 2012). However every drowning victim is unique and no one treatment fits all so treatment and management needs to be individualised (Salomez and Vincent, 2004).

2.4.1 At the scene

According to Maconochie (2015) bystander resuscitation is the single most important determinant of intact survival. However, the longer the resuscitation takes, the worse the prognosis. Studies have shown that submersion time and CPR have the most significant impact on the outcome of a drowning victim (Zuckerman and Saladino, 2005). Ambulance services should be called to the scene as quickly as possible. Airway, breathing and circulation should be managed so as to stabilise the patient for transport to an emergency room equipped to manage them (Topjian, Berg, Bierans, *et al.,* 2012). It is important to assess if the victim may have sustained any injuries to the spine (i.e. fall from a height or a high impact collision) before moving them (Burford *et al.,* 2005). However, Szpilman, Bierans, Handley, *et al*. (2012) suggest that only 0.5% of drowning victims have cervical spine injuries and none of these were younger than 15 years of age.

2.4.2 At the Emergency Room (ER)/Paediatric Intensive Care Unit (PICU)

Patient presentation at the ER can vary from asymptomatic to presenting with cardiac arrest (Zuckerman and Saladino, 2005). The patient should be assessed and any airway, breathing, or circulation problems should be managed. Reversing the hypoxaemia by

restoring oxygenation and maintaining adequate ventilation is at the core of managing drowning victims (Zuckerman and Saladino, 2005). Injuries to the spine should be assessed and stabilised, however these are rare in children. It is important to obtain peripheral venous access for drug administration (Szpilman, Bierans, Handley, *et al*., 2012).

Hypoxia, acidosis and hypothermia should be presumed to be present in all drowning patients. As pulmonary dysfunction is the most common pathology post drowning, oxygen levels should be closely monitored. The patient might need supplemental oxygen and nebulisers to counteract the bronchospasm. This supplemental oxygen should be given for two to three days while the body replenishes the surfactant. If the patient deteriorates, is unable to maintain their airway, fatigues or if there are low GCS scores, they may require intubation and ventilation (Szpilman, Bierans, Handley, *et al*., 2012). Mechanical ventilation with positive end-expiratory point pressure is crucial to the reversal of the hypoxaemia and preventing further damage to susceptible organs (Zuckerman and Saladino, 2005). ARDS ventilation guidelines should be followed (Zuckerman and Saladino, 2005).

The patient's temperature needs to be determined as soon as possible after the initial drowning event (Topjian, Berg, Bierans, *et al.,* 2012). There are two conflicting schools of thought as to whether a hypothermic patient should be warmed immediately or not. Previously, patients were aggressively warmed after drowning but recent studies have shown that hypothermia can have a beneficial effect on neurological outcome as it reduces the secondary neuronal cell death which usually occurs after hypoxic brain injury, although more studies are needed to confirm this. Therapeutic hypothermia is used for brain protection and, if used, should be instituted as soon as possible post drowning in patients at

risk for brain injury (Topjian, Berg, Bierans, *et al.,* 2012). However, therapeutic hypothermia needs a specialised unit equipped correctly and up-to-date with the latest protocols. The 2002 World Congress on Drowning supported the use of therapeutic hypothermia for 12 to 24 hours after the drowning incident to improve neurological outcome post cardiac arrest (Moon and Long, 2002). Temperature should be maintained at between 32 and 34 degrees Celsius and patients should be ventilated and shivering prevented pharmacologically (Topjian, Berg, Bierans, *et al.,* 2012). After the period of hypothermia, warming should occur very slowly, at no more than 0.5 – 1.0°C per hour. It is important that neuro-monitoring be used to direct management and monitor outcomes. ICP can be used as can non-invasive neuro-monitoring techniques such as neurological examination and EEG.

2.5 Outcome

The vast majority of research conducted on the outcome after drowning are retrospective record reviews. Drowning studies tend to be retrospective record reviews focussing on the outcome of the child immediately on discharge from hospital. The recommended classification of drowning outcome is death, morbidity, or no morbidity (Topjian, Berg, Bierans, *et al.,* 2012). The majority of patients that quickly regain consciousness usually survive without any neurological sequelae. However, drowning can also cause death or severe neurological impairments, with 10 - 25 % of children never recovering normal pre-drowning neurological status (DeBoer, 1997; Habib, Tecklenburg, Webb, *et al.*, 1996; Macnab, 1995; Pearn, Bart and Yamaoka*,* 1979). However, as studies have different inclusion criteria and different definitions of outcome, it is very difficult to compare mortality rates from each study.

Survivors of drowning can have deficits in memory, attention, executive functions, visuospatial functions and language (Pierro, Bollea, Di Rosa, *et al.,* 2005). Spastic quadriplegia is common and movement disorders include rigidity, dystonia, chorea, action myoclonus, ataxia, dysarthria and dysphagia (Pierro, Bollea, Di Rosa, *et al.,* 2005). According to Abrams and Mubarak (1991) the abnormal posturing and spasticity in children with significant anoxic encephalopathy secondary to drowning is extremely malignant and is generally worse than that which occurs in cerebral palsy or traumatic brain injury. In the most severe cases, patients can remain in a permanent vegetative state.

In South Africa, Kibel, Nagel, Myers, *et al.* (1990) found that 18% of children admitted to the Red Cross Children's Hospital (RCCH) had a poor neurological outcome and of these, 6% were severely neurologically compromised. Spack, Gedeit, Splaingard, *et al.* (1997) showed the highest mortality rate (49%) and, of those patients that survived, 18% were neurologically impaired. The study included 81 drowning victims and logistic regression analysis was used to determine that aggressive forms of post drowning treatment such as hyperventilation, therapeutic hypothermia, and drug induced comas do not significantly alter outcome.

2.5.1 Predictors of outcome

Previous studies have attempted to determine predictive factors of morbidity and mortality to help guide triage decisions, to reduce unnecessary interventions and to guide withdrawal of supportive treatment (Christensen, Jansen and Perkin, 1997). Studies show no consensus on which factors are most effective in this regard, as can be seen in Table 2.1. At the scene of the drowning, submersion of less than 25 minutes and cardiopulmonary

resuscitation (CPR) lasting less than 25 minutes are indicators of good outcome (Burford, *et al.*, 2005). In the emergency room, CPR, fixed and dilated pupils and an initial pH of less than seven are highly predictive of death or severe neurological outcome. In the ICU, indicators of poor outcome are apnoea or decreased respiratory rate, Glasgow Coma Scale (GCS) of three, the absence of motor activity, intracranial pressure (ICP) of more than 20*mmHg* (normal range between 5 – 15mmHg) and cerebral perfusion pressure (CPP) of less than 50*mmHg*, and an abnormal CT scan 36 hours post event (Burford, *et al.*, 2005; Bell, Ellenberg and McComb*,* 1985). Large, unreactive pupils are indicative of hypoxic ischaemic encephalopathy (HIE) and, in drowning patients, the absence of pupillary response to light at 24 hours post injury is associated with poor outcome (Topjian, Berg, Bierans, *et al.,* 2012). Admission values of glucose, pH and blood lactate have been used to determine outcome, with variable results. Glucose values of less than 11*mmol/L* are typically associated with better outcome while high lactate and low pH tend to indicate poor outcome (Moon and Long, 2002). Although not a study on children who have drowned, it is interesting to note that White, Furukho, Bull, *et al.* (2001) analysed predictors of outcome in severely head injured children and found that survivors had GCS of greater than eight, a higher systolic blood pressure, higher body temperature and higher $PaCO_2$ scores compared to non-survivors.

The two South African studies that have looked at outcome in children after drowning were based in the Red Cross Children's Hospital (RCCH) in Cape Town. Both were retrospective studies using the search criteria "drowning or near-drowning" to collect the appropriate records. The first study was completed between January 1976 and December 1987 with 107 children between the ages of 0.4 and 13.8 years included (Kibel, Nagel, Myers, *et al.*, 1990). Their mortality rate was determined to be 12.1% and six out of the 107 children

(5.6%) were found to have neurological sequelae. Using the student's t-test and the Fisher's exact test they determined that the following factors were significantly related to outcome: fixed and dilated pupils, flaccidity or posturing, metabolic acidosis and the need for CPR in the ER.

The more recent 2014 study was completed on children admitted to the Red Cross hospital between January 2007 and April 2013 with a diagnosis of drowning (Joanknecht, Argent, van Dijk, *et al.,* 2015). They found that in the ER the need for CPR, a GCS score of less than five, hypothermia, bradycardia, and asystole were all significantly associated with poor outcome. The strengths of the associations were strong with significant p-values but some of their confidence intervals were wide. The only similar finding in the previous study at RCCH was the association between poor outcome and the need for CPR. The authors stated that the new Utstein guidelines and changes in treatment techniques were the reasons for study being completed. However, in the discussion, they did not review the treatment changes nor compare the results of their study with the previous study's results. With 75 subjects, the cohort was smaller than the 1990 study and this small sample size was the reason no multivariate analysis was completed. In comparison to the previous study, mortality rate had decreased by almost one and half percent to 10.7% while the percentage of children with neurological sequelae remained similar (5.6% in 1990 compared to 5.3% in 2014). It would have been of interest to determine what exactly had changed in the treatment techniques which resulted in fewer children dying but had little impact on the neurological sequelae of the patients. However, a retrospective study of drowning victims between 1976 and 1992 showed that aggressive treatment techniques such as continuous hypothermia, ICP monitoring, maintaining CPP above 50*mmHg* and intracranial hypertension prevention did not significantly improve the outcome of patients

Table 2.1: Table showing predictors of outcome at different locations from retrospective record review studies of paediatric drowning populations

Location and time frame	*n*	Criteria	Factors associated with poor outcome	Factors not associated with outcome	Reference
Hospital based, Cape Town, South Africa. Jan 2007 – Apr 2013	75	Children admitted for "drowning" or "near drowning" Between Jan 2007 and Apr 2013	ER: GCS<5, CPR, unresponsive, dilated pupils, intubation, bradycardia, hypothermia,, severe acidosis (pH<7.1)	ER: electrolyte disturbances (Sodium, Potassium, Chloride)	Joanknecht, Argent, van Dijk, *et al.,* (2015)
Hospital based, Wisconsin, USA. Jan 1976 - 1992	81	Children with diagnosis of drowning, near drowning, submersion injury admitted into ICU with endotracheal tube in situ. Excluded: those dead on arrival at ER	Low GCS scores and Prism score≥20		Spack, Gedeit,, Splaingard, *et al.* (1997)
Hospital based, California, USA. Jan 1985 – June 1994	274	Children admitted due to drowning between Jan 1985 and June 1994	Low GCS score, CPR, low pH	Age, body temperature	Christensen, Jansen and Perkin, (1997)
Hospital based, South Carolina, USA, 24mnth period	93	Children responded to by CHOC paediatric transport with a diagnosis of drowning in a 24 month period	ER: haemodynamic status (asystole) PICU: neurological status (coma)		Habib, Tecklenburg, Webb, *et al.* (1996)
Hospital based, Washington, USA. Jan 1980 – March 1991	194	All submersion victims admitted between Jan 1980 and March 1991. Excluded: patients who died on arrival at ER	ER: absence of pupillary light reflex; high initial blood glucose concentration; history of CPR, CPR>25mins; male sex; absence of BP, pulse, respiration; hypothermia; PO2<60mmHg; low blood pH	Age, time of year, transfer from another hospital, intubation, use of IV glucose, temperature of day	Graf, Cummings, Quan, *et al.*, (1995)
British Isles, Jan 1988 – Dec 1989j	188	Children aged 14 or less admitted due to drowning or nearly drowning between Jan 1988 and Dec 1989	Dilated pupils >6hrs post admission and seizures continuing for 24hrs post admission		Kemp and Sibert (1991)
Hospital based, Cape Town, South Africa. Jan 1976 – Dec 1987	107	Children (between 0 – 14yrs) admitted for "drowning" or "near drowning" Between Jan 1976 and Dec 1987	CPR (ER), lack of pupil response (ER), decreased LOC (ER), Apnoea (ER), Metabolic acidosis, hypothermia, ventilated for more than 48hours	Age<3yr, sex, race, site of drowning	Nagel, Kibel and Beatty (1990)
King County, Washington, USA. Jan 1974 – Dec 1983	135	Patients younger than 20 years, admitted between Jan 1974 and Dec 1983.	CPR>25mins, hypothermia, tachycardia/ventricular fibrillation, pH<7.1, fixed pupils.	Age, sex, site of drowning (dependant factors associated with submersion time)	Quan, Wentz, Gore, *et al.* (1990)

who had drowned (Spack, Gedeit,, Splaingard, *et al.,* 1997). Further research is needed to determine if change in the treatment of a drowning patient yield improved outcome results or have no effect. If changes in interventions do not have an effect on outcome it may mean that the focus should be more on prevention than treatment.

Kemp and Sibert (1991) analysed data from children who drowned in the British Isles and attempted to identify factors that might predict a poor prognosis. The study population was large (330 children) but there was no description of the statistical methods used to determine which factors could predict outcome. The sample groups were poorly described and defined. While their conclusions agreed with previous studies, their results were not rigorously analysed and therefore it difficult to draw any significant conclusions.

A more rigorous study, Kieboom, Verkade, Burgerhof, *et al.* (2015), determined outcome in children admitted with cardiac arrest and hypothermia post drowning. Their results showed that resuscitation after 30 minutes was ineffective at changing outcome (Joanknecht, Argent, van Dijk, *et al.,* 2015). Although the study took into account confounding variables, it only used univariate analysis to analyses outcome. Multivariate analysis may have increased the statistical relevance of the study as drowning is a complex multifactorial condition. In the British Isles between 1988 and 1989, 330 children had drowned with 142 deaths (Kemp and Sibert, 1991). On admission to hospital, those with fixed and dilated pupils six hours after admission had the worst outcome. Most children survived neurologically intact and the study

showed that hypothermia had a protective effect on neurological outcome. In a case control study over 20 years, the role of submersion duration and the temperature of the water were evaluated with regards to outcome (Quan, Mack and Schiff, 2014). Cold water did not have a protective affect against neurologic impairment but the amount of time the child was estimated to have been submerged did affect outcome. This study agreed with the findings of Suominen *et al.,* (2001) which showed that estimated submersion time was the best indicator of outcome while water temperature was not.

As shown, there are conflicting reports of hypothermia being a protective or detrimental factor to outcome after drowning in children. In those studies in which hypothermia was protective, the areas in which the study was conducted had much colder water temperatures, especially in winter, than South Africa does. Johannesburg has a sub-tropical highland climate with mild winters averaging about four degrees Celsius at night in June/July (Nagel, Kibel & Beatty, 1990). Winter days are normally dry and sunny, while nights are cooler. Due to this, bodies of water rarely freeze. For a child to become hypothermic in warmer water they need to be submerged for a prolonged period of time - studies suggest that good outcome is unlikely if submerged in waters warmer than six degrees Celsius for more than 30 minutes – and increased submersion time is associated with poor outcomes (Tipton and Golden, 2011).

A retrospective study in Washington State showed that the two most important risk factors for a poor outcome were submersion time greater than nine minutes and a

resuscitation time greater than 25 minutes (Quan, Wentz, Gore, *et al.*, 1990). Of the 135 records reviewed, 45 children died and five had severe neurological impairment. Graf, Cummings, Quan, *et al.*, (1995) used logistic regression analysis to determine the outcome of 194 children admitted to a paediatric referral hospital in Washington due to a submersion incident. They found that the best predictors of outcome were sex, comatose state, initial blood glucose concentration and lack of pupillary light reflex. However, their confidence intervals were wide. Their prediction of outcome rule had a specificity of 100 percent but this was determined from the population on which the rule was derived. To determine if the rule is really useful, it needed to be validated in another cohort. They were also one of the only studies that showed male sex to be significantly related to poor outcome. In South Carolina, USA, 93 drowned children's records were reviewed and they showed that haemodynamic and neurologic status on arrival to the ER were highly predictive of outcome (Habib, Tecklenburg, Webb, *et al.*, 1996). Those patients who were comatose and asystolic in ER had a poor outcome (death or vegetative state).

The Pediatric Risk of Mortality (PRISM, version III) was developed to predict ICU survival or mortality. It derives mortality risk from the amount and extent of observed physiological dysfunction (Zuckerman, Gregory and Santos-Damiani, 1998). The predictor uses 17 physiological variables with 26 ranges to determine the risk of mortality with a score that ranges from zero to 100 (Pollock, Patel and Ruttiman, 1997). The higher the score, the greater the risk the child has of not surviving the admission. A score of greater than 20 shows a high degree of physiological instability (Spack, Gedeit,, Splaingard, *et al.,* 1997). The PRISM scoring system can also be used to determine the absence or presence of serious neurological

impairment in paediatric patients who have drowned (Gonzalez-Luis, Pons, Cambra, *et al.,* 2001). In Wisconsin, a retrospective study of drowning victims between 1976 and 1992 utilised the PRISM score in order to determine outcome retrospectively in 81 drowned children and it was found that a score greater than 20 on initial presentation to PICU, predicted poor outcome (Spack, Gedeit,, Splaingard, *et al.,* 1997). The study concluded that the PRISM score is of value to determine outcome of drowning victims in PICU. Zuckerman, Gregory and Santos-Damiani (1998) reviewed the use of the PRISM score in children who drowned to determine outcome in the ER and the PICU but their study population only consisted of 50 patients. They reported that the use of PRISM in the ER rather than the PICU, is more useful at predicting outcome. While they mention confounding variables, they did not take these in account when analysing the data. However, Gonzalez-Luis, Pons, Cambra, *et al.,* (2001) used a retrospective record review to try determine if the PRISM score could be used on children who had drowned to determine survival chances and also to determine if PRISM could be used to predict neurological outcome. They analysed the variables of 60 children admitted into PICU and determined that the PRISM score can be used in this population to determine death or disability, but only if the values lie on the extreme ends of the scales. The outcome of patients with intermediate PRISM scores cannot be predicted with any certainty.

Recently, genetics has been viewed as a contributing factor in the outcome of ICU patients. Research into multiple trauma and traumatic brain injury, has shown that despite similar injuries, outcome varies from patient to patient (Hildebrand, Pape, van Griensven *et al.,* 2005). This too has been seen in patients with acute lung injury (ALI) or acute respiratory distress syndrome (ARDS) therefore the pathogenesis of

most disease is multifactorial and influenced by the environment, the genotype, the premorbid condition and the disease process (Flores, Pino-Yanes, Casula, *et al,* 2010). After trauma, there is an exaggerated inflammatory response that can occur within hours after the even and which can lead to posttraumatic complications (Giannoudis, van Griensven, Tsiridis, *et al.,* 2007). Acute lung injury Studies have suggested that this inflammatory response is regulated at a genetic level (Hildebrand, Pape, van Griensven *et al.,* 2005). Several cytokine gene polymorphisms have been found to be associated with outcome in post trauma patients, such as tumour necrosis factor (TNF-α) and interleukins (IL-1β and IL-6) (Dardiotis, Grigoriadis, and Hadijgeorgious, 2012; Giannoudis, van Griensven, Tsiridis, *et al.,* 2007). There has been no research into this area with regard to victims of drowning but as there is evidence for a genetic mediated inflammatory response in neuro-trauma, trauma and acute lung injury, there may be a complex genetic component to the outcome in drowning (Flores, Pino-Yanes, Casula, *et al,* 2010; Dardiotis, Grigoriadis, and Hadijgeorgious, 2012; Giannoudis, van Griensven, Tsiridis, *et al.,* 2007).

In summary, there are no specific, sensitive and reliable indicators of outcome in drowning victims.

2.5.2 Long-term outcome

Long-term outcome after drowning has been poorly researched with very few studies available (Suominen and Vähätalo, 2012). In 2011, a literature review of long-term

follow-up post drowning showed only eight studies which met the search criteria (Suominen, *et al.,* 2011). From these studies there is evidence that the discharge neurological status does not show all the possible sequelae from a drowning event. Although a child may appear to survive a drowning relatively neurologically intact, there might be long term neurological sequelae which only become apparent later in life, such as at school age (Suominen, *et al.,* 2011). Recently, Suominen, Sutinen, Valle *et al.,* (2014) completed a long-term study looking at cognitive and neurological outcome post drowning. The study sample was small and skewed towards those children who had a more severe drowning incident (longer submersion time and CPR required). However, the researcher completed a comprehensive cognitive and neurological assessment on their subjects and it was found that more than half (57%) had neurological dysfunction and 40% had low full scale intelligence quotient (FIQ) with a range of 20 to 78.

There has been more research completed on the impact of focal and diffuse traumatic brain injuries in children than on the neurological sequelae of drowning, but these show conflicting results. In the past, the paradigm “the younger is better” has often been used when discussing brain injury recovery. The brain demonstrates a plasticity that enables uninjured areas to take over the functions of the damaged areas. This happens due to a “complex series of molecular, cellular, and physiological events” (Giza and Prins, 2006). It was postulated that the younger brain is more capable of plasticity than a more mature brain and therefore children may have a better outcome following a brain injury than adults. This was supported by studies mainly looking at children with focal TBI’s at different stages of development (Giza and Prins, 2006). However, recent research has shown a

different picture – a young age at injury is a strong predictor of poor long-term outcome, especially when considering diffuse cerebral pathology (Anderson, Morse and Catroppa, 2004). Post TBI, children under three years are more likely to show severe and long-term deficits in behaviour and cognition (Giza and Prins, 2006; Anderson, Spencer-Smith and Coleman, 2014). This new theory – brain vulnerability – hypothesises that the young brain is highly vulnerable to injury as the stepwise developmental process can easily be derailed and that the plasticity of the brain does not mean "functional plasticity" (Anderson, Morse and Catroppa, 2004).

During the first few years of life, the brain is developing rapidly, with neural processes undergoing growth, pruning, synaptogenesis and myelination to form a cohesive functional unit. Any damage to the brain at this key stage can derail normal neural development, promote poor connectivity and dysfunctional networks (Anderson, Spencer-Smith and Coleman, 2014). Additionally, the brain has no previous set of building blocks or learnt skills so is unable to transfer skills to an undamaged area. In some cases, brain plasticity can be detrimental, where abnormal neural connections can impair function even further (Giza and Prins, 2006). This results in long-term sequelae which can include poor verbal and non-verbal skills, social and behavioural problems, spatial, perceptual, cognitive and executive function deficits (Anderson, Spencer-Smith and Coleman, 2014). To complicate matters further, brain development is further reliant on environmental conditions which can affect its recovery, such as maternal behaviour, enriched environment, and social conditions (Giza and Prins, 2006). When considering that drowning can cause hypoxic ischaemic injury to the brain (diffuse damage) and that the majority of children who drown fall in the under five year age group, long term follow-up studies are essential in this high-risk group (Anderson, Morse and

Catroppa, 2004).. The follow-up should extend well into the child's school years as this is when many of the long-term sequelae will appear to have an effect (Suominen, *et al.,* 2014).

2.6 Costs and quality of life after drowning

As intact neurological survival after drowning cannot be accurately predicted, all children are usually aggressively resuscitated and treated, no matter their initial presentation. The costs involved rapidly increase when those who survive the drowning event are severely disabled or remain in a vegetative state (Christensen, Jansen and Perkin, 1997). These patients need repeat hospital admissions, surgeries (such as percutaneous endoscopic gastrostomy (PEG) insertion), medications and long-term therapy as well as assistive devices. This places an additional financial burden on a family already under severe emotional strain as well as having an impact on society's public health or medical system. However, due to the uncertainty of intact survival, withdrawal of care should not be considered as there would be loss of neurologically intact survivors. Suominen *et al.,* (2011) determined that although quality of life was good among survivors of drowning and their families, this decreased with increased submersion time, especially if submersion time exceeded ten minutes.

Although a child might appear to survive the incident without any neurological fallout, there may significant problems later in life (Suominen *et al.,* 2011). This often manifests in school age children with impairments in reading and comprehension skills as well as with fine motor skills. This may put increased pressure on the

schooling system as these children are not recognised as having problems until later on. These neurologically affected children present a huge financial, emotional and personal cost to the child's family, and, an increased burden to society (Christensen, Jansen and Perkin, 1997).

2.7 Drowning Prevention

While drowning is in the top ten causes of death in children, it is also important to realise that it is entirely preventable (Maconochie, 2015). The WHO (2014) recommends that school aged children need to be taught to swim, public should be made aware of CPR and rescue skills and there should be increased public awareness campaigns on water safety. Legislation should be implemented to increase safely around bodies of water.

2.8 Conclusion

Drowning is a significant public health problem in South Africa. Boys are more likely to drown than girls and those under the age of four years old are at a higher risk of drowning. Many studies have analysed factors which impact outcome after drowning but there is no consensus between studies about which factors can predict outcome accurately. Due to the extent of the hypoxic insult to the brain, the severely affected survivors of drowning may place a large financial and emotional burden on their caregivers and the health systems resources. There are very few studies based in South Africa that look at the population of children who have drowned. Therefore much of the information on these children is obtained from other countries so it is

important to understand if our population of children who have drowned have similar mortality rates and outcome factors.

Chapter 3: Methodology

The following methods and materials were used to complete the study:

3.1 Location, site description and patient management

The study was based in a private hospital located in central Johannesburg, South Africa. The hospital has a nine bed Paediatric ICU. Throughout the study period, the unit used the same treatment protocol for every patient who was admitted due to drowning. This protocol includes the uses of therapeutic hypothermia and neuro-monitoring techniques such as ICP monitoring for those patients that need these interventions. Due to increased resources available to the unit, there are adequate numbers of ventilators, and cooling units as well as ICP monitors for the amount of beds in the unit, ensuring doctor is able to access the equipment if a patient needs it. The medical team based at the ICU includes an intensivist, ICU trained nurses, physiotherapist, and dietician. Specialists (such as neuro-surgeons, orthopaedic surgeons) and other allied medical professionals (such as occupational therapists, speech and language therapists) are called on a case to case basis as needed.

3.2 Study design

This study is a retrospective descriptive cohort study utilising convenience sampling.

3.3 Ethical considerations

Prior to data collection, an ethics clearance certificate (no. M131038) was obtained from the University of the Witwatersrand *Human Research Ethics Committee*

(Medical) on the 25/10/2013 (Appendix A) and the research protocol was approved by the University of Witwatersrand protocol committee. This was then taken to the hospital's research committee and permission was obtained for a record review to occur at the hospital (Appendix B). The doctor in charge of the unit gave his permission for his *PICUE* (Pediatric ICU Evaluator, version 3, Children's Research Institute 2003) database to be used (Appendix C). The database is maintained by the doctor and his assistant and is store on his private password protected computer with limited access to it. Once the records of the children were obtained from PICUE, patient confidentiality was assured by assigning each patient a unique case number identifier and removing their names and hospital identification numbers form the data to be analysed. This list was kept separately in a password protected file.

3.4 Cases

Children, between zero and 14 years of age, admitted to the hospital's Paediatric ICU were included into the study using the following criteria:

> *Inclusion criteria*: patients classified in *PICUE* database with the diagnosis of "near-drowning" or "drowning" with a PICU admission date from January, 2003 to December, 2013.
>
> *Exclusion criteria*: Previous neurological impairment or pathology (recorded in database along with diagnosis), duplicated records and those with more than 65% of data missing.

3.5 PICUE data and definitions

PICUE stores certain physiological parameters that are measured in the first 12 hours after admission to the PICU (see Table 3.2). Only the highest and lowest scores of these parameters are recorded in *PICUE*. All data analysed in this report was recorded in the first 12 hours, except for the Paediatric Overall Performance category (POPC) outcome scores which were recorded when the patient was discharged from PICU. The data was collected daily from PICU for each patient and recorded and stored in the PICUE database by the doctor in charge of the unit or his assistant. Only the information stored in the PICUE database was able to be analysed for the current study. Other data such as drowning medium, length of time submerged, water temperature, and allied therapy intervention was not recorded in the database.

Table 3.1: Table showing the physiological data stored in the *PICUE* programme for each patient collected in the first 12 hours of admission to PICU

System	Parameter	Units	Value recorded in the first 12 hours: highest or lowest reading or both
Cardio-respiratory	Systolic Blood Pressure	*mmHg*	Both
	Diastolic Blood Pressure	*mmHg*	Highest
	Heart Rate	*beats per minute*	Both
	Respiratory Rate	*breaths per minute*	Both
	Temperature	*°Celsius*	Highest
Neurological vital signs	GCS	*GCS scale 3 to 15*	Highest
Acid-Base/Blood Gases	pH		Highest
	PaO2	*mmHg*	Lowest
	PaCO2	*mmHg*	Highest
Chemistry and Haematology	Glucose	*mmol/L*	Highest
	Sodium (Na)	*mmol/L*	Both
	Potassium (K)	*mmol/L*	Both
	Bicarbonate	*mmol/L*	Both
	Creatinine	*µmol/L*	Highest
	Blood Urea Nitrogen	*mmol/L*	Highest
	White Blood Cell Count	*cells x 10^9/L*	Highest
	Platelet count	*cells x 10^9/L*	Highest
	Haemoglobin	*gm/dL*	Highest
PRISM	PRISM score		(calculated)

Each patient's neurological outcome at discharge from PICU was determined by the discharging doctor using the Pediatric Overall Performance Category (POPC) as recorded in *PICUE*. The POPC categorises outcome into six different categories including normal, disabled (mild to severe), coma/vegetative state or dead (See Table 3.1). The patients were grouped into the following two outcome groups:

- Good outcome: patients discharged from PICU with normal neurological function as determined by the POPC score of one (normal)
- Poor outcome: patients who died while in PICU or patients discharged from PICU with neurological sequelae i.e. POPC scores of two to six

Table 3.2: Description of Pediatric Overall Performance Category (POPC)

Score	POPC	Description
1	Good	Normal; age appropriate activities. Medical and physical problems do not interfere with normal activities
2	Mild disability	Mild, minor permanent physical or mental problems present minor limitations but are compatible with normal life
3	Moderate disability	Moderate; medical and physical conditions which cause physical disability; can affect age appropriate activities of daily living but will limit participation in competitive physical activities
4	Severe disability	Severe, child is dependent on others for most activities of daily living
5	Coma/vegetative state	Vegetative state is a complete unawareness of self and the environment, accompanied by sleep-wake cycles, with either complete or partial preservation of hypothalamic and brainstem autonomic functions (Gosseries, Bruno, Chatelle, *et al.*, 2011) Coma is defined as "a severe disturbance of consciousness, which precludes awakening and the directed movement of the extremities" (Haupt, Hansen, Janzen, *et al*, 2015)
6	Death	

3.6 Procedure

Data was retrieved from the PICUE database by the doctor's assistant by searching for the patients with the diagnosis of "near-drowning" or "drowning". Each patient was given a unique data reference number. This was kept separately from the rest of the data so that confidentiality could be maintained. This data was then extracted from these *PICUE* records (see Appendix D for data collection sheet) and entered into an Excel spreadsheet (*Microsoft, version 2007*).

3.7 Data and Statistical Analysis

The data was then preliminarily analysed using Excel's basic statistical functions and further analysis was performed with Statistica (*Statsoft, version 10*).

Categorical variables were presented as numbers and percentages. Continuous data was checked for normality by plotting histograms, P-P plots, checking skewness and kurtosis, and using Shipiro-Wilk normality test ($p<0.05$). Normal data was shown using means and standard deviations while non-normal data used median, and minimum to maximum ranges. All available measures were included into the calculations and no imputations were made. Physiological variable limits were determined from Pryor and Prasad (2003).

Patients were classified into outcome groups by discharge POPC values. For normally distributed data, Student's t-test was used to determine the difference between the means of each variable for good or poor outcome. To determine if there

was a difference between medians in non-parametric data, the Mann-Whitney U test was used. Variables were then analysed to determine potential prognostic factors for outcome. This was first completed by univariate analysis using Relative Risk and Fisher's Exact test and the risk of poor outcome was measured for its strength of association with certain predictor variables and compared to the outcome of those without the predictor.

A forward stepwise multivariate discriminant analysis was then performed using Wilks' Lamba values to determine those variables most strongly associated with outcome.

A two tailed p value of 0.05 was considered statistically significant for all analysis.

CHAPTER 4: Results

The following results analysis looks at the data obtained from the units *PICUE* database. The population's descriptive statistics were analysed and then the population was placed into two different groups according to outcome. From these two outcome groups, the neurological, acid-base, haematological, and cardiorespiratory variables associated with outcome were analysed. Finally a multivariate analysis was completed on all variables.

For the eleven year study period from the beginning of 2003 to the end of 2013, 215 patients were identified in the *PICUE* program with the diagnosis of "near drowning". This is an average of 19.55 patients per year. Of the 215 children, 11 were excluded from the study as they did not meet the inclusion criteria. Two of these were duplicate records, three children had a previous neurological impairment or pathology and five records did not have sufficient data to analyse (more than 65% data missing). Figure 4.1 shows a flow diagram of all these patients and the outcome of those included in the study. The outcome data was collected on discharge from PICU by the attending doctor. A good neurological outcome was seen in 71.6% (n=146) of the patients. There was a poor neurological outcome in 49 (24%) of children included in the study, including those who died. The mortality rate found in this study was 10.3% (n=21). For nine of the children in the study (4.4%), no outcome was recorded. This affects the number of children analysed with regards to outcome in each group as numbers were determined by data available.

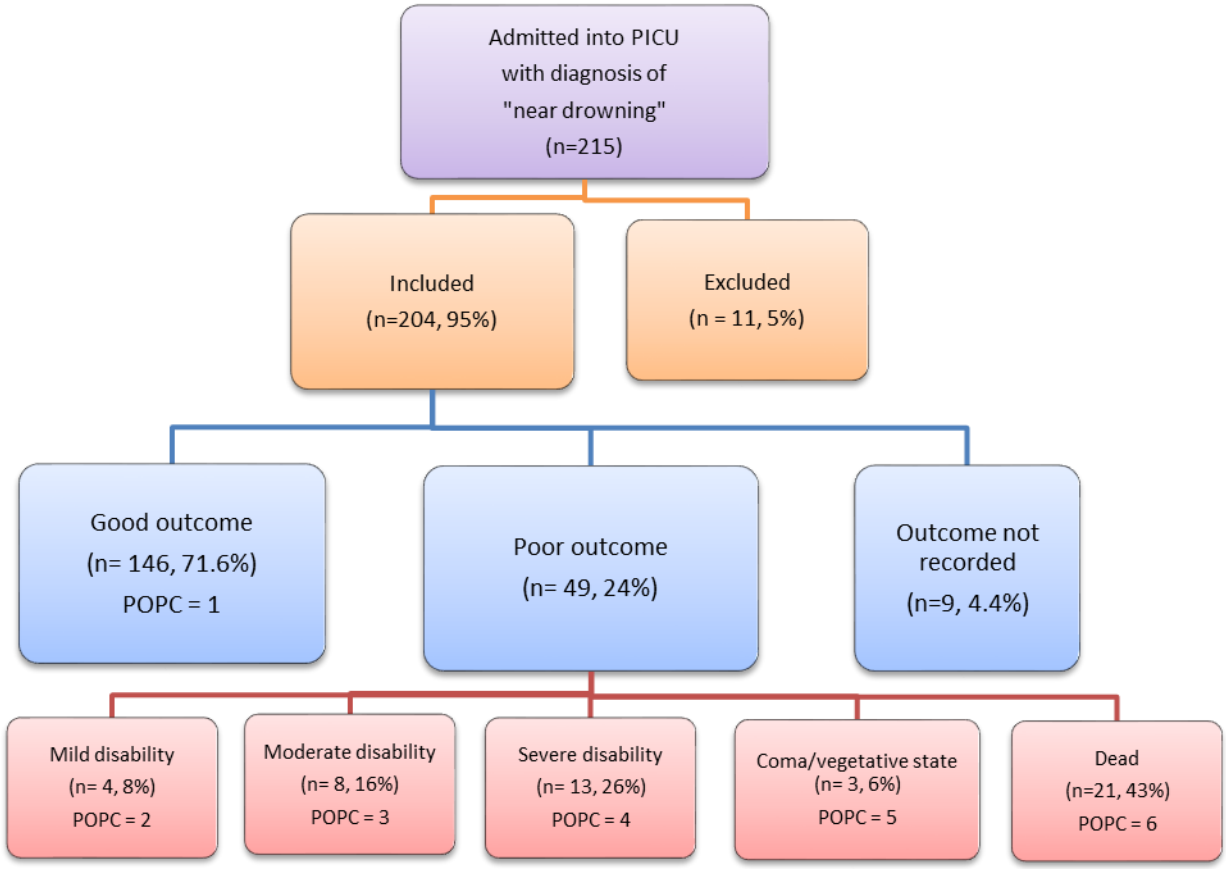


Figure 4.1: Flow diagram showing the total number of patients with the diagnosis of "near drowning" included and excluded in the study, with their outcomes

The majority of the data form the variables analysed were not normally distributed (See Table 4.1). The high heart rate and the low bicarbonate variables were the only ones to show normality when tested. Therefore all data was treated as non-parametric and the appropriate statistical tests were used.

Table 4.1 Table showing the results for normality testing of the data using histogram, Q-Q plot, Skewness, Kurtosis and the Shapiro-Wilk Test for Normality (p<0.05).

	Histogram	Q-Q plot	Skew-ness	Kurt-osis	Shapiro-Wilk	p-value	Decision
Age (months)	Not normal	Not normal	2,07	5,35	0,79	0,000	Not normally distributed
Temperature (°C)	Normal	Normal	-1,06	4,06	0,94	0,000	Not normally distributed
PCO2	Not normal	Normal	1,47	3,52	0,89	0,000	Not normally distributed
Urea	Not normal	Not normal	9,06	96,52	0,33	0,000	Not normally distributed
Glucose	Not normal	Not normal	0,76	0,01	0,93	0,000	Not normally distributed
Ph	Not normal	Normal	-0,87	0,37	0,94	0,000	Not normally distributed
Pupils	Not normal	Not normal	1,14	-0,69	0,55	0,000	Not normally distributed
GCS	Not normal	Not normal	0,59	-1,29	0,79	0,000	Not normally distributed
PRSIM	Not normal	Not normal	0,49	-1,52	0,79	0,000	Not normally distributed
Weight (kg)	Not normal	Not normal	2,46	9,78	0,78	0,000	Not normally distributed
Systolic BP High	Normal	Normal	0,86	3,62	0,94	0,000	Not normally distributed
Systolic BP low	Not normal	Not normal	-1,16	1,49	0,915	0,000	Not normally distributed
Diastolic BP	Normal	Normal	0,27	1,57	0,98	0,012	Not normally distributed
Heart Rate high	Normal	Normal	0,02	-0,52	0,99	0,348	Normal
Heart Rate low	Not normal	Normal	-0,63	1,30	0,97	0,000	Not normally distributed
Resp. Rate high	Not normal	Normal	0,17	-0,37	0,97	0,001	Not normally distributed
Respiratory Rate low	Not normal	Not normal	0,71	1,28	0,92	0,000	Not normally distributed
PaO2 low	Not normal	Not normal	1,83	4,44	0,84	0,000	Not normally distributed
Sodium high	Not normal	Not normal	1,39	3,00	0,91	0,000	Not normally distributed
Sodium low	Normal	Normal	-0,23	1,81	0,97	0,001	Not normally distributed
Potassium high	Not normal	Not normal	7,05	69,24	0,5	0,000	Not normally distributed
Potassium low	Not normal	Not normal	7,11	56,90	0,37	0,000	Not normally distributed
Bicarb. High	Not normal	Not normal	-0,46	2,39	0,98	0,000	Not normally distributed
Bicarbonate low	Normal	Normal	-0,07	-0,38	0,98	0,174	Normal
Creatinine	Not normal	Normal	0,56	0,40	0,98	0,020	Not normally distributed
Haemoglobin	Not normal	Normal	-0,17	1,42	0,97	0,002	Not normally distributed
White Blood Cell count	Not normal	Not normal	0,72	0,09	0,95	0,000	Not normally distributed
Platelets	Normal	Normal	0,37	-0,49	0,97	0,013	Not normally distributed

4.1 Descriptive statistics

Table 4.2 shows the characteristics of the study population. There was a predominance of boys, accounting for 72% of the population. The ratio of boys to girls was 2.6 is to one. Ninety children (44%) were recorded as having cardiac arrest requiring CPR, either at the scene, during transport, at the hospital or within the first 12 hours of being admitted to PICU.

Table 4.2: Table showing the descriptive characteristics of the 204 children admitted to PICU after drowning between the years 2003 to 2013

Characteristic	Number of children (%)
Gender	
Male	147 (72%)
Female	57 (28%)
Age (months):	
Median	25.00
IQR	23.00
Min to Max	3.00 to 162.00
Weight (kg):	
Median	12.00
Min to Max	8.00 to 45.00
Transferred from another hospital	130 (63.7%)
Cardiac arrest before hospital admission or within first 12 hours after admission	90 (44.1%)
Length of stay in PICU (days):	
Median	4.00
Min to Max	1 to 96
Ventilation:	
Number ventilated	137 (67%)
Number of days on ventilator	
Median	5.00
Min to Max	1 to 96
Intracranial Pressure:	
Number monitored	75 (36.8%)
Number of days monitored	
Median	5.00
Min to Max	1 to 27

There were 74 (36%) patients in the study population admitted directly to the hospital from the site of drowning. Fourteen patients (19.7%) that were transferred directly from the hospital's emergency room had poor outcomes, while 57 (80.2%) had a good outcome. One hundred and thirty (63.7%) patients were admitted into another hospital. From this hospital they were then transferred to the current study hospital's PICU for further treatment. Of these transferred patients, 71.7% were classified as having a good outcome on discharge from the unit.

Length of PICU stay ranged from one to 96 days, with a median of four days. One hundred and thirty seven children (67%) received mechanical ventilation for a median of five days. Intracranial pressure was monitored in 75 of the 204 (36.8%) children. The children ranged in age from three months to 13 years, with a median of 2.08 years (refer to Figure 4.2). The highest number of drowning occurred in the 12 to 23 month age group and 76.5% of the children were between one and three years of age.

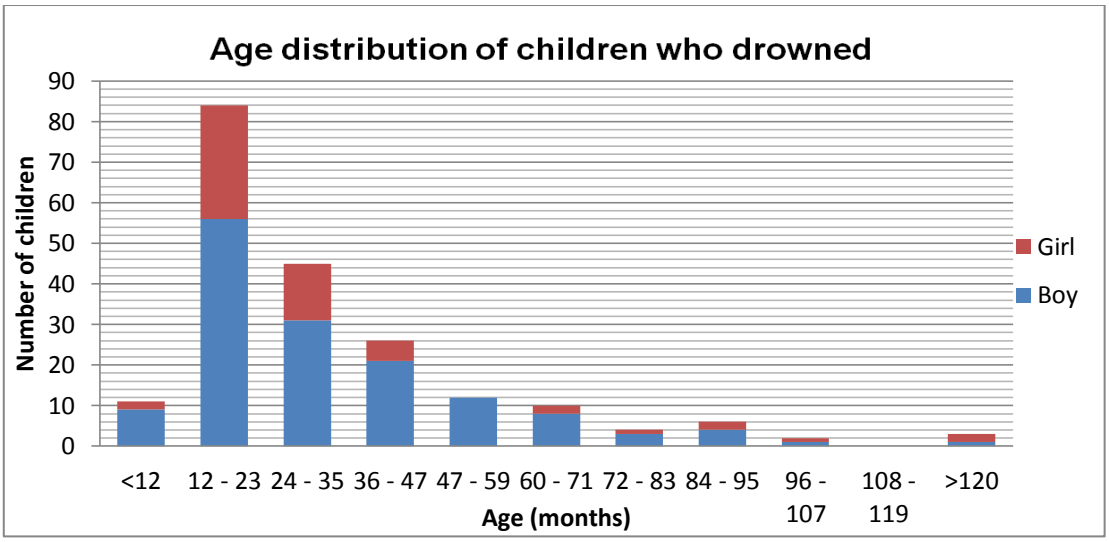


Figure 4.2: Bar graph showing the age distribution of the children admitted to the unit who drowned from 2003 to 2013, separated by gender

In Table 4.3 the Mann-Whitney U tests showed that there is no difference in median age between the two outcome groups (U=3409.0, p=0.624). However there were significant differences between the medians of the outcome groups when looking at the temperature in the first 12 hours after admission and the calculated PRISM scores.

Table 4.3: Table showing the Mann-Whitney U test results for the differences between the medians between the descriptive variables of the two outcome groups

Variable	*n* total	*Median good outcome*	*n* good outcome (%)	*Median poor outcome*	*n poor* outcome (%)	Mann-Whitney U	Z	p-value
Age (months)	195	24.5	146 (75)	25	49 (25)	3409.00	-0.49	0.624
Temperature (°C)	195	36.9	146 (75)	35.00	49 (25)	2036.50	4.51	**0.000**
PRISM	195	4.8	146 (75)	90.90	49 (25)	468.00	-9.12	**0.000**

*the significant p-value are shown in red

A temperature of less than 34 degrees Celsius puts a child who has drowned at 3.08 times greater risk of having a poor outcome than those children with temperatures above 34 degrees Celsius (CI 95% 1.95 to 4.84). Although there were double the number of boys in the study population (2.6:1), boys did not have significantly greater risk for a poor outcome when compared to girls (Table 4.4; p = 0.469, RR = 1.28 with 95%CI 0.72 to 2.28). Those patients who were recorded as having cardiac arrest in the first 12 hours after drowning, were at significantly higher risk for a poor outcome, however the confidence interval for this variable is large (p = 0.00, RR = 5.87 with 95% CI 1.99 to 17.26).

Table 4.4: Table showing the relative risk and Fisher's exact two-tailed test for the descriptive variables of the two outcome groups

Variable	Limits	Poor Out-come	Good Out-come	Fisher's Exact p value	Relative Risk	95% CI lower	95% CI upper
Male	Yes	37	100	0.469	1.28	0.72	2.27
	No	12	45				
Age (months)	≥24	27	78	0.870	1.05	0.64	1.71
	<24	22	68				
Temper-ature (°C)	≤34	10	5	**0.001**	3.08	1.95	4.84
	>34	39	141				
Cardiac Arrest	Yes	42	20	**0.000**	5.87	1.99	17.26
	No	3	23				
Season	Winter	11	38	1.000	0.99	0.52	1.89
	Summer	21	72				
PRISM score	≤25	2	101	**0.000**	0.04	0.01	0.15
	>25	47	45				
	≥85	36	9	**0.000**	9.23	5.38	15.83
	<85	13	137				

*significant p values are shown in red

PRISM scores showed significant associations with outcome (Table 4.2, $p < 0.05$). Those children with a PRISM score of above 85 had 9.23 times increased risk of poor outcome (Table 4.3, 9.23, 95%CI 5.38 to 15.83) while those patients with a score of less than or equal to 25, only had a four percent greater risk of poor outcome (RR=0.04, 95%CI 0.01 to 0.15). The PRISM scores ranged from 0.4 to 95.5 and the 146 patients with good outcomes had a median PRISM score of 4.8. However, there were 12 patients who had a PRISM score of more than 80 (predicting a poor outcome) who were classified as having a good outcome. Similarly, two patients who had PRISM scores of less than 25 had poor outcomes. There were 103 children with a PRISM score of less than 25. Of these children with

a score of less than 25, only 2 had a poor outcome. Therefor 98 percent of children with a score of less than 25 had a good outcome.

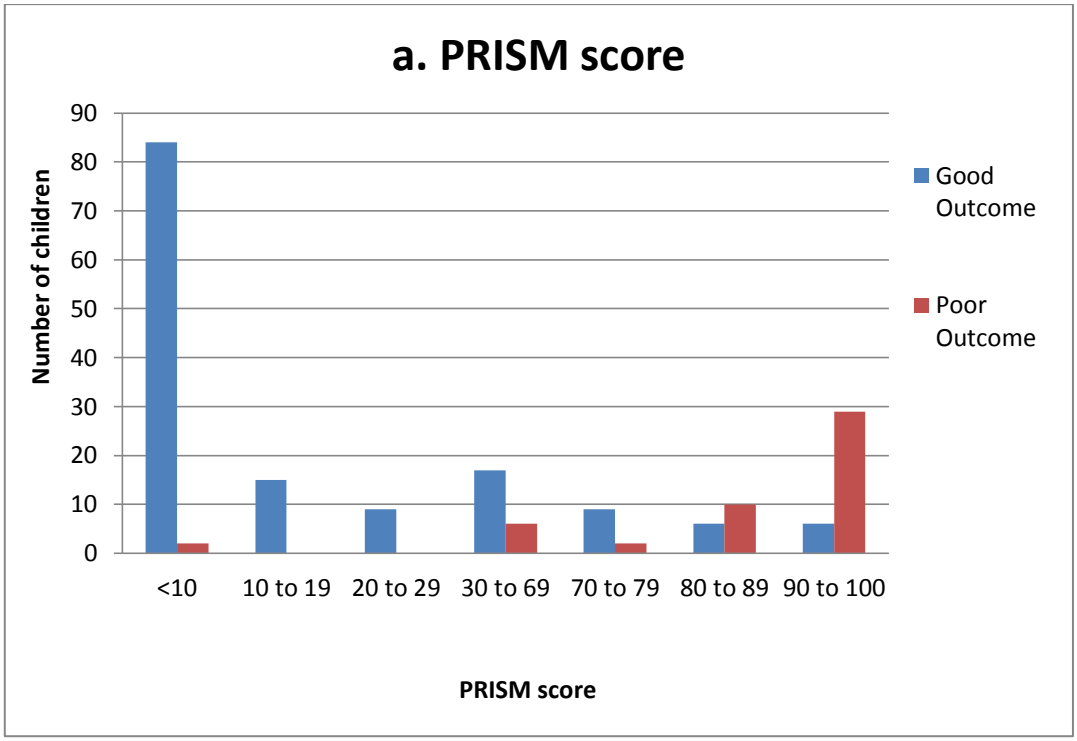


Figure 4.3: Bar graph showing the PRISM scores of the two outcome groups admitted to PICU between 2003 and 2013

4.2 Season/Time of year

Summer months were defined as October to March and winter was considered to fall between April to September. Figure 4.4 shows that there are a greater number of drownings in the summer months, with a peak in December, over the eleven year period. There were fewer drownings in the winter months. The relative risk for poor outcome in patients who drowned in winter compared to other seasons was 0.99 (CI 95% 0.52 – 1.88, Fisher's exact p = 1.0). There was therefore, no significant association between the time of year the drowning occurs and outcome.

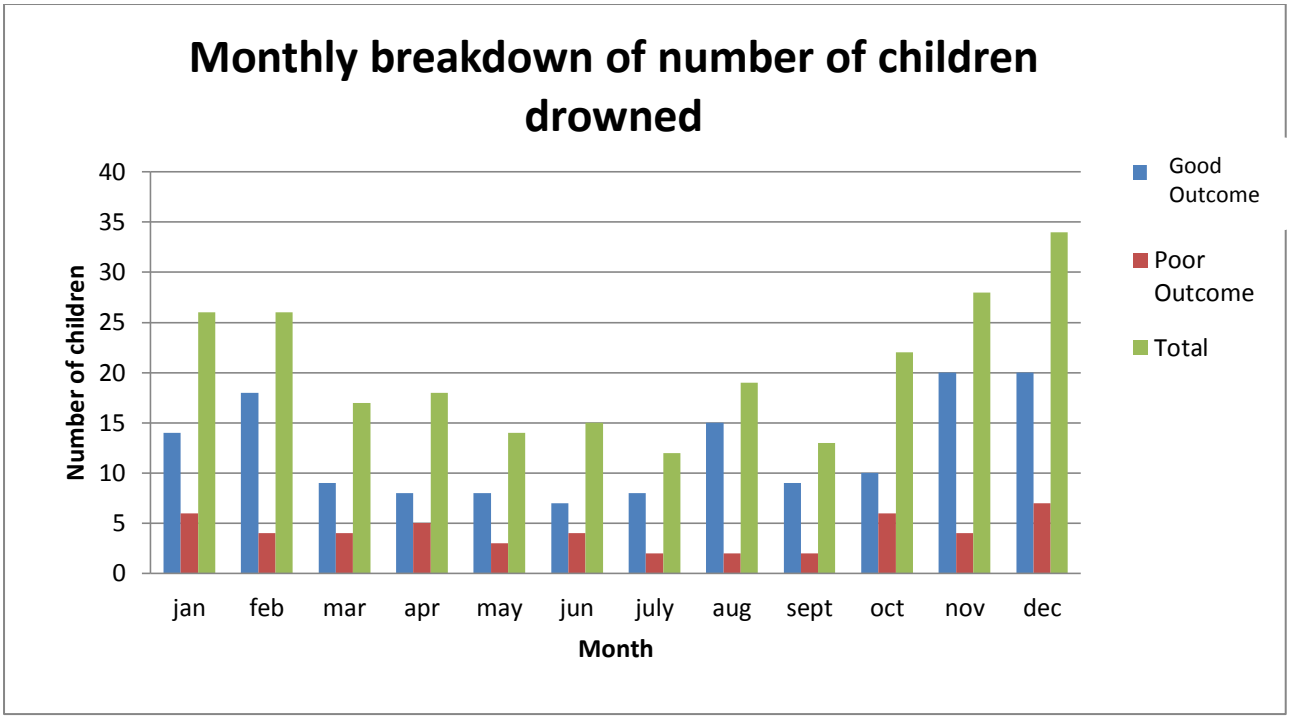


Figure 4.4: Bar chart showing the outcome of both outcome groups and the total number of children admitted to PICU stratified by month, 2003 to 2013

4.3 Neurological

Table 4.5 shows that the GCS median differed significantly between outcome groups. In Table 4.6, a child with a GCS score of six or less had a 43 times significantly increased risk of poor outcome but the confidence interval for this is very large (RR = 43.72, 95% CI 5.73 to 310.42).

Table 4.5 Table showing the Mann-Whitney U test results of the differences between the medians of the Glasgow Coma Scale (GCS) of the two outcome groups

Variable	*n* total	*Median good outcome*	*n* good outcome (%)	*Median poor outcome*	*n* poor outcome (%)	Mann Whitney U	Z	p-value
GCS	193	7	144 (74)	3	49 (26)	698.50	8.65	**0.000**

*significant p-value shown in red

Table 4.6: Table showing the relative risk and Fisher's exact two-tailed test for GCS scores of the two outcome groups

Variable	Limits	Poor Out-come	Good Out-come	Fisher's Exact p value	Relative Risk	95% CI lower	95% CI upper
GCS	≤6	48	53	**0.000**	43.72	6.15	310.42
	>6	1	91				

*significant p-value shown in red

4.4 Acid-Base/Blood Gases

In Table 4.7, variables that measured acid-base balance or blood gas, PCO2, PaO2 and pH, all showed significant differences between the medians of those with a good outcome and those without. However, of these, only pH showed a significant association with outcome (Table 4.8). Those with a pH of less than 7.1 had over two times the risk of a poor outcome (RR= 2.73, 95%CI 1.70 to 4.38)

Table 4.7: Table showing the Mann-Whitney U test results of the differences between the medians of the acid-base/blood gas variables of the two outcome groups

Variable	*n* total	*Median good outcome*	*n* good outcome (%)	*Median poor outcome*	*n* poor outcome (%)	Mann-Whitney U	Z	p-value
PCO2 (mmHg)	153	44.10	105 (68)	55.50	48 (31)	1704.50	-3.90	**0.000**
PaO2 (mmHg)	166	79.5	118 (71)	59.5	48 (29)	2224.00	2.16	**0.030**
pH	153	7.22	104 (68)	7.01	49 (32)	1571.00	3.82	**0.000**

*significant p-value shown in red

Table 4.8: Table showing the relative risk and Fisher's exact two-tailed test for the acid-base/blood gas variables of the two outcome groups

Variable	Limits	Poor Out-come	Good Out-come	Fisher's Exact p value	Relative Risk	95% CI lower	95% CI upper
PCO2	≥65	12	17	0.121	1.55	0.92	2.60
(*mmHg*)	<65	36	99				
PaO2	≤42	14	19	0.086	1.65	1.01	2.71
(*mmHg*)	>42	34	99				
pH	≤7.1	30	26	**0.000**	2.73	1.70	4.38
	>7.1	19	78				

*significant p-value shown in red

(RR= 2.73, 95%CI 1.70 to 4.38)

4.5 Chemistry/Haematology

Nine out of the 13 variables for chemistry and haematology showed a significant difference in their medians between the different outcome groups (Table 4.9). These included bicarbonate levels (both the highest and lowest readings in the 12 hours after admission), creatinine, glucose, platelet count, the lowest potassium reading, the highest sodium reading and the urea levels, haemoglobin, potassium (lowest reading) and white blood cells showed no significant difference between the medians of the different groups.

Table 4.9: Table showing the Mann-Whitney U test results of the differences between the medians of the chemistry and haematology variables of the two outcome groups

	n total	*Median good outcome*	*n* good outcome (%)	*Median poor outcome*	*n* poor outcome (%)	Mann Whitney U	Z	p-value
Bicarbonate								
>20 *mmol/L*	152	19.5	109 (72)	18.0	43 (28)	845.00	5.32	**0.000**
<16 *mmol/L*	148	15.0	106 (72)	9.55	42 (28)	2048.50	2.72	**0.006**
Creatinine								
>75 *µmol/L*	145	33	103 (71)	46	42 (29)	1254.50	-3.85	**0.000**
Glucose								
>22*mmol/L*	136	10.10	94 (69)	19.00	42 (31)	1244.50	-6.24	**0.000**
Haemoglobin								
>14 *gm/dL*	168	12.5	119 (71)	12.7	49 (29)	2184.00	-0.65	0.515
Platelet								
<200 *cellsx10^9/L*	153	393.5	105 (69)	329	48 (31)	1480.50	3.17	**0.002**
Potassium								
>6.5*mmol/L*	153	4.20	104 (68)	4.30	49 (32)	2888.00	0.09	0.925
< 3*mmol/L*	178	3.20	129 (72)	2.70	49 (28)	1417.00	4.34	**0.000**
Sodium								
>148*mmol/L*	194	137	145 (75)	144	49 (25)	1266.50	-5.85	**0.000**
<133*mmol/L*	164	133	116 (71)	133	48 (29)	2349.00	-0.67	0.501
Urea								
>6*mmol/L*	165	4.50	117 (71)	6.45	48 (29)	1134.50	-4.48	**0.000**
WBC								
>15 *cells x 10^9/L*	145	10.52	104 (72)	10.30	41 (28)	1977.50	-0.68	0.499

*significant p-value shown in red

Haemoglobin (>14*gm/dL)*, white blood cell count (>15 *cells x 10^9/L)*, low sodium (<133*mmol/L*) and both high and low bicarbonate (<16*mmol/L* and >20*mmol/L*) readings showed no significant association with outcome (Table 4.10). Those variables that had an association with outcome according to a significant Fisher's Exact value included urea (>6*mmol/L)*, glucose (>22*mmol/L)*, sodium (>148*mmol/L)*, potassium (< 3*mmol/L*), bicarbonate (<16 *mmol/L*), and platelets (<200 *cellsx10^9/L)*. There was a 2.88 times increased risk of having a poor outcome if a patient had a

urea level of over six millimoles per litre in the first 12 hours after admission (95%CI 1.73 to 4.80) than if the level was below six. Similarly a high glucose reading (above 22 *mmol/L*) increased the risk of poor outcome by 3.16 fold (95%CI 2.09 to 4.75). A sodium level of above 148 *mmol/L* increased the likelihood of a poor outcome by 3.51 times (95% CI 2.41 to 5.10). Having decreased levels of potassium (less than or equal to 3 *mmol/L)* also increased the risk of a poor outcome by 2.39 fold (95% CI 1.38 to 4.15) and bicarbonate (less than or equal to 16 *mmol/L)* increased the risk of poor outcome by over 3 times (RR=3.42, 95% CI 1.31 to 8.91). High creatinine readings above 75*μmol/L* (RR=3.02 95% CI 1.80 to 5.08) and low platelet reading (RR = 2.92 95%CI 1.79 to 4.75) also showed a strong association with outcome.

Table 4.10: Table showing the relative risk and Fisher's exact two-tailed test for the chemistry and haematology variables of the two outcome groups

Variable	Limits	Poor Out-come	Good Out-come	Fisher's Exact p value	Relative Risk	95% CI lower	95% CI upper
Bicarbo-nate	≥20	16	55	0.122	0.66	0.40	1.10
	<20	32	62				
mmol/L	≤16	38	62	**0.003**	3.42	1.31	8.91
	>16	4	32				
Creatinine	>75	4	1	**0.003**	3.02	1.80	5.08
µmol/L	≤75	37	103				
Glucose	≥22	14	6	**0.000**	3.16	2.09	4.75
mmol/L	<22	35	123				
Haemoglobin	>14	7	21	0.100	0.86	0.43	1.73
gm/dL	≤14	36	88				
Platelets	≤200	6	2	**0.007**	2.92	1.79	4.75
cellsx10^9/L	>200	36	104				
Potassium	≥7	1	2	1.000	1.14	0.22	5.77
mmol/L	<7	48	117				
	≤3	35	46	**0.001**	2.39	1.38	4.15
	>3	13	59				
Sodium	≥148	15	4	**0.000**	3.51	2.41	5.10
mmol/L	<148	34	117				
	≤133	27	62	0.860	0.92	0.58	1.48
	>133	21	43				
Urea	≥6	25	24	**0.000**	2.88	1.73	4.80
mmol/L	<6	17	79				
WBC Count	≥15	14	34	1.000	1.04	0.61	1.81
	<15	27	70				

*significant p-value shown in red

4.6 Cardio-respiratory

The cardio-respiratory variables that showed the most significant difference between outcome group medians were a heart rate of more than 190 beats per minute, a respiratory rate of less than 15 breaths per minute, and a low systolic blood pressure

(less than 45*mmHg*) within the first 12 hours after admission (Table 4.11). Table 4.12 shows that a low systolic pressure (less than 45*mmHg*), a high heart rate (greater than 190 beats per minute) and a low respiratory rate (less than 15 breaths per minute) had a significant association with outcome. The relative risk of having a poor outcome was 2.77 times higher in patients with a lower systolic reading (95% CI 1.64 to 4.66). It was 1.72 times higher for those with a heart rate higher than 190 beats per minute (95%CI 0.84 to 3.53) and more than four times higher in a patient with a low respiratory rate in the first 12 hours after admission (RR = 4.11, 95%CI 2.41 to 6.99).

Table 4.11: Table showing the Mann-Whitney U results of the differences between the cardio-respiratory variables of the two outcome groups

Variable	*n* total	*n* good outcome (%)	*Median good outcome*	*n poor* outcome (%)	Median poor outcome	Mann-Whitney U	Z	p-value
Heart rate								
>190 beats pm	194	145 (75)	150	49 (25)	162	2853.50	-2.06	**0.040**
< 90 beats pm	193	145 (75)	106	48 (25)	111	3432.50	0.14	0.889
Respiratory rate								
>75 breaths pm	194	145 (75)	40	49 (25)	31	2770.50	2.30	0.021
<15 breaths pm	194	145 (75)	21	49 (25)	6	1978.50	4.64	**0.000**
Diastolic BP								
>95 *mmHg*	194	145 (75)	73	49 (25)	67	2980.00	1.68	0.092
Systolic BP								
>160 *mmHg*	194	145 (75)	120	49 (25)	115	3130.50	1.24	0.215
<45 *mmHg*	194	145 (75)	90	49 (25)	77	1735.50	5.35	**0.000**

*significant p-values shown in red

Table 4.12: Table showing the relative risk and Fisher's exact two-tailed test for the cardio-respiratory variables of the two outcome groups

Variable	Limits	Poor Out-come	Good Out-come	Fisher's Exact p value (two tailed)	Relative Risk	95% CI (lower)	95% CI (upper)
Systolic BP (mmHg)	≥160	4	3	0.069	2.37	1.19	4.73
	<160	45	142				
	≤45	7	4	**0.000**	2.77	1.64	4.66
	>45	42	141				
Diastolic BP (mmHg)	≥95	8	14	0.050	1.53	0.83	2.82
	<95	41	131				
Heart rate (beats per min)	≥190	5	7	**0.030**	1.72	0.84	3.53
	<190	44	138				
	≤=90	16	29	0.076	1.64	0.99	2.70
	>90	32	116				
Respiratory Rate (breaths per min)	≥75	5	8	0.320	1.58	0.76	3.29
	<75	44	137				
	≤15	34	35	**0.000**	4.11	2.41	6.99
	>15	15	110				

*significant p-value shown in red

4.7 Outcome comparison: first versus second half of study

Figure 3.4 shows a bar graph of the outcome for the first six years and the last five years of the study period. Treatment protocol remained constant throughout the 11 years but staff knowledge of the treatment of children who drowned may have improved however, there was no greater risk associated with being admitted into the unit in the first half of the study period compared to the last (RR=0.97, 95%CI 0.59 to 1.58 and Fisher's Exact *p* =1) (Table 4.13).

Table 4.13: Table showing the relative risk and Fisher's exact two-tailed test for the first six years of the study period compared to the last five years for the two outcome groups

Variable	Limits	Bad Out-come	Good Out-come	Fisher's Exact p value	Relative Risk	95% CI lower	95% CI upper
Treatment change	2003 - 2008	21	64	1.000	0.97	0.59	1.58
	2009 - 2013	28	82				

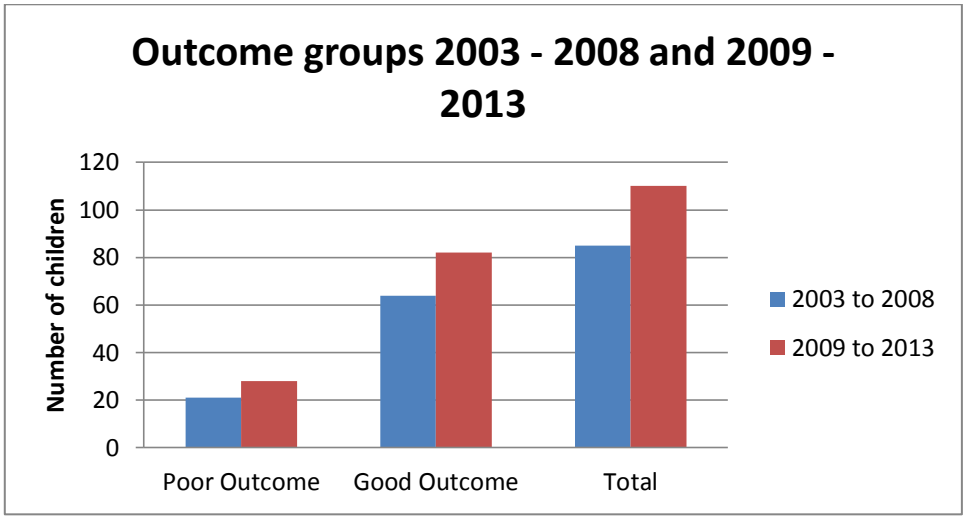


Figure 4.5: Bar chart showing the outcome between 2003 to 2008 and 2009 to 2013

4.8 Summary of univariate analysis

Table 4.14 provides a summary of the variables found by univariate analysis (fisher's Exact test) to be significantly associated with outcome.

Table 4.14: Summary of the variables that show significant association with poor outcome using Fisher's Exact test (95%CI).

Variable with a significant association with poor outcome	**Limit**
Temperature	≤34 °C
Cardiac arrest in first 12 hours	Yes
PRISM	≤25 ≥85
GCS	≤6
pH	≤7.1
Bicarbonate	≤16 *mmol/L*
Creatinine	>75 *µmol/L*
Glucose	≥22*mmol/L*
Platelets	≤200 *cells x* 10^9*/L*
Potassium	≤ 3*mmol/L*
Sodium	≥148*mmol/L*
Urea	≥6*mmol/L*
Systolic BP	≤45 *mmHg*
Heart Rate	≥190 beats per minute
Respiratory rate	≤15 breaths pm

4.9 Multivariate Analysis

A forward stepwise discriminant analysis was performed on the variables using Wilk's Lamba values. PRISM scores were excluded as they were calculated by including many of the variables and so might skew the results. Six variables were shown to found to have a significant Wilk's Lamba value (Table 4.15). These were GCS (≤6), sodium (*>148mmol/L),* platelets (<200cell x 10^9/L), WBC count (>15 *cells x* 10^9*/L), creatinine (*>75 *µmol/L), and pH (<7.1).* These variables contributed the most to the prediction of outcome group membership. The only one of these not

found to have a significant association with outcome from the previous univariate analysis was white blood cell count. The other variables included in the results of the forward stepwise discriminant analysis include bicarbonate (<16 *mmol/L), PCO2 (*>65 *mmHg),* temperature *(*≤34 °Celsius), urea (>6*mmol/L), haemoglobin (*>14 *gm/dL), and PaO2 (*<42 *mmHg).*

Table 4.15: Table showing the forward stepwise discriminant analysis (multivariate) summary using Wilks' Lamba distribution

Variable	Wilks' Lamba	Partial	F-remove	p-value	Toler.	1-Toler.
GCS ≤6	0.492	0.837	16.824	**0.000**	0.758	0.241
Sodium *>148mmol/L*	0.46	0.881	11.777	**0.000**	0.923	0.077
Platelet <200cell x 10^9/L	0.496	0.831	17.704	**0.000**	0.755	0.245
WBC >15 *cells x* 10^9*/L*	0.443	0.932	6.317	**0.013**	0.775	0.225
Creatinine >75 *µmol/L*	0.464	0.888	10.934	**0.001**	0.662	0.337
Bicarbonate >20 *mmol/L*	0.426	0.967	2.936	0.090	0.737	0.262
Ph <7.1	0.452	0.912	8.329	**0.005**	0.390	0.609
PCO2 >65 *mmHg*	0.430	0.960	3.598	0.061	0.557	0.443
Temperature ≤34 °C	0.419	0.984	1.452	0.231	0.788	0.211
Urea >6*mmol/L*	0.427	0.965	3.086	0.082	0.669	0.331
Haemoglobin >14 *gm/dL*	0.420	0.981	1.638	0.203	0.735	0.264
PaO2 <42 *mmHg*	0.417	0.988	1.040	0.310	0.797	0.202

(Wilk's Lambda=0.41253, approx. F (12.87) = 10.324, p<0.000). Grouping: good and poor outcomes. Significant p values are shown in red)

4.11 Conclusion

In conclusion, there were a total of 204 records of children who had drowned between the years 2003 to 2013 and were admitted to the PICU analysed by this study. One hundred and forty six (76%) children had a good neurological outcome, however of the total population, 21 children (10.3%) died and 14.7% (n=28) were discharged from PICU with a poor neurological outcome. There were twice as many boys as girls in the study population and the majority of the children were under the age of 36 months. Season did not significant affect outcome and it was found that the outcome in the first half of the study was similar to the second half. Numerous recorded variables, such as a low GCS score, high sodium levels and a low platelet count, were found to be significantly associated with outcome. In the multivariate analysis only six of theses (GCS less than three, sodium greater than 148*mmol/L*, platelet count of less than 200*cells x* 10^9*/L*, white blood cell count of more than 15*cells x* 10^9*/L*, creatinine more than 75 *µmol/L* and a pH of less than 7.1) were found to be significant.

CHAPTER 5: Discussion

Drowning is a significant but preventable public health problem however, there are only a few studies looking at morbidity and mortality rates from paediatric intensive care units in South Africa.

5.1 Population description

This study determined that there were 215 children admitted due to drowning into one Johannesburg's private hospital PICU over a period of eleven years (2003 to 2013). This is a rate of 19.55 children who drowned per year. Other South Africa studies, all based at Cape Town's Red Cross Children's Hospital, showed rates of between 9.7 and 12.5 drownings admitted per year however due to differing inclusion criteria and management strategies, direct comparisons cannot be made. (Nagel, Kibel and Beatty, 1990). The data shows that over half (63.7%, n=130) of the cohort were transferred from other hospitals. In those patients that were transferred from other hospitals, 71.7% were classified as having a good outcome on discharge from the unit. There were 74 patients admitted directly into the hospital and of these, 80.2% (n=57) had a good outcome. This means that the patients admitted directly into the unit had a slightly higher rate of good outcome compared to those transferred from another hospital. Nagel, Kibel and Beatty (1990) found that the patients referred from another hospital had nearly three and a half times greater risk of poor outcome and they postulated that only the very severe cases were transferred which would then increase the chance of a poor outcome.

5.2 Age

This study showed similar findings to the WHO (2014) report, and many other in-hospital based studies, that the largest group of children affected by drowning is the one to four year age group (Wallis, Watt, Franklin, *et al.*, 2012; Joanknecht, Argent, van Dijk, *et al.,* 2015; Quan, Wentz, Gore, *et al.*, 1990; Kibel, Nagel, Myers, *et al.*, 1990). Of the current study's population, 76.5% were three years of age and younger. Children of this age are mobile but unaware of potential hazards or dangers in their environment. Often the caregiver is also unaware of the danger posed by open bodies of water, such as swimming pools, and fails to maintain the proper supervision necessary to prevent accidents from occurring. Swimming pools are often not fenced in and safely precautions, such as pool nets and pool alarms, are not installed. Developmentally, toddlers may also use buckets to pull to stand and, as discussed in Chapter 2, can fall in head first due to their high centre of gravity (Burford *et al.,* 2005). While not as common, drowning in this age group could also be due to non-accidental injury and each case should be investigated, for neglect and for physical abuse.

There was no significant association found between outcome and age which was similarly found in a number of other studies (Nagel, Kibel and Beatty, 1990; Quan, Wentz, Gore, *et al.*, 1990; Graf, Cummings, Quan, *et al.*, 1995; Christensen, Jansen and Perkin, 1997). While the age of the child does not impact discharge outcome, it may be an important factor in the long term neurological outcome of the drowning victim. The opposing brain plasticity versus vulnerability theories are pertinent when considering the long-term outcome of drowning victims. As found in many other

studies, and indeed in this study, the majority of children that drown fall under the five year age group (Wallis, Watt, Franklin, *et al.*, 2012; Joanknecht, Argent, van Dijk, *et al.,* 2015; Quan, Wentz, Gore, *et al.*, 1990; Kibel, Nagel, Myers, *et al.*, 1990). Drowning causes hypoxic ischaemic brain injury which is a diffuse cerebral pathology. If brain vulnerability theorists are correct, then, due to these factors, children who have drowned are at high risk of long-term neurocognitive sequelae. Further long-term follow-up studies are needed to investigate these ideas.

5.3 Gender

Males are twice as likely to drown as females and a review of the literature shows that males make up about 70% of children who drown (Gonzalez-Luis, Pons, Cambra, *et al.,* 2001). In this study, there were predominantly more males than females (ratio 2.6:1). However, there was no significant association between male gender and poor outcome in this study. The majority of studies found similar results (Christensen, Jansen and Perkin, 1997; Nagel, Kibel and Beatty, 1990). One study however, Graf, Cummings, Quan, *et al.*, (1995) found a strong association between male sex and poor outcome. They, however, questioned this result as it did not compare to the majority of other studies and postulated that males may have worse outcomes post drowning in their study due to a number of factors such as they "sustain greater injuries, are more susceptible to hypoxia, are less responsive to treatment or may receive less beneficial treatment" (Graf, Cummings, Quan, *et al.*, 1995).

It is interesting to note that research on childhood injuries has found that boys have a higher rate of injuries when compared to girls (Pretorius and van Niekerk, 2014). A study looking at the South African National Injury Mortality Surveillance System determined that the majority of childhood injuries (65.6%) occur in boys (Pretorius and van Niekerk, 2014). This may be due to a tendency of boys to be more physical and act more impulsively than girls. Girls may also be viewed as less robust than boys and be more carefully monitored. This may explain the higher number of boys being involved in drowning incidents than girls.

5.4 Outcome

Existing research into outcomes post drowning shows a wide range of survival rates of between ten to 86% (DeBoer, 1997; Macnab, 1995; Habib, Tecklenburg, Webb, *et al.*, 1996; Pearn, *et al.,* 1979). This wide range may be due to a large number of factors inherent in each study such as cohort definitions, environment, bystander CPR, availability of advanced paediatric life care support, hospital resources and treatment techniques, thus making it difficult to compare studies. In this study, over 71 percent (71.6%, n= 146) were discharged from PICU neurologically intact post drowning. The mortality rate of the study was 10.3%. In the literature, studies show that there is a variable mortality rate of between five and 73% (DeBoer, 1997; Macnab, 1995; Habib, Tecklenburg, Webb, *et al.*, 1996; Pearn, *et al.,* 1979).

A quarter of this study cohort was found to have a poor outcome (24%, n=49). Of these, 28 were found to have some degree of neurological impairment. When

compared to the total study population, this 13.7%. Other studies have found a range from five to 25% in children who have drowned. A recent South African study from Cape Town's Red Cross Children's hospital showed an 84% intact neurological survival rate and only a 5.3% rate of neurological impairment (Joanknecht, Argent, van Dijk, *et al.,* 2015). This differs from the current study (the survival rate is lower and the neurological impairment rate is higher) but no direct comparisons can be made as the differences may be due to the study inclusion criteria, different methods used across studies to determine neurological impairment, the interventions used, and the type of patient that is accepted for admission into the hospital.

5.5 Predictors of outcome

There is no one single, nor any multiple group of factors, that can specifically and accurately determine outcome in children post drowning. The complex interplay of environment, genetics, interventions and resources which impact on the final outcome result in a different set of factors being significant in different settings. In this study 15 factors were identified that were associated with outcome.

Genetics has recently become the focus point of much new research with regards to outcome after injury or illness. Patients with similar injuries/diseases and medical management show varying outcome results and it has been shown that genes such as tumour necrosis factor (TNF-α) and interleukins (IL-1β and IL-6) have a role in outcome of patients with neurotrauma and acute lung disease (Dardiotis, Grigoriadis, and Hadijgeorgious, 2012; Giannoudis, van Griensven, Tsiridis, *et al.,* 2007). This

has not been studied further in drowning victims but it should be considered when discussing outcome factors and future areas of research.

Some studies suggest that up to 40 percent of comatose patients in the ER can have a normal outcome but on arrival in PICU, coma has been found to significantly increase the risk of poor outcome (Habib, Tecklenburg, Webb, *et al.*, 1996). Duration and severity of a drowning event causes an increased risk of hypoxic ischaemic brain injury (Topjian, Berg, Bierans, *et al.,* 2012). Therefore patients with more severe drowning events would have poor neurologic signs such as low GCS scores (Nagel, Kibel and Beatty, 1990; Graf, Cummings, Quan, *et al.*, 1995). This was similarly found in this study population as children with a GCS of six or less had over 43 times greater risk of poor outcome than those with a higher score however with wide a confidence interval (RR= 43.72, 95% CI 6.15 to 310.42). By using multivariate analysis, GCS was found to be the one of the variables that contribute most to outcome prediction. In a thirty month follow-up study of children with TBI's, severity of injury was measured by GCS scores and it was found low scores were related to poor recovery and poor long-term outcome (Anderson, Morse and Catroppa, 2004).

In this study, patients who had cardiac arrest before or after admission to PICU were significantly more likely to die or have neurological sequelae. In a South Carolina study, haemodynamic status on arrival to the ER was highly predictive of outcome (Habib, Tecklenburg, Webb, *et al.*, 1996).Those patients who were asystolic in the ER had a significantly worse outcome.

Quan, Wentz, Gore, *et al.* (1990) showed an increased number of children with a poor neurological outcome (but not mortality) in the second half of their study when compare to the first. They postulated that this may be due to a “tendency to prolong resuscitation efforts”. However, Kieboom, Verkade, Burgerhof, *et al.* (2015) reported no change in treatment outcomes between the first five years and last five years. According Spack, Gediet, Splaingard *et al.*, (1997) aggressive PICU protocols have been shown to have no positive effect on outcome in many studies. This study showed no increased risk for poor outcome between the first six years and the last five years of the study period. The unit implemented the same treatment protocol throughout the treatment period (including therapeutic hypothermia and ICP monitoring) so the results should not reflect any change in treatment. It might be postulated that there would be an increase in nursing and therapy staff knowledge about the treatment of these patients during this time, but as the results show this is not true as there was no significance difference in the outcome between the two halves of the study.

High blood glucose was also shown to be a significant indicator of outcome in this study. This study showed a 3.16 times increased risk of poor outcome if blood glucose was more than 22*mmol/L.* In Graf, Cummings, Quan, *et al.* (1995) high initial blood glucose was a strong indicator of poor outcome. In children with head injuries, blood glucose is an important prognostic factor (Chiaretti, De Benedict, Langer *et al.,* 1998). Hyperglycaemia occurs as a normal stress response. In adults with TBI, it has been shown that hyperglycaemia increases toxic metabolites which when worsen the

ischaemic damage to the brain through cerebral lactic acidosis (Chiaretti, De Benedict, Langer *et al.,* 1998).

High blood urea nitrogen levels were found to have a significant effect on outcome (Linder, Funk, Schwarz, *et al.,* 2007). Blood urea concentrations may be elevated due to decreased blood flow to the kidneys which can be caused by shock, stress, or myocardial infarction. It is likely that those patients who have a serious drowning incident and require vigorous resuscitation will go into shock which may explain this study's findings of significantly increased urea levels.

The Pediatric Risk of Mortality (PRISM, version III) was developed to predict ICU survival or mortality and it derives mortality risk from the amount and extent of observed physiological dysfunction (Zuckerman, Gregory and Santos-Damiani, 1998). Studies show it can be used for children who have drowned (Gonzalez-Luis, Pons, Cambra, *et al.,* 2001). Spack, Gedeit, Splaingard, *et al.* (1997) concluded that a PRISM score above 20 was an indicator of poor prognosis. In this study PRISM score below 25 and above 85 were shown to be significantly associated with outcome. With just a four percent chance of poor outcome with a score of equal or less than 25 but a 9.23 times risk of poor outcome when given a score of more than or equal to 85, PRISM provides a good indicator of the outcome in this cohort. Caution must be taken when analysing the PRISM score as nine of the 45 children who had a PRISM score over 80 (which would predict a poor outcome), survived neurologically intact while two of the children with a score of less than 25 were discharged with a poor outcome. Again the interplay of the many complex factors

that occur in children who have drowned are relevant. There is no tool that is specific and accurate enough to determine which children may have a poor outcome and so it is important to give every child a chance at survival with aggressive treatment, no matter what their PRISM score.

Previous research has shown that patients arriving at the ER with hypothermia usually have worse outcomes (Graf, Cummings, Quan, *et al.*, 1995) while others show no association between temperature and outcome (Quan, Wentz, Gore, *et al.*, 1990; Christensen, Jansen and Perkin, 1997). This may be due to two different factors: either the temperature of the water in which submersion occurred was very low, thereby quickly cooling the patient, even if time submerged was short. Secondly, the water temperature was temperate and so it would be necessary for the patient to be submerged for a long period of time to have become hypothermic. Most incidents of drowning occur in summer and in this study cohort, nearly 50% of the drowning events happened in the summer months of November to February. Studies have produced conflicting results as to whether winter drowning increases the chance of having a good outcome. In Kieboom, Verkade, Burgerhof, *et al.* (2015) season was strongly indicative of outcome, with those children who drowned in winter having a better outcome due to quick cooling in icy waters. In this study, the season or time of year (and therefore water temperature) the child drowned has no significant association with poor outcome. However hypothermia was a strongly significant indicator of poor outcome. This may be due to Johannesburg's temperate climate. Winter temperatures seldom go below 0°C, so submersion in icy-cold water is unusual (Nagel, Kibel and Beatty, 1990). Studies suggest that good outcome is unlikely if submerged in waters warmer than six degrees Celsius for more than 30

minutes (Tipton and Golden, 2011). Therefore, in South Africa, to become hypothermic, a patient must have been submerged for a prolonged period of time (Quan, Wentz, Gore, *et al.*, 1990; Joanknecht, Argent, van Dijk, *et al.,* 2015). Increased time submerged is an indicator of poor outcome (Burford *et al.,* 2005; Kieboom, Verkade, Burgerhof, *et al.*, 2015).

When a multivariate stepwise discriminant analysis was performed, 12 of the variables were found to contribute to the prediction of outcome of the children (Table 4.14). Half of these were found to be significant and included GCS (<=6), sodium (*>148mmol/L),* platelets (<200cell x 10^9/L), WBC count (>15 *cells x* 10^9*/L), creatinine (*>75 *µmol/L),* and pH (<7.1). Hasper, von Haehling, Storm, *et al.* (2009) reports after cardiac arrest (and with it, consequences of "global ischemia perfusion"), patients with poor outcomes tend to have high creatinine levels within the first 24 hours after an arrest. In this study, high levels of creatinine were found to be a predictor of outcome. Future research should maybe look into this relationship between creatinine levels and cardiac arrest in this cohort further.

This study showed that low platelet levels are significantly associated with outcome in both univariate and multivariate analysis. Thrombocytopenia is commonly found in the ICU patient and can be due to numerous causes such as platelet consumption, destruction, production and sequestration (Greinacher, and Selleng, 2010). Most probable cause of thrombocytopenia in the drowning patient in the first 12 hours would haemodilution due to infusion of fluids. Studies frequently show that a low platelet count is often associated with increased length of stay on hospital, and

increased risk of morbidity and mortality (Greinacher, and Selleng, 2010). Interestingly, Mallet (2012) found that thrombocytopenia can result from accidental hypothermia. As discussed above, for South African patients to be hypothermic in the PICU, they had to undergo a prolonged submersion so this may be another factor to consider for the cause of thrombocytopenia.

One of the primary issues associated with drowning, is pulmonary related complications (Burford *et al.,* 2005). All acid-base/blood gas parameters (PaO2, PCO2, and pH) showed significant differences in the medians between the good and poor outcome groups. However, only pH showed a significant difference with Fisher's exact test and was found to significantly contribute to the prediction of outcome with multivariate analysis. Bronchospasm, aspiration and atelectasis will lead to progressive hypoxia and acidosis which will lead to a worse prognosis (Zuckerman and Saladino, 2005). The current study showed that there was a significant risk of poor outcome when bicarbonate was lower than 16*mmol/l* and when there was an acidosis present (pH of less than seven). During the drowning even, breath holding, laryngospasm and aspiration cause hypoxia and resulting mixed respiratory-metabolic acidosis. If there is hypothermia present, this will cause further hypoventilation, increasing the hypoxia. Studies show that on arrival to the ER, nearly 70% of all drowning patients present with an acidosis and often show a combined respiratory and metabolic acidosis caused by hypercapnia and anaerobic metabolism (Szpilman, Bierans, Handley, *et al*., 2012). A pH of less than seven showed a significant association with poor outcome in this study. This is similar to previous research which shows severe acidosis to have a strong association with poor outcome (Joanknecht, Argent, van Dijk, *et al.,* 2015; Kieboom, Verkade,

Burgerhof, *et al.*, 2015). In Nagel, Kibel and Beatty (1990), patients with acidosis had a six times greater risk of poor outcome.

Hypernatremia and hypokalaemia were found to be significantly associated with poor outcome in this study, high sodium levels being one of the variables that contribute most to the prediction of outcome in multivariate analysis. Hypernatremia is commonly found in hospitalised patients and those in ICU and is often caused by inappropriate isotonic fluid therapy (Aiyagari, Deibert, Diringer, *et al*, 2006). Oehmichen, Hennig and Meissner (2008) showed that nearly 48% of drowning victims who died had decreased potassium levels. It has also been found that hypothermia may cause an intracellular shift of potassium, resulting in hypokalaemia (Schubert, 1995). Patients with high levels of sodium were also found to have a significantly worse outcome than those with levels below 148*mmol/l*. To maintain fluid status during resuscitation, a patient may be given sodium bicarbonate, which may affect the blood sodium levels (Aiyagari, Deibert, Diringer, *et al*, 2006). Hypernatremia may indicate those patients who experienced a drowning even that was more severe or prolonged than others as they required more intensive resuscitation. Another cause of hypernatremia is the normal saline used to dilute parenteral drugs and to maintain patent catheters in the ER and the ICU (Choo, Groeneveldt, Driessan, *et al.*, 2014). Previous studies have found that hypernatremia is an independent risk factor for mortality in ICU but the underlying reason for this remains to be identified (Lindner, G., Funk, G., Schwarz, *et al.,* 2007).

A high white blood cell count was found, by multivariate analysis, to be a contributing factor in the outcome of this study population. According to Hildebrand, Pape and van Griensven (2005), an increased or exaggerated inflammatory response after trauma is a recognised physiological occurrence and this is what predisposed the patient to post traumatic complications and increases the chance of a poor outcome. The inflammatory system has been shown to alter within hours after trauma (Giannoudis, van Griensven, Tsiridis, *et al.,* 2007).This inflammatory response is governed by certain genes responsible for the inflammatory cascade. This is only recently being researched and there are still many unidentified genes that could play a role in this response.

5.6 Study Limitations and future research opportunities

This study had the limitations inherent in any retrospective record review, such as incomplete or missing records, observer bias in outcome reporting and inaccurate recording. The limits imposed on each of the variables were focussed on a certain age range and as such may have overestimated or under estimated the number of patients in outcome groups. In future studies, it may be beneficial to stratify according to age group and then classify into groups. The PICUE program only records physiological variables in the first 12 hours after admission and discharge outcome. It does not record environmental factors (such as temperature of what), drowning incident factors (how long the child was submerged for, how long CPR lasted) and it does not record the therapeutic interventions that the child was given during the hospital stay (such as physiotherapy or speech therapy). These factors

are have all been shown to be important as outcome measures and a future prospective study could look at these factors in this unit.

The patient's outcome was recorded at discharge by the discharging doctor using the POPC. While this measure classifies the outcome into six different categories, it is lacking in detail and the patients should have a long term follow-up to determine their true neurological outcome. As discussed previously, brain vulnerability puts these children at high risk for long-term impairments. An area of future research on this study population could investigate the neurological, motor, and behavioural outcomes of the children that survived drowning using a comprehensive neurodevelopmental assessment tool. No formal assessment tool for children who have drowned is available which limits the impact these studies have when comparing populations It would be interesting to see if those discharged with a POPC of one (no neurological impairments) had any long-term repercussions from their drowning such as attention deficit hyperactivity disorder (ADHD), fine motor impairments or reading difficulties. Suominen and Vähätalo (2012) reviewed the literature and concluded that a gross neurological examination at discharge is insufficient to determine all the long term sequelae post drowning. This lack of long-term follow-up means that morbidity from the current study could have been underestimated.

The study records were obtained from a private hospital only and did not include data from government hospitals in the province. It would therefore include only those patients on a medical aid or very affluent families that could afford to pay upfront for

private medical care. However, it has also been reported that aggressive treatment techniques (such as would be available in a private hospital due to increased resources) may have no impact outcome (Spack, Gedeit, Splaingard, *et al.,* 1997). However, further research could expand the record review to nearby hospitals in the province and compare the results between private and government facilities as well as treatment protocols. As this was a PICU hospital based study, patients who died while being transported to the hospital and in the ER were not included in the mortality rate. The *PICUE* programme does not include those children who died less than two hours after admission into the PICU so again, mortality rates may be higher than recorded. A further limitation is that the full intervention received by the patient (such as physiotherapy) is not recorded in the *PICUE* database. These interventions may have an impact on the outcome of these patients and future research should look into this further.

The children who drown and survive with neurologic impairment, present a huge financial, emotional and personal cost to the child's family and an increased social and medical burden (Christensen, Jansen and Perkin, 1997).These factors were not investigated in this study and should be included in any future research into this population. It may confront the ethical question as to the limits of resuscitation interventions.

CHAPTER 6: Conclusion

The main conclusions that can be drawn from this study, are that this cohort from a Johannesburg private hospital PICU closely resemble worldwide norms. There were a total of 215 children admitted due to drowning between 2003 to 2013 with 71.6% children (n= 146) discharged from PICU neurologically intact. Poor outcome, either death or neurological impairment, occurred in 49.24% of the population. This study showed similar findings to the WHO (2014) report, and many other in-hospital based studies, that the largest group of children affected by drowning is the one to four year age group and there were predominantly more males than females (ratio 2.6:1). In agreement with previous research, age, sex, and time of year have no significant impact on neurological outcome. Of the physiological variables analysed, 15 showed significate associations with outcome. When a multivariate analysis was utilised, low GCS scores, hypernatremia, and low pH levels as well as high white blood cell count were found to be significant predictors of outcome. Low platelets and high creatinine levels were also found to have a significant to outcome which has not been reported in previous hospital based studies.

Due to the localised nature of the study, the clinical significance is mainly to the unit in which the study was completed. The variables that have a show a relationship with outcome can be re-examine with new patients. The PRISM score, which is currently being used, has been shown to have a significant relationship with outcome however it is not completely accurate and some misclassification of children can result. A more sensitive tool still needs to be developed. Future research should include a

long-term follow-up on the children discharged from the unit with thorough neurological, motor and cognitive assessment.

No one factor could predict, with acceptable accuracy, the outcome of all patients. There is a complex interplay of many factors and so all drowning victims should receive aggressive resuscitation and treatment on arrival at the ER, regardless of previous history or current presentation. However, preventing drowning is the first step. Similarly to other studies form around the world, this study showed the age group at highest risk of drowning in children is the one to four years. Thus, extensive public health education to prevent drowning (such as bystander CPR, education about supervision of children around bodies of water and the importance barriers around swimming pools) should be aimed, especially in the summer months, when there is an increase in the incidences of children being admitted due to drowning.

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APPEDIX A: Ethics Clearance Certificate



R14/49 Ms Tamsen Peta Edwards

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M131038

NAME: (Principal Investigator)	Ms Tamsen Peta Edwards
DEPARTMENT:	Paediatrics [redacted]
PROJECT TITLE:	Childhood Drowning: Morbidity and Mortality from a Johannesburg Paediatric ICU, 2003 to 2013 (Revised Title 04/07/2014)
DATE CONSIDERED:	25/10/2013
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Dr Joanne Potterton
APPROVED BY:	Professor PE Cleaton-Jones, Chairperson, HREC (Medical)
DATE OF APPROVAL:	25/10/2013

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Secretary in Room 10004, 10th floor, Senate House, University.
I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit the application to the Committee. **I agree to submit a yearly progress report**

Principal Investigator Signature Date

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

***Hospital's name blocked out to ensure anonymity**

APPEDIX B: Institution Approval of Research

RESEARCH OPERATIONAL COMMITTEE FINAL APPROVAL OF RESEARCH

Approval number: UNIV-2014-0034

Ms TP Edwards

E mail: edwardstp@gmail.com

Dear Ms Edwards

RE: CHILDHOOD DROWNING: MORBIDITY AND MORTALITY FROM A JOHANNESBURG PAEDIATRIC ICU, 2003 TO 2013

The above-mentioned research was reviewed by the Research Operational Committee's delegated members and it is with pleasure that we inform you that your application to conduct this research at Private Hospital, has been approved, subject to the following:

i) Research may now commence with this FINAL APPROVAL from the Committee.

ii) All information with regards to Company will be treated as confidential.

iii) Company's name will not be mentioned without written consent from the Committee.

iv) All legal requirements with regards to patient rights and confidentiality will be complied with.

v) Insurance will be provided and maintained for the duration of the research. This cover provided to the researcher must also protect both the staff and the hospital facility from potential liability

vi) In accordance with MCC approval, that medicine will be administered by or under direction of the authorised Trialist

vii) The research will be conducted in compliance with the GUIDELINES FOR GOOD PRACTICE IN THE CONDUCT OF CLINICAL TRIALS IN HUMAN PARTICIPANTS IN SOUTH AFRICA (2000)

viii) Company must be furnished with a STATUS REPORT on the progress of the study at least annually on 30th September irrespective of the date of approval from as well as a FINAL REPORT with reference to intention to publish and probable journals for publication, on completion of the study.

ix) A copy of the research report will be provided to Company once it is finally approved by the tertiary institution, or once complete.

x) Company has the right to implement any Best Practice recommendations from the research.

xi) Company reserves the right to withdraw the approval for research at any time during the process, should the research prove to be detrimental to the subjects/Netcare or should the researcher not comply with the conditions of approval.

xii) APPROVAL IS VALID FOR A PERIOD OF 36 MONTHS FROM DATE OF THIS LETTER.

We wish you success in your research.

Yours faithfully

1/9/2014

Prof Dirk du Plessis
Full member: Research Operational Committee & Medical Practitioner evaluating research applications as per Company Policy

Shannon Nell
Chairperson: Research Operational Committee
Date: 23/9/2014

This letter has been anonymised to ensure confidentiality in the research report. The original letter is available with author of research

APPENDIX C: Unit's Intensivist's approval of research

8 September 2013

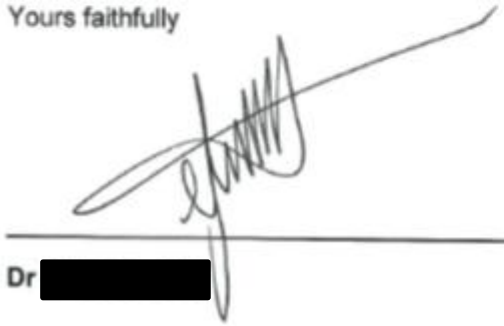
To: University of the Witwatersrand: Protocol and Ethics Committee

RESEARCH TO BE CONDUCTED IN [redacted]

Factors predicting morbidity in childhood drowning - Tamsen Edwards

I, Dr [redacted] the intensivist in charge of [redacted] Hospital's PICU, am aware that Tamsen Edwards will be conducting a retrospective record review of children admitted to the unit due to drowning and will also allow her access to my PRISM records of these children. In principle, I do not have any reservations for the abovementioned research to be conducted subject [redacted] group's research committee approval and to unconditional ethics approval being granted.

Yours faithfully



Dr [redacted]

18/09/13

Date

***Hospital's name blocked out to ensure anonymity**

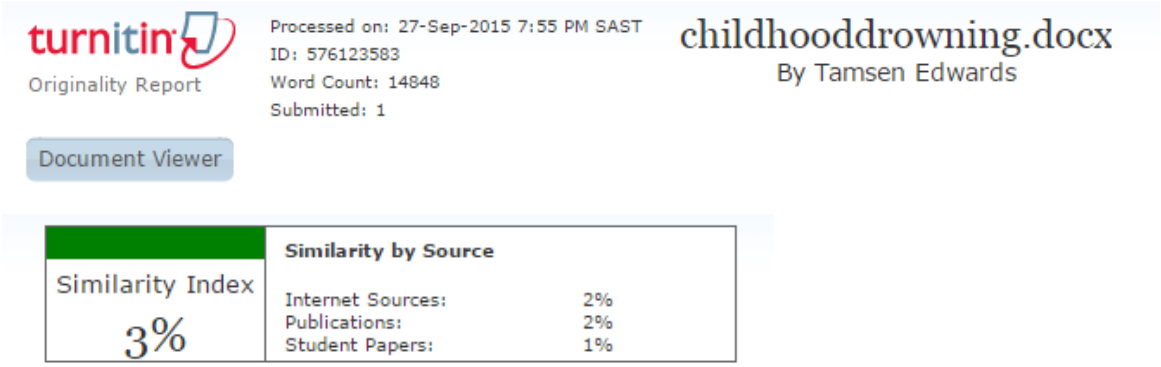
APPENDIX D: Data Collection Sheet

Data Collection Sheet **Study Number:_____**

Sex:		**Weight:**		
Date of birth:				
Date of drowning:				
Date of admission:				
Date of discharge from PICU:				
Cardiac arrest:	Yes: □	No: □		
Transferred from another hospital:	Yes: □	No: □		
No. of days on ventilator:				
No. of days ICP monitoring:				
Highest ICP value:				
POPC score on discharge:				
PRISM score:				
Result:	D/C Home: □	D/C Rehab: □	Died: □	

System	Parameter	Highest reading	Lowest reading
Cardio-respiratory	Systolic Blood Pressure		
	Diastolic Blood Pressure		
	Heart Rate		
	Respiratory Rate		
	Temperature		
Neurological vital signs	GCS		
	Pupillary Reflexes		
Acid-Base/Blood Gases	pH		
	PaO2		
	PaCO2		
Chemistry and Haematology	Glucose		
	Sodium (Na)		
	Potassium (K)		
	Bicarbonate		
	Creatinine		
	Blood Urea Nitrogen		
	White Blood Cell Count		
	Platelet count		
	Haemoglobin		

APPENDIX E: Turnitin Plagiarism Report



Turnitin Originality Report
childhooddrowning.docx by Tamsen Edwards
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Ellen H. Koo. "Cortical Blindness Following a Near-Drowning Incident :", Journal of Neuro-Ophthalmology, 12/2011

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Submitted to University Of Tasmania on 2014-02-14

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Christine M. Branche. "The Epidemiology of Drowning", Handbook on Drowning, 2006

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M. M. Pierro. "Anoxic brain injury following near-drowning in children. Rehabilitation outcome: Three case reports", Brain Injury, 12/1/2005

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Richards, David B., and Andrew L. Knaut. "Drowning", Rosen s Emergency Medicine â€“ Concepts and Clinical Practice, 2010.

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Amy E. Burford. "Drowning and Near-Drowning in Children and Adolescents", Pediatric Emergency Care, 09/2005

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Zuckerbraun, N.S.. "Pediatric Drowning: Current Management Strategies for Immediate Care", Clinical Pediatric Emergency Medicine, 200503

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Simon Fleminger. "Head Injury", Lishman s Organic Psychiatry, 07/31/2009

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