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ORIGINAL RESEARCH

Impact of lifeguard oxygen therapy on the resuscitation of drowning victims: Results from an Utstein Style for Drowning Study

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Abstract

Introduction: No published evidence was identified regarding the use of oxygen in the treatment of drowning in two recent systematic reviews. The aim of our study was to investigate the impact of on scene, pre-Emergency Medical Services (EMS) oxygen therapy by lifeguards in the resuscitation of drowning victims.

Method: We conducted a retrospective case match analysis of drowning patients presenting to the EDs of Sunshine Coast Hospital and Health Service. Patients were matched for age, sex and severity of drowning injury. The primary outcome was in-hospital mortality. Secondary outcomes included positive pressure ventilation (PPV) by EMS and the ED, as well as admission to the Intensive Care Unit.

Results: There were 108 patients in each group. Median (IQR) age was 22 (15–43) in the oxygen group and 23 (15–44) years in the non-oxygen group. There were 45 females in the oxygen group and 41 females in the non-oxygen group. Sixteen patients had suffered cardiac arrest and three patients respiratory arrest in each group. There were five deaths in each group. Initial oxygen saturation on arrival of EMS was identical in both groups 89.2% (±19.9) in the oxygen group *versus* 89.3% (±21.1) ($P = 0.294$) in the non-oxygen group. The oxygen group required PPV more frequently with EMS (19 *vs* 11, $P < 0.01$) and in the ED (19 *vs* 15, $P < 0.01$).

Conclusion: On scene treatment with oxygen by lifeguards did not improve oxygenation or outcomes in drowning patients.

Key words: *drowning, lifeguard, oxygen therapy, resuscitation.*

Key findings

- Lifeguard oxygen treatment did not improve oxygenation in drowning victims.
- Lifeguard oxygen treatment did not improve mortality in drowning victims.

Introduction

In 2023, there were 281 fatal drownings in Australia and 90 in New Zealand.[1,2] Estimated hospital in-patient admissions for drowning are in-excess of 1100 annually across the two countries[3] with another 4000 drowning presentations to the Emergency Department (ED) either admitted to the Short Stay Unit or discharged home from the ED.[4]

Australia has a proud history of leading drowning prevention efforts globally. The research and advocacy of dedicated individuals such as Professor John Pearn[5] as well as the efforts of Australia's largest volunteer organisation,[6] Surf Life Saving Australia (SLSA) and Royal Life Saving Society – Australia have seen Australia achieve a 26% reduction in drowning fatalities over the last 20 years.[2] Unfortunately, there has not been a similar reduction in New Zealand.[1] Globally, there are approximately 300 000 fatal drownings annually,[7] making drowning the third leading cause of unintentional traumatic death worldwide after falls and motor-vehicle accidents.[8]

Drowning is defined as the process of experiencing respiratory impairment as a result of submersion in liquid.[9] It leads to hypoxia which may result in injury to the central nervous system and other organs. However, drowning is more than a hypoxic insult. Lung damage may result from forceful ventilation against a larynx closed by laryngospasm and/or the aspiration of hypo/hypertonic fluid into the lungs.[10] This leads to disruption of the alveolar-capillary membrane, dilution of surfactant,

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collapse of alveoli and the development of alveolar oedema.[10]

Basic and advanced life support for drowning patients is centred around re-oxygenation of vital organs[11] and the absence of hypoxia whereas in the ED has been shown to improve outcomes in drowning.[12] However, neither a scoping review[13] nor two systematic reviews[14,15] published recently found any studies which specifically examined the use of oxygen in the treatment of drowning.

In recent years, the routine use of oxygen in clinical situations has been questioned.[16] In patients immediately post cardiac arrest, high arterial levels of oxygen (hyperoxia) may have deleterious effects on outcomes[17–20] although the evidence continues to be contradictory.[21] The mechanisms suggested to explain the toxicity of hyperoxia include the generation of reactive oxygen species, oxidative stress and local vasoconstriction.[22] A recent article has shown that both hypoxia and hyperoxia are associated with increased mortality in paediatric drowning patients admitted to a Paediatric Intensive Care Unit (ICU).[23] This reinforces the need to aim for oxygen levels within the normal range when resuscitating drowning patients. The aim of our study was to investigate the impact of on scene, pre-Emergency Medical Services (EMS) oxygen therapy by lifeguards in the resuscitation and treatment of drowning victims.

Method

This case match analysis utilised retrospective observational data collected on drowning patients presenting to the EDs of the Sunshine Coast Hospital and Health Service (SCHHS) between 1 January 2015 and 31 December 2022. The protocol for the data collection has been published previously[24] and is reported using STROBE guidelines.[25] Records from Surf Life Saving Queensland, Queensland Ambulance Service and SCHHS were accessed for patient data and an Utstein Style for Drowning[26] type database used for data entry.[24] Ethics approval to conduct the present study was obtained from Metro North Human Research and Ethics Committee (Project 49754) and James Cook University Human Research Ethics Committee (H8014), with an exemption from obtaining patient consent. The authors have received grants from the Emergency Medicine Foundation (EMLE-162R34-2020-THOM) and Wishlist Foundation (2020-05, ED treatment of the drowning victim) to conduct the present study. The funding bodies had no role in the design conduct or reporting of the present study.

The study was conducted on the Sunshine Coast, approximately 100 km north of Brisbane in Queensland, Australia. The region has a population of 393 039,[27] enjoys a subtropical climate with many popular surf beaches and receives approximately 13 million visitors each year.[28] Lifeguards patrol the beaches of the Sunshine Coast 365 days a year, most frequently between 07:30 and 17:00 hours. On weekdays and winter weekends, lifeguards are professional, employed by the Australian Lifeguard Service (ALS). On weekends and public holidays between mid-September and the end of April, lifeguards are volunteers from SLSQ. Lifeguards are also present at all public swimming pools on the Sunshine Coast. They are not typically present at private or hotel/resort swimming pools nor other bodies of water such as rivers and dams.

Lifeguards with Surf Life Saving Queensland (SLSQ) and the ALS can administer oxygen at either 8 L/min *via* Hudson mask or 15 L/min *via* bag-valve-mask ventilation.[29] The ALS and SLSQ are both integrated with the national body, SLSA. Oxygen therapy must be administered by lifeguards who have completed an additional SLSA module of training in advanced resuscitation techniques.[29] In this module, lifeguards are trained to recognise the clinical indications for oxygen therapy.[29] Perhaps because of initial reported difficulties with the use of pulse oximetry in patients post immersion[30] training in the use of pulse oximetry has only been recently introduced.

Cases that received lifeguard oxygen therapy were case matched by sex, age and severity of drowning, with cases that did not receive oxygen from lifeguards. The strongest predictor of outcome in drowning, duration of submersion was not used in the case-matching because of its limited availability ($n = 44$ non-oxygen group, $n = 40$ oxygen group) as well as clinically significant differences in methods of estimation for the same patient.[4] The severity of drowning was graded using the clinically orientated grading system described by Szpilman[31] (Table 1). This occurred retrospectively using data recorded at either the first point of contact with either EMS or the ED if not transported by EMS. A normal respiratory examination was defined as Grade 0. The primary outcome was survival to hospital discharge. Secondary outcomes included the need for positive pressure ventilation (PPV) and oxygen therapy by EMS, in the ED and In-Patient Units (IPU). They also included patient disposition from the ED. For the purposes of the present study, oxygen therapy was defined as supplemental oxygen delivered by nasal prongs, Hudson mask or non-rebreather mask, whereas PPV was defined as use of hi-flow

TABLE 1. *Classification of drowning severity*[31]

Severity of drowning	Clinical finding
Grade 0	Normal respiratory examination
Grade 1	Cough
Grade 2	Unilateral rales
Grade 3	Bilateral rales
Grade 4	Bilateral rales, arterial hypotension
Grade 5	Isolated respiratory arrest
Grade 6	Cardio-respiratory arrest

nasal prongs, continuous positive airway pressure ventilation, bi-level positive airway pressure ventilation, bag valve mask ventilation and mechanical ventilation.

Statistical analysis was conducted using IBM SPSS (version 27, Armonk, NY: IBM Corp). Descriptive statistics were presented using median and inter-quartile range (IQR) when data were not normally distributed. Normality was assessed using the Shapiro–Wilk test. Categorical variables were described using frequencies and percentages. Statistical significance was assumed with a $P < 0.05$. Independent samples *t*-tests were used to compare means, chi square to compare proportions, and binary logistic regression to look for variables independently associated with lifeguard oxygen. The model included all variables with a $P < 0.05$ on univariate analysis as well as sex, age and duration of drowning (Table 4). Multiple comparisons of the same data were approached using the Bonferroni correction.

Results

There were 577 drowning presentations to ED during the study period. One hundred and eight patients received lifeguard oxygen and were case matched with 108 that did not. The typical patient was male (60%), 22–23 years old, with a drowning duration of less than 5 min. All patients with Grade 6, Grade 5, Grade 1 and Grade 0 drowning severity were case matched with patients of identical severity. The case matching for Grades 2–4 was unable to obtain identical matches for all patients (Table 2).

There were five deaths in each group. Patients receiving lifeguard oxygen therapy also received oxygen therapy and PPV with EMS and in the ED, and were more frequently admitted to the ICU than patients who did not receive lifeguard oxygen therapy (see Table 3). Patients receiving oxygen were also more likely to have signs of respiratory distress (increased work of breathing, cyanosis) reported at the scene as well as increased respiratory rate. Oxygen saturation measured by EMS showed patients in both groups were typically hypoxic with no difference between groups (see Table 3). Diagnostic imaging was more likely to demonstrate pulmonary oedema in the group receiving oxygen and they were also more likely to have blood gas analysis performed. Blood gas analysis revealed metabolic acidosis in both groups with a significantly lower lactate in the oxygen group. On multivariate analysis, the requirement for PPV by EMS and elevated lactate levels in the ED were independently associated with lifeguard oxygen therapy.

Lifeguard oxygen therapy was independently associated with EMS oxygen therapy and EMS PPV. It was not associated with duration of submersion, ED oxygen or ventilation or patient disposition (Table 4).

All 32 patients suffering cardiac arrest received bystander CPR. There were no deaths in the 17 (53.1%) patients that experienced a return of spontaneous circulation (ROSC) prior to EMS arrival. Three of the 15 (20%) patients still in cardiac arrest on arrival of EMS never achieved ROSC and a further seven (46.7%) died after withdrawal of treatment in the hospital. Five (33%) patients in cardiac arrest on arrival of EMS survived.

The 15 patients in cardiac arrest at EMS arrival were attended to by critical care paramedics or doctor. All were intubated by EMS and received advanced cardiac life support protocols including use of adrenaline. Two had clear chest examinations. Median (IQR) pH was 6.69 (6.55–6.94) and lactate

TABLE 2. *Patient demographics*

Variable	Oxygen group (n = 108)	Non-oxygen group (n = 108)	P
Age (median, IQR)	22 (15–43)	23 (15–44)	0.85
Female sex (%)	45 (41.7)	41 (37.9)	0.31
Severity Grade 6	16 (14.8%)	16 (14.8%)	0.55
Severity Grade 5	3 (2.7%)	3 (2.7%)	0.84
Severity Grade 4	3 (2.7%)	1 (0.9%)	0.84
Severity Grade 3	20 (18.5%)	24 (22.2%)	0.48
Severity Grade 2	12 (11.1%)	10 (9.3%)	0.62
Severity Grade 1	19 (17.6%)	19 (17.6%)	0.48
Severity Grade 0	35 (32.4%)	35 (32.4%)	0.32
Duration of drowning (min) (median, IQR)	1 (1–2) (n = 40)	1 (1–2) (n = 44)	0.14
Salt water	93 (86.1%)	70 (64.8%)	<0.01
Pre-existing lung disease	6 (5.6%)	4 (3.7%)	0.77
EMS Transport	106 (98.1)	96 (88.9%)	<0.01

EMS, Emergency Medical Services.

TABLE 3. *Patient outcomes (univariate analysis)*

Outcome	Lifeguard oxygen group ($n = 108$)	Non-oxygen group ($n = 108$)	P value
Mortality (%)	5 (4.6)	5 (4.6)	1.00
EMS oxygen (%)	56 (51.9)	34 (31.5)	<0.01
ED oxygen (%)	19 (17.6)	15 (13.9)	<0.01
EMS PPV (%)	19 (17.6)	11 (10.2)	<0.01
ED PPV (%)	32 (29.6)	20 (18.5)	<0.01
Intubation	16 (14.8)	11 (10.2)	<0.01
Inpatient admission	45 (41.7)	31 (28.7)	<0.01
ICU admission (%)	26 (24.1)	15 (13.9)	0.09
IPU admission (%)	19 (17.6)	16 (14.8)	0.44
ED SSU admission (%)	23 (21.3)	32 (29.6)	0.99
LATC (%)	0 (0)	5 (4.6%)	0.13
Cyanosis (%)	22 (20.4)	13 (12.0)	0.053
IWOB (%)	68 (63.0)	45 (41.7)	0.002
EMS HR mean (SD)	105 (±29.6)	100 (±32.6)	0.277
EMS SBP mean (SD)	118 (±35.2)	116 (±33.1)	0.931
EMS RR mean (SD)	25 (±12.8)	22 (±11.3)	0.895
EMS SpO_2 mean (SD)	89.2 (±19.9)	89.3 (±21.1)	0.294
ED HR mean (SD)	97 (±23.7)	96 (±24.5)	0.281
ED SBP mean (SD)	117 (±25.5)	118 (±25.2)	0.898
ED RR mean (SD)	24 (±9.9)	22 (±10.0)	0.143
ED SpO_2 mean (SD)	94.0 (±14.9)	96.6 (±3.9)	0.135
Imaging-no oedema (%)	38 (35.2)	44 (40.7)	0.37
Unilateral oedema (%)	5 (4.6)	8 (7.4)	0.37
Bilateral oedema (%)	37 (34.2)	28 (25.9)	0.06
No imaging (%)	28 (25.9)	30 (27.8)	0.69
ED Blood Gas (%)	60 (55.6)	41 (38.0)	0.023
Lactate mean (SD)	5.88 (±5.33)	7.62 (±7.85)	0.03
pH mean (SD)	7.22 (±0.178)	7.19 (±0.279)	0.24
HCO_3^- mean (SD)	21.12 (±5.13)	19.86 (±5.86)	0.44
Base excess mean (SD)	−6.23 (±7.12)	−6.22 (±6.70)	0.99
Pre-existing heart disease (%)	7 (6.5)	3 (2.8)	0.57

ED, Emergency Department; EMS, Emergency Medical Services; HR, heart rate; ICU, Intensive Care Unit; IPU, In-Patient Unit; IWOB, increased work of breathing; LATC, left after treatment commenced; PPV, positive pressure ventilation; RR, respiratory rate; SBP, systolic blood pressure; SpO_2, peripheral oxygen saturation; SSU, Short Stay Unit.

16.15 (11.58–23.00) mmol/l on arrival in the ED. Of the 10 deaths, two (20%) had a shockable initial rhythm (VF), the others had asystole or pulseless electrical activity. Submersion duration was only known in 5 of the 10 deaths but was 10 min or above in 3 of those 5 cases.

Discussion

The primary outcome in the present study, survival to hospital discharge, did not differ between groups. The overall mortality rate of 4.6% is low compared to previous studies.[3,32] This likely reflects differences in patient populations as both studies utilised hospital inpatient admission datasets, rather than ED presentations.[3,32] Our mortality rate for patients admitted to hospital is slightly higher (10/76, 13.16% *vs* 1186/12 506, 9.5%) to a study from the United States[32] but lower than a previous Australian study

TABLE 4. *Binary logistic regression of independent associations with lifeguard oxygen therapy*

Variable	OR	95% CI	*P*-value
Sex	0.67	0.22–2.01	0.470
Age	1.00	0.97–1.02	0.662
Submersion duration	1.61	0.35–7.49	0.541
EMS oxygen	17.79	2.53–125.24	0.004
EMS PPV	25.19	2.56–248.20	0.006
ED oxygen	0.59	0.10–3.42	0.555
ED PPV	0.49	0.07–3.47	0.475
Lactate	0.97	0.89–1.06	0.500
Patient disposition	0.64	0.15–2.78	0.552

ED, Emergency Department; EMS, Emergency Medical Services; PPV, positive pressure ventilation.

which included fatalities not transported to hospital.[3] The survival rate (22/32, 68.8%) from drowning associated cardiac arrest is much higher than in previous studies[33,34] as was rate of bystander CPR (32/32, 100%).[35]

Both groups were equally hypoxic on arrival of EMS. This raises the question as to why lifeguard oxygen therapy was failing to achieve its primary objective, oxygenating the patient. Both groups had small numbers of patients with pre-existing medical conditions likely to affect oxygenation, and both groups were able to be oxygenated by EMS. Optional use of pulse oximetry by Surf Life Saving Clubs was introduced in the last year of the study,[29] which could have impacted the care of nine patients in the oxygen group. However, only four of this group were adequately oxygenated ($SpO_2 \geq 93\%$) at the time of EMS arrival. The inability to gauge the therapeutic effect of the oxygen without pulse oximetry is a potential explanation for the low pulse oximetry readings at the arrival of EMS and their subsequent improvement under the care of EMS. Clinical assessment of a patients' oxygenation without the use of pulse oximetry is difficult in the most controlled clinical situations,[36] let alone in a hostile environment such as a beach. Initial reports on the use of pulse oximetry in the management of drowning victims were not favourable[30] and this may have influenced the delayed introduction of pulse oximetry to surf lifesaving. We would argue that our findings provide clear evidence that any organisation providing oxygen therapy must also be able to monitor its therapeutic effect (or lack of) with pulse oximetry.

Other than the absence of pulse oximetry, another potential explanation for the failure to improve oxygen saturation lies in the pathophysiology of the lung injury in drowning.[10] In both fresh and salt-water drowning, supranormal hydrostatic pressures lead to disruption of the alveolar-capillary membrane, resulting in plasma entering the alveoli, dilution of surfactant and atelectasis.[10] This results in a localised clinical picture similar to adult respiratory distress syndrome (ARDS).[37,38] The benefit of positive end expiratory pressure (PEEP) in improving outcomes in ARDS[39] potentially suggests that oxygen therapy alone may be insufficient to improve on-scene oxygenation of drowning patients. The potential role of PEEP in improving the on-scene oxygenation of drowning patients should be explored in future studies.

The secondary outcomes appear to show an association between lifeguard oxygen therapy and increased numbers of patients on oxygen and ventilatory support. Although oxygen toxicity can lead to a ventilation perfusion mismatch secondary to pulmonary vasoconstriction,[40] the identical oxygen saturations of both groups on arrival at the ED would suggest this to be an unlikely mechanism. An alternative explanation is that the oxygen group were a sicker cohort, appropriately selected for oxygen therapy by lifeguards despite our matching for severity of drowning. We attempted to control for the severity of the drowning injury by matching patients using the system described by Szpilman.[31] There was a significantly higher proportion who received EMS assessment and care in the lifeguard oxygen group and thus had an earlier clinical assessment than the patients who self-presented to the ED. It is thus possible that the earlier clinical assessment introduced a selection bias towards a sicker cohort of patients because of resolution of clinical signs prior to assessment in the group that did not receive lifeguard oxygen.

The only variables independently associated with lifeguard use of oxygen were the need for oxygen and PPV by EMS. These findings support the hypothesis that lifeguards are correctly administering oxygen therapy to a sicker cohort of patients, not controlled for by our severity matching, although this may be influenced by a treatment bias with EMS, reluctant to discontinue oxygen therapy. Although the classification system for assessing drowning severity we used[31] is commonly referenced in the literature, it has only undergone one external validation study.[41] That study reported differing outcomes than the original for all grades of severity other than drowning-related cardiac arrest.[41] We also found no association between increasing severity of drowning injury as per Szpilman and the use of oxygen by lifeguards.

The classification system is based on the findings of the clinical examination, increasing in severity from isolated cough, unilateral rales, bilateral rales (with and without hypotension) and cardio-respiratory arrest.[31] Lung auscultation for rales has the advantages of allowing a rapid assessment and grading of the severity of injury of the drowning patient. However, the presence of lung rales has been found to be neither sensitive nor specific for the presence of lung oedema in heart failure[42] or in the assessment of Acute Respiratory Distress Syndrome.[37,38] The definition of ARDS, to which the lung injury of drowning is compared[10] does not utilise clinical examination findings of rales in the lungs.[43] Instead it utilises the degree of hypoxia (PaO2/FiO2), the severity of radiological findings and ventilatory parameters.[43] Perhaps it is time to review how we grade the severity of injury in drowning patients.

Limitations

This was a retrospective case match analysis. Our case matching was identical for the most severe grades and for the mildest grades of drowning injury. Despite a cohort of 577 patients, we were unable to obtain exact matches for patients with Grade 2–4 severity of injury. However, it is the only classification system for drowning derived from data on thousands of patients[31] and consequently was the most robust system to use.

The key factor in determining prognosis of drowning is the duration of submersion.[44] Unfortunately, there is clinically significant disagreement on measures of duration for the same patient[4] and it is poorly documented,[4] being unavailable for 61% of our patients (132/216). Including duration of submersion would have resulted in a sample size of 17 matched pairs. For this reason, we excluded duration of drowning from the case matching. However, the duration of drowning data that was available, was identical for both groups.

Lifeguard oxygen therapy is fortunately an uncommon event. SLSQ data shows oxygen was used an average of 180 times a year between 2017 and 2020 (inclusive). This includes patients requiring oxygen for medical needs as well as for drowning. SLSQ has over 150 patrolling locations, many of which are patrolled 365 days a year. Thus, on average, oxygen therapy is used 1.2 times per year per location indicating its rarity. This data does not include swimming pools, where it is likely even less common. The patrolling experience of SLSQ members administering the oxygen was also documented, with 3+ years of experience in 249/741 (33.6%) of cases. Although there are many doctors, nurses and paramedics who patrol with SLSQ, and there is compulsory annual renewal of training in delivering oxygen therapy, an average of 1.2 instances of oxygen therapy per location per year, likely indicate that oxygen was delivered by clinically inexperienced personnel. Again, this data does not include pool lifeguards.

We did not record the use or otherwise of pulse oximetry by lifeguards in patients enrolled in the present study. When data collection began, pulse oximetry was not used by either SLSQ or ALS and it is possible that pulse oximetry may have been used on 9 patients in the oxygen group and 11 patients in the non-oxygen group. However, mean SpO_2 on arrival of was 83.1% for the 9 patients in the oxygen group and 88.7% for the non-oxygen group. If pulse oximetry was used, it does not appear to have affected our results.

Conclusion

This is the first study examining the therapeutic benefit of oxygen in drowning patients. The use of lifeguard oxygen on drowning patients prior to the arrival of EMS does not appear to improve oxygenation. Understanding and rectifying the reasons for this is required in-order to improve outcomes. Mandatory use of pulse oximetry is recommended to guide oxygen therapy at the scene for all drowning patients.

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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