EMA Emergency Medicine Australasia

Emergency Medicine Australasia (2022) doi: 10.1111/1742-6723.14036

ORIGINAL RESEARCH

Cervical spine immobilisation is only required in drowning patients at high risk of axial loading of the spine

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Abstract

Objectives: Wave forced impacts are known to result in cervical spine injuries (CSI) and approximately 20% of drownings in Australia occur at the beach. The most common mechanism of injury in studies examining the frequency of CSI in drowning patients is shallow water diving. The aim of the present study was to determine what proportion of CSIs occurring in bodies of water experienced a concomitant drowning injury in a location where wave forced impacts are likely to be an additional risk factor.

Methods: Electronic medical records at the Sunshine Coast Hospital and Health Service EDs, Queensland Ambulance Service case records and Surf Life Saving Queensland data between 1 January 2015 and 21 April 2021 were manually linked. Outcomes recorded included victim demographics, scene information, hospital course and patient disposition.

Results: Ninety-one of 574 (15.9%) CSIs occurred in a body of water with risk of drowning. However, only 4 (4.3%) had a simultaneous drowning injury, representing 0.8% (4/483) of drowning presentations. Ten (10.9%) patients reported loss of consciousness, including the four with drowning. The principal mechanism of CSI was a wave forced impact (71/91, 78%). Most injuries occurred at the beach (79/91, 86.8%). Delayed presentation was common (28/91, 31%). A history of axial loading was 100% sensitive when indicating imaging.

Conclusions: The combination of CSI and drowning is uncommon. Cervical spine precautions are only required in drowning patients with signs or a history, or at high risk of, axial loading of the spine. This paper supports the move away from routine cervical spine precautions even in a high-risk population.

Key words: *cervical vertebrae injury, drowning, emergency medicine.*

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Accepted 3 June 2022

Key findings

- The combination of cervical spine injuries and drowning is uncommon.
- A history of axial loading is 100% sensitive for indicating imaging.
- Delayed presentation to the ED is common.

Introduction

Drowning is the third leading cause of traumatic death globally and can occur in any body of water, such as swimming pools, the ocean, rivers, lakes and dams.[1] Recently, there has been a move away from routine cervical spine immobilisation in drowning patients.[2] However, it is unclear if this is supported by evidence.

Although the potential consequences of shallow water diving have long been known,[3,4] there is evidence from the USA,[5–7] France,[8] the UK[9] and Mexico[10,11] that wave forced impacts can result in cervical spine injury (CSI). The wave forced impact causes a head-first collision with the ocean floor, resulting in an axial load down the cervical spine, a very high-risk mechanism (odds ratio [OR] 7.3, 95% confidence interval [CI] 5.1–10.4) for CSI.[12] In fact, cervical and spinal injuries at the beach are common, making up almost 20% of the injuries occurring within the surf zone.[8]

The prevalence of CSI in several cohorts of drowning patients has also been investigated.[13–17] Although these studies have all found a low prevalence of CSI in drowning patients, ranging from <1%[17] to 5%,[16] all of these studies were conducted in the USA and very few (5–10%) of these injuries occurred in natural bodies of water.[13,16] As a consequence, despite the potential for wave forced impact to cause CSI,[3–11] none of the patients in these studies were reported as being injured secondary to a wave forced impact.

In contrast to the USA, Australia has a strong beach going culture with 11 million people visiting the coast to wade, swim or surf in 2020, of which 3.9 million people did so frequently.[18] To put this into context, these numbers represent 43% and 15% of the national population respectively.[19] Australians are also much more likely to drown at the beach with over 20% of drowning fatalities occurring at the beach.[20] Given the frequent combination of mechanism and exposure in Australia as well as the lack of evidence supporting the change in practice away from routine cervical spine immobilisation in a high-risk population, we investigated the relationship between CSI and drowning in a population we hypothesised is at a higher risk than those previously studied.

Methods

This retrospective case series included all patients that presented to the EDs of the Sunshine Coast Hospital and Health Service (SCHHS) with diagnosed CSI that occurred in a body of water (such as an ocean, river, canal, lake or swimming pool) between 1 January 2015 and 21 April 2021. The present study received ethical approval from The Prince Charles Hospital Human Research and Ethics Committee (Project no: 49754) and James Cook University Human Research Ethics Committee (H8014).

The Sunshine Coast is located in South-East Queensland, approximately 100 km north of Brisbane, Australia, and the region has many popular surf beaches. In 2016, it had a population of 346 522.[19] The Sunshine Coast is a frequent destination for visitors with over 8.5 million overnight stays and over 4.5 million visitor day visits during the 2019/2020 financial year.[21] Until 2017, it was served by the EDs of Nambour General Hospital and Caloundra Hospital. In 2017, Sunshine Coast University Hospital became the tertiary referral centre for the Sunshine Coast and the ED at Caloundra Hospital closed.

Electronic medical records were searched using terms relevant to CSI and drowning (the search strategy is in Appendix S1). Data sources included SCHHS integrated electronic Medical Record and ED Information System as well as the Surf Life Saving Queensland (SLSQ) Lifesaving Incident Management System and Operations Console (LIMSOC) electronic databases. Queensland Ambulance Service (QAS) case record forms were accessed as part of the medical record or obtained directly from QAS when not included in the medical record. LIMSOC data were only available from September 2016 onwards. A list of the data collected is included in Appendix S2.

A wave forced impact was recorded as the mechanism of injury when the EMR or QAS records included phrases such as ‘dumped’, ‘tumbled’, ‘wiped out’ or ‘thrown’ by a wave. When the notes suggested a voluntary action, such as diving, the mechanism was recorded as shallow water diving. With regards to the activity undertaken at the time of the injury, surfing was defined as the use of a rigid or finned board that would preclude use in an area patrolled by lifeguards. Use of bodyboards (non-rigid foam boards without fins) was classified as swimming. This classification was used partly because the most common cause of injuries to surfers is the surfboard.[22–24] Subjects were classified as locals if their residential postcode was within one of the two local government areas (Sunshine Coast and Noosa) that form the Sunshine Coast.

Data were abstracted on a standardised case report form by two investigators (OT, KR) and entered into an Excel (Microsoft) spreadsheet. Abstractors were not blinded and a kappa was not calculated. Variables recorded included victim demographics, scene information including body of water (pool, beach and river), and activity being undertaken (swimming, surfing and other), pre-QAS scene information, time points and intervals from QAS data, hospital course and care provided to the patient.

Clinical and epidemiological features were recorded, including the imaging criteria for the National Emergency X-Radiography Utilization Study (NEXUS)[25] and the Canadian C-Spine Rule for Radiography Study.[26] Radiological reports were assessed for the number and location of cervical vertebral fractures and recorded as unstable if the report included the findings of ‘three column injury’, ‘potentially unstable injury’ or ‘unstable injury’. Spinal cord injuries were classified using the American Spinal Cord Injury Association Impairment Scale (AIS).[27] Drowning

TABLE 1. *Classification of drowning severity*[28]

Severity	Clinical features
Grade 1	Normal pulmonary auscultation with cough
Grade 2	Abnormal pulmonary auscultation with rales in some fields
Grade 3	Pulmonary auscultation of acute pulmonary oedema without arterial hypotension
Grade 4	Pulmonary auscultation of acute pulmonary oedema with arterial hypotension
Grade 5	Isolated respiratory arrest
Grade 6	Cardiopulmonary arrest

injuries were classified using the system described by Szpilman[28] ranging from Grades 1 to 6 (Table 1).

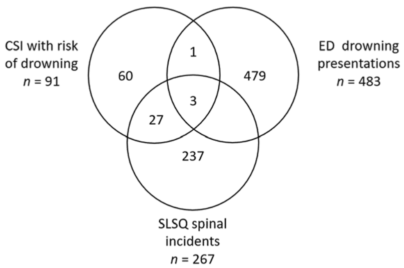

Figure 1. *Relationships between SLSQ spinal incidents, confirmed CSI and drowning presentations. CSI, cervical spine injury; SLSQ, Surf Life Saving Queensland.*

Statistical analysis was conducted using IBM SPSS (version 27; IBM, Armonk, NY, USA). Descriptive statistics were presented using means and standard deviation or median and interquartile range (IQR) when data were not normally distributed. Normality was assessed using the Shapiro–Wilk test. Categorical variables were described using frequencies and percentages. Means were compared using ANOVA and categorical variables using chi-squared (X^2) with a $P < 0.05$ considered significant and was adjusted using the Bonferroni correction where multiple categories within the one variable were analysed.

Results

During the study period, there were 574 ED presentations with a diagnosed CSI of which 91 (15.9%) occurred in a body of water with concomitant risk of drowning. There were also 483 ED presentations coded as immersion or drowning. There were four patients diagnosed with both CSI and drowning. There were 267 spinal incidents documented by SLSQ on Sunshine Coast beaches with 30 (11.2%) being subsequently diagnosed with CSI in the ED (Fig. 1).

Patients experiencing a CSI in a body of water were most likely to be male (77/91, 85%) and the mean age was 47.1 years (SD ±17.0). The majority of injuries occurred at the beach (79/91, 85.9%) and the majority (91.1%) of activities were swimming (54/91, 59.3%) and surfing (29/91, 31.8%). Two injuries caused by wave forced impact were the result of collisions with boards and not the ocean floor. One was a surfer struck by their own board and the other was a swimmer struck by the lifeguard's rescue board after being rescued. Seventy-five (82.4%) of the injuries occurred in the warmer months between November and April. There was no difference between locals and visitors with regards to season. Surprisingly, 28 (30.7%) of the 91 CSI presentations to the ED were delayed (>4 h) from the time of injury. Most of these presentations were within 1–2 days, but the longest delay was 5 days (Table 2).

The four patients, who had both CSI and drowning, had significant drowning morbidity. One patient was Grade 2 (rales in some pulmonary fields), one was Grade 3 (acute pulmonary oedema without hypotension), one was Grade 4 (acute pulmonary oedema with hypotension) and one was Grade 6 (cardiorespiratory arrest) according to the Szpilman classification.[28] All four patients were male. There were no deaths. A common feature among the four patients with CSI and drowning injury was head injury resulting in a loss of consciousness. Six other CSI patients also reported a loss of consciousness, but had no associated drowning injury. Three of the four were injured by wave forced impact and one by shallow water diving. All four were clinically suspected of

TABLE 2. *Baseline characteristics of patients with CSIs*

	Females	Males	Total
Number (%)	14 (15%)	77 (85%)	91 (100%)
Mean age (SD) (years)	41.9 (19.6)	48.1 (16.5)	47.1 (17.0)
Activity, *n* (%)			
Swimming	8 (8.8%)	46 (50.5%)	54 (59.3%)
Surfing	5 (5.5%)	24 (26.4%)	29 (31.9%)
Other†	1 (1.1%)	7 (7.7%)	8 (8.8%)
Mechanism, *n* (%)			
Wave forced impact‡	7 (7.7%)	64 (70.3%)	71 (78.0%)
Shallow water diving	7 (7.7%)	11 (12.1%)	18 (19.8%)
Other	0	2 (2.2%)	2 (2.2%)
Body of water, *n* (%)			
Beach	10 (10.9%)	69 (76.7%)	79 (86.8%)
River/creek/canal	2 (2.2%)	4 (4.4%)	6 (6.6%)
Swimming pool	2 (2.2%)	2 (2.2%)	4 (4.4%)
Other§	0	2 (2.2%)	2 (2.2%)
Delay to ED, *n* (%)	5 (17.9%)	23 (82.1%)	28 (30.8%)
Local resident, *n* (%)¶	8 (17.0%)	39 (83.0%)	47 (51.7%)

†Other activities: not recorded $n = 4$, socialising $n = 2$, kite surfing $n = 1$, occupational $n = 1$. Other mechanism: fall from height $n = 1$, crush injury $n = 1$. ‡Wave forced impact: head-first collision with ocean floor (or other object) secondary to the action of a wave resulting in an axial load. §Other body of water: not recorded $n = 1$, rock pool $n = 1$. ¶Local resident: patient with a residential postcode located within Sunshine Coast or Noosa local government areas. CSI, cervical spine injury.

TABLE 3. *Performance of the Canadian C-Spine rule and NEXUS low-risk criteria*

Number of patients with imaging criteria present	Total ($n = 91$)	Patients with unstable fractures ($n = 35$)	Patients with multiple vertebrae fractured ($n = 29$)
Canadian C-Spine high-risk criteria			
Age ≥65 years	12 (13.2%)	9 (25.7%)	5 (17.2%)
Dangerous mechanism	91 (100%)	35 (100%)	29 (100%)
Extremities paraesthesia	42 (46.2%)	17 (48.5%)	16 (55.2%)
Canadian C-Spine low-risk criteria			
Sitting position in ED	12 (13.2%)	10 (28.5%)	5 (17.2%)
Ambulatory at any stage	68 (74.7%)	22 (62.8%)	20 (68.9%)
Delayed onset of pain	4 (4.4%)	2 (05.7%)	1 (3.4%)
Absence of midline tenderness	18 (19.7%)	9 (25.7%)	8 (27.5%)
NEXUS low-risk criteria			
Absence of midline tenderness	18 (19.7%)	9 (25.7%)	8 (27.5%)
Absence of focal neurological deficit	87 (95.6%)	29 (82.8%)	27 (93.1%)
Normal alertness	87 (95.6%)	31 (88.6%)	27 (93.1%)
Absence of intoxication	85 (93.4%)	30 (85.7%)	28 (96.6%)
Absence of distracting injury	88 (96.7%)	33 (94.2%)	27 (93.1%)
Other criteria			
Delayed ED presentation	28 (30.7%)	7 (20.0%)	6 (20.6%)

having both CSI and drowning injury at the scene. There were no CSI detected in the remaining 479 drowning patients nor drowning injuries found in the other 87 CSI patients.

The frequency of the fractures increased the lower the cervical vertebrae, ranging from 10 patients with C1 fractures to 41 patients with C7 fractures. There were 35 unstable fractures and 29 patients had fractures in multiple vertebrae. Fifteen of the unstable fractures involved multiple vertebrae. There was one patient with a spinal cord injury (AIS – A). The performance of the Canadian C-Spine Rule and the NEXUS low-risk criteria in correctly indicating cervical spine imaging in this patient group (Table 3).

A CT scan of the cervical spine was the initial investigation in all 91 patients. Subsequently, 31 (34.0%) patients had MRI scans of the cervical spine and 17 (18.7%) had CT angiography. Forty-one (45.1%) had flexion and extension X-rays to assess stability of the spine. The high-risk criteria for the Canadian C-spine rule indicated imaging in 100% of the patients. Use of the NEXUS low-risk criteria indicated imaging in 78 (86%) patients. Thirteen patients, who would not have been scanned using NEXUS criteria, included five with unstable fractures and seven with multiple fractured vertebrae. Twenty-eight patients, who had a delayed presentation to the ED, included seven with unstable injuries and six with multiple vertebrae fractured.

Discussion

The present study demonstrated that even in a high-risk population where wave forced impacts are a common cause of CSI, the combination of CSI and drowning is uncommon. Previous papers examining the prevalence of CSI in drowning patients[13–17] have not included any patients injured by wave forced impacts. Although the link between wave forced impact and spinal injuries has been previously reported,[5–11] none of those studies examined any link between CSI and drowning. Constant findings among these papers included a greatly increased risk (up to sixfold) of CSI in visitors compared with local residents and a predominance of males among the injured.[5–8,10] Although we had a similar result with regards to the sex of those injured (85% male, 15% female), injuries were evenly distributed between visitors and locals in our study. We postulated that this might be because of local cultural factors with more frequent use of the water by locals compared to the previous study sites, but Chang's study was conducted in Hawaii, with a similarly strong beach going culture.[5] Two papers reported the frequency (100–74%)[5,10] of wave forced impacts as a cause of the CSI, and our results were similar, with 78% of CSI caused by wave forced impacts.

A conscious drowning patient can typically provide a history of the circumstances of the incident allowing an appropriate clinical decision regarding cervical spine immobilisation. This decision is obviously more difficult in the unconscious patient. The four patients with both drowning and CSI all reported a loss of consciousness at the time of injury and all were treated with spinal immobilisation by rescuers and first responders. This was because of either a history of witnessed axial load or physical signs, such as facial abrasions, suggesting impact with the ocean floor. Interestingly, six other patients reported a loss of consciousness at the time of injury but did not have evidence of drowning. The absence of occult CSI in the other 479 drowning presentations and the presence of either a history or signs of a dangerous mechanism of injury in the four drowning patients with CSI allow us to make the following recommendations.

1. A witnessed drowning where the patient is seen struggling and then found unconscious without either a witnessed axial loading or signs of axial loading – does not require cervical spine immobilisation.
2. An unconscious drowning patient with a witnessed axial load or signs of axial loading does require cervical spine immobilisation.
3. An unwitnessed drowning with no signs of axial loading found unconscious in a surf zone with dumping waves or other high-risk environment or activity does require cervical spine immobilisation.
4. An unwitnessed drowning found unconscious in a low-risk environment such as open ocean or still water with no history of high-risk activity, cervical spine precautions are most likely not warranted. In this case, local guidelines and clinical judgement should be followed.
5. A conscious drowning patient should have cervical spine immobilisation instituted only if they have a history or signs of axial loading or other dangerous mechanism of injury.

The one consistent criterium for imaging across all 91 patients was a history of a dangerous mechanism of injury (axial loading). This held true no matter how delayed the presentation to the ED. An obvious consequence of this finding regarding the mechanism of injury is that the Canadian high-risk criteria performed better than the NEXUS criteria. In fact, the 13 patients who would not have been scanned using NEXUS criteria include seven with fractures of multiple vertebrae and one patient with an unstable injury. These results allow us to recommend the Canadian C-Spine criteria as the sole criteria for assessing the need for imaging in patients presenting with neck injuries occurring in a body of water. This holds true no matter how delayed the presentation to the ED is.

The poor performance of the NEXUS criteria in correctly indicating cervical spine imaging in this cohort of patients was a surprise. We postulated that this might be because of the definition of clinically significant fracture used in the original derivation study, which excluded injuries such as spinous process fractures and end plate fractures.[25] However, seven of the fractures missed by NEXUS criteria in our study would have been included as clinically significant in the NEXUS study, and five were reported as unstable. These included displaced fractures of the PEG, lamina fractures and teardrop fractures. Midline tenderness was absent in 19.7% of our patients, contributing to the poor performance of the NEXUS criteria. However, this proportion is consistent with that reported in the derivation paper for the Canadian C-Spine Rule of 14.9%[26] and a subsequent comparison of the Canadian C-Spine Rule and the NEXUS criteria of 16.0%.[29] The significant number of patients who were ambulatory (74.7%) is likely because of the requirement to get themselves out of the water and seek help.

Fortunately, abnormal neurological signs were uncommon in this cohort. Although paraesthesia of the extremities was reported in 42 (46.2%) patients, objective neurological signs were a rare finding in the ED (4/91, 4.4%). This contrasts with previous studies where neurological deficits were much more common (75%)[5] as were spinal cord injuries.[5,6,10] A potential explanation for this is the location of the state-wide spinal injuries unit in one of the two neurosurgical trauma centres approximately 100 km away in Brisbane, to which patients with significant abnormal neurological signs may have been transported directly from the scene. The SCHHS did not have a neurosurgical service during the study period and the Sunshine Coast has a well-established aero-medical (helicopter) retrieval service.

Although our study was conducted in a region with many popular surf beaches, the catchment area for our hospitals includes a large number of other aquatic locations, including domestic, hotel and public swimming pools, rivers, swimming holes, canals, dams and other bodies of water. Despite the wide range of geographical locations with potential for CSI injury in water, the beach was the location for 84% of these injuries. This contrasts significantly with the locations reported in previous studies of CSI and drowning in more temperate climates, with 10% or less occurring in natural bodies of water.[2–6]

The mean age of those injured in the present study (47 years) and sex (predominance of males with only 15% being female) is consistent with multiple studies examining surf zone injuries, where males have represented between 70% and 100% of the injured.[5,6,8–10] The reason for this is not clear with inconsistent differences between sexes noted in risk-taking behaviours at the beach.[30]

Strengths and limitations

The present study was the first to examine the incidence of CSI in drowning patients in a coastal environment where the action of ocean waves frequently results in CSI. As such, our findings that CSI and drowning are uncommonly found together support the move away from routine cervical spine immobilisation in drowning patients. As with any retrospective study, data such as the activity being undertaken at the time of injury was occasionally missing, so our findings are incomplete. The small proportion of SLSQ spinal patients (30/267, 11.2%) who were subsequently diagnosed with CSI was surprising. It is routine for QAS to be notified of these incidents and patients are typically transported to the ED. Unfortunately, the LIMSOC data does not include identifying data and the data linkages relied on working backwards from the EMR and QAS records using the time, date and location of injury and linkages were confirmed by sex and age of the patient. The vast majority of these injuries occurred on beaches in close proximity to SCHHS EDs and outside of the study hospitals, the nearest ED and trauma centre are 50 and 100 km away, respectively. Given the geographic distance to other hospitals and our comprehensive search strategy for both drowning and CSI (Appendix S2), we believe that these patients most likely attended SCHHS and were diagnosed with neither drowning nor CSI.

Conclusions

The combination of CSI and drowning is uncommon, even in a region where CSI frequently occurs in the water and this paper provides an evidentiary basis for the move away from routine cervical spine immobilisation in drowning patients, even in a region where CSIs frequently occur in a body of water. Cervical spine precautions should be instituted in drowning patients with history of loss of consciousness secondary to trauma or at high risk of having suffered axial loading. The Canadian C-Spine Criteria should be used to assess the need for imaging in these patients, no matter how delayed their presentation. Further research should examine the risk factors for these injuries, so that opportunities for preventive measures can be identified. Factors behind delayed presentation to hospital should also be examined.

Acknowledgement

Open access publishing facilitated by James Cook University, as part of the Wiley - James Cook University agreement via the Council of Australian University Librarians.

Competing interests

None declared.

Data availability statement

Data collected for this study is subject to the Public Health Act 2005, Queensland. Application for access to the data can be made through Queensland Health.

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Supporting information

Additional supporting information may be found in the online version of this article at the publisher's web site:

Appendix S1. Search strategy.

Appendix S2. List of data collected.