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Research Article

Incidence and characteristics of device-related pressure injuries in intensive care: A four-year analysis

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ABSTRACT

Objectives: To describe and analyse the incidence and characteristics of intensive care-acquired device-related pressure injuries.
Design: Secondary data analysis of intensive care-acquired pressure injuries during 2019–2022.
Setting: Single general intensive care unit in Brisbane, Australia.
Main outcome measures: Intensive care-acquired pressure injury incidence, device-related pressure injury incidence, non-device-related pressure injury incidence, pressure injury category and location, device associated with pressure injury.
Results: During the 4-year period, there were 7343 intensive care admissions of whom 413 (5.6 %) patients developed an intensive care-acquired pressure injury. The incidence of device-related pressure injury was 4.0 % compared to 2.7 % non-device-related pressure injury. In total there were 461 device-related pressure injuries, which were mostly (55 %) associated with endotracheal tubes or the methods used to secure them. Consequently, the majority of injuries were found on the mucous membranes (lips, mouth and tongue). The other main devices associated with injuries were high-flow nasal prongs (9.3 %), indwelling urinary catheters (6.7 %), nasogastric tubes (6.5 %) and oxygen masks (5.0 %). Overall, device-related pressure injuries were less severe than non-device-related pressure injuries, however they occurred in a shorter time frame (median 4 days versus 6 days). A range of factors was associated with device-related pressure injuries but overall, their presence or duration was less than with non-device-related pressure injuries.
Conclusion: The study results provide rigorous evidence of the incidence and characteristics of device-related pressures injuries, that can be used to benchmark with other intensive care units nationally and internationally.
Implications for Clinical Practice: Endotracheal tube-associated pressure injuries were the most common type of device-related injury, providing a clear focus for preventative intervention. Given the high proportion of these device-related injuries, effective interventions would have a significant impact on overall reduction of intensive care-acquired pressure injuries. Since most injuries occur within three days of device insertion, early preventative intervention is time-critical.

Introduction

Patients admitted to the intensive care unit (ICU) are vulnerable to pressure injury (PI) development, with ICU patients nearly four times more likely to develop a PI than non-ICU patients [1]. Their vulnerability is related to multiple risk factors associated with critical illness [2], including impaired mobility, mechanical ventilation and prolonged length of stay [3]. Several studies have reported higher hospital-acquired PI rates in ICU than acute ward settings [1,4–7]. In a national sub-set study of the international DecubICUs study [8], point-prevalence of ICU-acquired PI within 16 Australian ICUs was found to be 9.7 %, with half of the identified PIs occurring on the face/head [9]. Development of PI has been associated with significant pain, psychological stress and prolonged hospital length of stay [10–12]. The cost of hospital-acquired PI to Australian public hospitals was estimated to be AUD 5.5 billion in 2020 [13].

Care of ICU patients involves the implementation of multiple medical devices for the purpose of both monitoring and treatment, with an

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undesirable consequence being that the device is a source of pressure on the tissues, potentially causing a device-related PI (DRPI), which usually mimics the shape of the applied device [14]. They can occur in several anatomical areas, with the most common areas being the lips, mouth and nose [15] with most DRPIs caused by endotracheal tubes (ETTs), nasogastric tubes, and indwelling urinary catheters [16,17]. When inserted, these medical devices are in contact the mucosal membrane surface, which makes up the lining of the respiratory, gastrointestinal, and genitourinary tracts [14], therefore most DRPI that occur in ICU are mucous membrane PI. In ICU, the proportion of mucous membranes DRPIs has been reported to be between 34.2 % [18] to 63.7 % [17]. However, the prevalence and incidence rates of ICU-acquired DRPI are highly variable in the literature, with a recent *meta*-analysis including studies from 11 countries found ICU MDRPI incidence rates ranging from 3.3 % to 48.8 %, with a pooled incidence from 10 studies of 14.7 % (95 % CI 9.7–19.6) [19]. Within Australia, a point prevalence study from a single ICU, reported a DRPI prevalence of 11.3 % [16].

To prevent DRPI in ICU it is necessary to understand the full scope of the problem. Therefore, the aim of this study was to describe and analyse the incidence and characteristics of ICU-acquired DRPI.

Methods

Design

A secondary data analysis of hospital clinical incident reports of ICU-acquired PI was conducted. Approval for use of the data for this study was granted by the relevant data custodians and ethical approval was obtained from the hospital's research ethics committee (reference: HREC/2021/QPCH/80804). In addition, Public Health Act approval was given to access patient data (reference: PHA 80804.2). The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) [20] checklist was used to guide reporting (Supplementary File 1).

Setting and sample

The setting was a single adult ICU 27-bed facility providing care to critically ill patients with a wide range of conditions, including cardiothoracic surgery, in a 663-bed tertiary general hospital in south-east Queensland, Australia. In the study ICU, pressure injury prevention practices are described in detail within work unit guidelines. All methods of prevention are described, including repositioning (2–4 hourly according to risk level), use of support surfaces and pressure offloading devices, use of prophylactic dressings, medical device securement, incontinence management, and endotracheal tube (ETT) management. All adult (≥ 18 years) ICU patients that were reported to have had an ICU-acquired PI between the years 2019–2022 were included in the sample.

Data collection

In the study hospital, pressure injuries occurring within ICU are reported via the clinical incident reporting system (Riskman™) and are reviewed visually and validated by specialist nurses from the Quality and Effectiveness Support Team (QuEST) to confirm their presence, location and stage or category. As well, each PI is checked and validated by Clinical Nurses from the ICU's Quality and Safety team. Any reporting discrepancies are then corrected via the hospital's clinical incident monitoring system.

All identified and validated PI that were reported in ICU between the years 2019 to 2022 were extracted from ICU and QuEST databases and were cross-referenced against a database of all PI clinical incident reports logged during the study period, which were provided by the hospital's Coordinator Clinical Incidents – Safety and Quality Unit. All data were provided in Microsoft Excel™ databases, where they were collated, checked and cleaned. Any discrepancies in the data were checked and amended; and cross-checked with original patient medical records if necessary. Patient demographic, disease and treatment factors, and device insertion dates were retrieved directly from patients' records.

Data analysis

Data were imported into SPSS™ version 28 statistical software [21] for analysis. Descriptive statistics are used to describe sample characteristics. Means (M) with standard deviation (SD) are used to describe central tendency of scale data and medians (Md) with interquartile range (IQR) and proportions used to describe ordinal and categorical variables respectively. Time intervals were calculated within SPSS™ based on dates and measured in whole days. For the purpose of time-to-PI estimations, the date of ICU admission or the date of device insertion were categorised as day zero. As time intervals were not exact (i.e., to the nearest whole day), central tendency is described using Md (IQR). To test for differences, *t*-tests or one-way analysis of variance were used to analyse scale variables, Mann-Whitney *U* to analyse ordinal variables, and Chi Square (with Yates correction for 2x2 tables) or Fisher's Exact test were used for categorical variables. ICU-acquired PI incidence was calculated as: [(numerator ÷ denominator) x 100 %], where the numerator was defined as the number of unique ICU episodes of care (admissions) in which the patient developed at least one ICU-acquired PI (or non-DRPI or DRPI) and the denominator was defined as the number of ICU episodes during the same period (2019–2022). Significance was set at $p < 0.05$.

Results

Sample

From January 2019 to December 2022 there were 7343 adult (≥18 years) ICU episodes of care (admissions). The characteristics of the sample with ICU-acquired PI ($n = 413$) are shown in Table 1. There was a much larger proportion of males in the sample (71.7 %, $n = 296$). The mean age of the sample was 60.6 (SD 16.4, range 19–91) years. Most admissions were from the operating rooms (OR) 37.3 %, $n = 154$), interhospital transfers (22.3 %, $n = 92$), or the emergency department

Table 1
Patient characteristics, $n = 413$ ICU episodes.

	Overall $n = 413$	Male $n = 296$ (71.7 %)	Female $n = 117$ (28.3)	Significance p
Age in years mean (SD)	60.6 (16.4)	61.1 (15.7)	59.5 (18.2)	0.414
Emergency admission % (n)	70.0 (289)	67.2 (199)	77.1 (91)	0.062
[1]Body mass index mean (SD)	28.9 (7.2)	28.9 (7.0)	29.0 (7.6)	0.939
[2]APACHE II admission score mean (SD)	20.0 (7.1)	19.8 (7.1)	20.5 (7.2)	0.330
[2]APACHE 3 J admission score mean (SD)	75.3 (27.4)	74.1 (27.6)	78.1 (26.8)	0.190
[3]SOFA admission score mean (SD)	8.7 (3.4)	8.7 (3.4)	8.6 (3.4)	0.772
Main ICD admission 11 diagnosis % (n)	58.8 (243)	62.5 (185)	49.6 (58)	0.022
12	22.0 (91)	18.6 (55)	30.8 (36)	0.010
Non-DRPI % (n)	47.5 (196)	47.3 (140)	47.9 (56)	1
DRPI % (n)	71.4 (295)	72.0 (213)	70.1 (82)	0.796
Both non-DRPI and DRPI % (n)	18.9 (78)	19.3 (57)	17.9 (21)	0.889

[1] missing $n = 52$, [2]missing $n = 2$, [3]missing $n = 4$. APACHE = Acute Physiology and Chronic Health Evaluation, SOFA = Sequential Organ Failure Assessment.

(ED) (16.9 %, $n = 70$). The majority (70.0 %, $n = 289$) were emergency admissions to ICU, of which most were from interhospital transfers (29.1, $n = 84$), the ED (24.2 %, $n = 70$) or the OR (20.4 %, $n = 59$). In terms of International Classification of Disease (ICD) code, the main diagnoses on admission to ICU were *ICD 11 Diseases of the circulatory system* (58.8 %, $n = 243$) *and ICD 12 Diseases of the respiratory system* (22.0 %, $n = 91$), with significantly more males presenting with these diagnoses (see Table 1).

ICU-acquired pressure injury incidence

In total, across the four years, 413 patients developed at least one ICU-acquired PI during their admission; giving an overall ICU-acquired PI incidence of 5.6 % (413/7343). In these patients, a total of 757 ICU-acquired PIs were reported.

Non-device-related pressure injury

Of the 413 ICU admissions with ICU-acquired PI, 47.5 % ($n = 196$) had at least one non-DRPI, giving a non-DRPI incidence of 2.7 % (196/7343). Of these, most (67.3 %, $n = 132/196$) had only one non-DRPI (Md 1, IQR 1–2, range 1–5), and 40.0 % ($n = 78/196$) had both a non-DRPI and a DRPI. In total there were 296 non-DRPIs, representing 39.1 % of the total number of ICU-acquired PIs reported ($n = 757$). The largest proportions of non-DRPIs were categorised as SDTIs (44.3 %, $n = 131$) and Stage 2 PIs (29.1 %, $n = 86$). Most non-DRPIs were found on the sacrum (31.4 %, $n = 93$), heels (22.3 %, $n = 66$) or buttocks (17.6 %, $n = 52$). See Table 2.

The median time-to-non-DRPI from ICU admission was 6 days (IQR 3–11, range 0–55). Only 1.4 % ($n = 4$) of non-DRPIs occurred on the day of admission to ICU. Nearly half (49.3 %, $n = 146$) occurred by day 5 of ICU admission and 73.6 % ($n = 218$) had occurred by day 10.

Device-related pressure injury

Of the 413 ICU admissions with hospital-acquired PI, most (71.4 %, $n = 295$) had at least one DRPI, giving a DRPI incidence of 4.0 %. Of these, most (62.0 %, $n = 183$) had only one DRPI (Md 1, IQR 1–2, range 1–7) and 26.4 % ($n = 78$) also had at least one non-DRPI. In total, there were 461 DRPIs reported, representing 60.9 % of the total number of ICU-acquired PIs (see Table 3). Over half of all DRPIs were categorised as mucosal membrane PIs (54.4 %, $n = 251$). The main site of DRPI was the lips (31.7 %, $n = 146$), followed by the ears (10.4 %, $n = 48$) and mouth (8.7 %, $n = 40$). The body site and the type of device associated with each DRPI are shown in Table 4. The other main devices found to be associated with DRPI were high flow nasal prongs, indwelling urinary catheters, nasogastric tubes, and biphasic positive airway pressure (BiPAP) and non-invasive ventilation (NIV) masks (see Table 4).

Table 2
Top five non-device-related pressure injuries by stage and site ($n = 296$).

	PI stage					
	Stage 1	Stage 2	Stage 3	Unstageable	SDTI	Total
Sacrum	24 (25.8) (38.1)	37 (39.8) (43.0)		4 (4.3) (33.3)	28 (30.1) (21.4)	93 (100) (31.4)
Heel	12 (18.2) (19.0)	4 (6.1) (4.7)			50 (75.8) (38.2)	66 (100) (22.3)
Buttock	6 (11.5) (9.5)	18 (34.6) (20.9)	3 (5.8) (75.0)	3 (5.8) (25.0)	22 (42.3) (16.8)	52 (100) (17.6)
Head	5 (33.3) (7.9)	9 (60.0) (10.5)		1 (6.7) (8.3)		15 (100) (5.1)
Natal cleft	3 (20.0) (4.8)	8 (53.3) (9.3)			4 (26.7) (3.1)	15 (100) (5.1)
Other sites	13 (23.2) (20.6)	10 (18.2) (11.8)	1 (1.8) (25.0)	4 (7.2) (33.3)	27 (49.1) (28.2)	55 (100) (18.6)
Total *n* (%)	63 (21.3) (100)	86 (29.1) (100)	4 (1.4) (100)	12 (4.1) (100)	131 (44.3) (100)	296 (100) (100)

Endotracheal tube devices were associated with 8 of the 10 most common sites and were associated with over half of all DRPIs (55.4 %, $n = 255$), with most ETT-related DRPIs occurring on the lips (56.4 %, $n = 144/255$) or in the mouth (15.3 %, $n = 39$). In nearly all cases 97.3 %, $n = 248$) the direct cause of the ETT device was identified. In half of all cases (50 %, $n = 124/248$) the DRPI was caused by the tape used to tie the ETT, with over a third (36.7 %, $n = 91$) caused by the tube itself. Endotracheal tube attachment devices (ETAD) accounted for 9.4 % ($n = 24$) of ETT-related DRPIs, with the remainder caused by bite blocks (2.4 %, $n = 6$) or the ETT pilot tube (1.2 %, $n = 3$). Most ETT tape DRPIs were reported on the lips (48.4 %, $n = 60/124$), mouth (19.4 %, $n = 24$) or perioral skin (13.7 %, $n = 17$), whereas there were more lip DRPIs associated with the ETT itself (71.4 %, $n = 65/91$) with a smaller proportion in the mouth (12.1 %, $n = 11$). The largest proportions of ETAD DRPIs were reported on the lips (45.8 %, $n = 11/24$) and philtrum (25.0 %, $n = 6$).

In 18 (3.9 %) cases, the device insertion date was not recorded in the medical records. The median time-to-DRPI from ICU admission was 4 days (IQR 2–8, range 0–44) and the median time from device insertion to DRPI was 4 days (IQR 2–6, range 0–38). The median time-to-PI from ICU admission was significantly shorter for DRPIs (Md 4) compared to non-DRPIs (Md 6; $p < 0.001$). A small but significant proportion of DRPIs (6.7 %, $n = 31$) occurred on the day of ICU admission (which, in all cases, was also the same day as device insertion), 40.1 % (n = 185) occurred by day 3, 59.7 % ($n = 275$) by day 5, and 83.9 % ($n = 387$) by day 10. Nearly half of all DRPIs (47.4 %, $n = 210$) occurred by day 3 following insertion, 70.0 % ($n = 310$) by day 5, and 89.8 % ($n = 398$) by day 10. For each device, the median time from device insertion to DRPI is shown in Table 5. The median time to DRPI for ETTs, the most commonly associated device, was 3 days, and 54.4 % ($n = 136/250$) had occurred by day 3. For the second most commonly associated device, high flow nasal prongs, the median time to DRPI was 4 days, and 47.6 % ($n = 20/42$) injuries occurred by day 3. Of the other more commonly associated devices, BiPAP/NIV masks were associated with the shortest median time-to-DRPI of 2.5 days, with 50.0 % ($n = 11/22$) occurring by day 2. Nasogastric tubes were also associated with a relatively short median time-to-DRPI of 4 days. In contrast, the median time-to-DRPI for indwelling urinary catheters was 8 days, with 51.7 % ($n = 15/29$) occurring within this time frame. See Table 5.

Various patient, disease and treatment factors were compared between patients with a DRPI, those with a non-DRPI, and those with both (see Table 6). As demonstrated by lower APACHE and SOFA admission scores, the illness severity of patients who developed DRPI was less than those that developed non-DRPI. Also, there were significantly smaller proportions of patients with diabetes, cardiovascular disease, and peripheral vascular disease in patients that developed a DRPI. As well, a smaller proportion was diagnosed with sepsis during their admission. ICU treatment factors were also compared between DRPIs and non-DRPIs (see Table 7). Significantly smaller proportions of four treatments (vasopressor, ECMO, IABP, VAD) were associated with DRPIs. However, for all six treatment factors investigated (ventilation, sedation, vasopressor, ECMO, IABP, VAD), the number of days of treatment provided before the PI occurred was significantly less for DRPIs than non-DRPIs.

Discussion

The results from this study are highly relevant to nursing practice as they provide demonstrable evidence that DRPIs represent the greatest

Table 3
Device-related pressure injury by body site and pressure injury category ($n = 461$).

	Pressure injury category						Total
	Stage 1	Stage 2	Stage 3	Unstageable	SDTI	Mucosal	
Lip						146 (100) (58.2)	146 (100) (31.7)
Ear	14 (29.2) (27.5)	13 (27.1) (18.8)	1 (2.1) (25.0)	9 (18.8) (33.3)	11 (22.9) (18.6)		48 (100) (10.4)
Mouth						40 (100) (15.9)	40 (100) (8.7)
Nose	6 (16.7) (11.8)	9 (25.0) (13.0)		10 (27.8) (37.0)	11 (30.6) (18.6)		36 (100) (7.8)
Genitals	3 (10.0) (5.9)					27 (90.0) (10.8)	30 (100) (6.5)
Neck	2 (9.1) (3.9)	9 (40.9) (13.0)	3 (13.6) (75.0)	1 (4.5) (3.7)	5 (22.7) (8.5)	2 (9.1) (0.8)	22 (100) (4.8)
Cheek	6 (28.6) (11.8)	9 (42.9) (13.0)		1 (4.8) (3.7)	5 (23.8) (8.5)		21 (100) (4.6)
Nare						21 (100) (8.4)	21 (100) (4.6)
Perioral skin	3 (14.3) (5.9)	16 (76.2) (23.2)		1 (4.8) (3.7)	1 (4.8) (1.7)		21 (100) (4.6)
Tongue						14 (100) (5.6)	14 (100) (3.0)
Philtrum	1 (11.1) (2.0)	5 (55.6) (7.2)		3 (33.3) (11.1)			9 (100) (2.0)
Finger	1 (12.5) (2.0)				7 (87.5) (11.9)		8 (100) (1.7)
Heel	1 (16.7) (2.0)				5 (83.3) (8.5)		6 (100) (1.3)
Thigh	1 (16.7) (2.0)	3 (50.0) (4.3)			2 (33.3) (3.4)		6 (100) (1.3)
Head				1 (20.0) (3.7)	4 (80.0) (6.8)		5 (100) (1.1)
Knee	3 (60.0) (5.9)	1 (20.0) (1.4)			1 (20.0) (1.7)		5 (100) (1.1)
Calf	3 (75.0) (5.9)				1 (25.0) (1.7)		4 (100) (0.9)
Foot	2 (50.0) (3.9)	1 (25.0) (1.4)			1 (25.0) (1.7)		4 (100) (0.9)
Forehead				1 (25.0) (3.7)	3 (75.0) (5.1)		4 (100) (0.9)
Back/scapula	1 (50.0) (2.0)	1 (50.0) (1.4)					2 (100) (0.4)
Chin	1 (50.0) (2.0)				1 (50.0) (1.7)		2 (100) (0.4)
Perianal		2 (100) (2.9)					2 (100) (0.4)
Buttock	1 (100) (2.0)						1 (100) (0.2)
Forearm	1 (100) (2.0)						1 (100) (0.2)
Gastrointestinal tract						1 (100) (0.4)	1 (100) (0.2)
Jaw					1 (100) (1.7)		1 (100) (0.2)
Wrist	1 (100) (2.0)						1 (100) (0.2)
Total *n* (%)	51 (11.1) (100)	70 (15.0) (100)	4 (0.9) (100)	27 (5.9) (100)	59 (12.8) (100)	251 (54.4) (100)	461 (100) (100)

proportion of ICU-acquired PIs and occur more quickly than non-DRPIs. In our study, the incidence of DRPI was found to be 4.0 % compared to the much lower incidence of non-DRPI (2.7 %). This is similar to the DRPI point prevalence of 4.3 % reported in a large study of 44 ICUs across Australia and New Zealand [22] but was lower than that the point prevalence of 11.3 % found in a more recent longitudinal study in a single Australian ICU [16]. In our study, of all patients that developed an ICU-acquired PI, 71.5 % developed at least one DRPI compared to 47.5 % who developed a non-DRPI. Of these, 26.4 % developed both types of PI. To date, there have been few studies that have reported both non-DRPIs and DRPIs. In a Japanese observational study of 1418 critically ill patients over 9 months, the incidence of non-DRPI (4.2 %, $n = 60$) was found to be higher than DRPI (3.3 %, $n = 47$), however the number of PIs was the same in each group ($n = 66$), and 11 (0.8 %) patients developed both types of PI [23]. The overall PI incidence in that study was calculated to be 8.3 % ($n = 118/1418$), however only patients aged ≥ 20 years were included. In a recent Australian study that used an educational intervention to reduce ICU-acquired PI, the incidence of ICU-acquired PI at baseline was 37.9 % ($n = 33/87$) with a DRPI incidence of 23.0 % (20/87) [24]. Proportionally, 60.6 % of patients with an ICU-acquired PI had a DRPI ($n = 20/33$) and although the incidence of PI fell significantly in the post-intervention period, the proportional incidence of DRPI was similar (57.1 %, $n = 8/14$). In an Australian audit over 14 months, 27.8 % (50/179) of all hospital-acquired PIs were found to be DRPI, of which the majority were reported in ICU (68.0 %, $n = 34/50$), however the number of non-DRPI in ICU was not reported [25].

Table 4
Device-related pressure injury ($n = 460$) by body site and device type.

	Device type																					
	Endotracheal tube	High-flow nasal prongs	Indwelling urinary catheter	Nasogastric tube	BiPAP/ NIV mask	Saturation probe	Tracheostomy tube	Nasal prongs	TED stocking	Foot splint	Faecal management system	Orogastric tube	Arterial line	ECMO cannula	Incontinence pad	Chest drain	Central venous pressure line	Electrocardiogram lead	Foot pump	Oral temperature probe	Tubing (other)	
Lip	144			1																1		146
*Ear	2	35				1		9														47
Mouth	39											1										40
Nose	2	5		8	19	1		1														36
Genitals			30																			30
Neck	10				1		10										1					22
Cheek	18	1			2																	21
Nare		2		19																		21
Perioral skin	20											1										21
Tongue	13											1										14
Philtrum	7			2																		9
Finger						7							1									8
Heel										6												6
Thigh			1								2			2	1							6
Head						4															1	5
Knee									4					1								5
Calf									4													4
Foot									2	1									1			4
Forehead						4																4
Back/ scapula																1		1				2
Chin					1							1										2
Perianal											2											2
Buttock															1							1
Forearm													1									1
GIT											1											1
Jaw												1										1
Wrist													1									1
Total	255	43	31	30	23	17	11	10	10	7	5	5	3	3	2	1	1	1	1	1	1	460

*Missing $n = 1$, BiPAP = biphasic positive airway pressure, ECG = electrocardiogram, ECMO = extracorporeal membrane oxygenation, GIT = gastrointestinal tract, NIV = non-invasive ventilation, TED = thrombo-embolic deterrent.

Table 5
Device type by time to device-related pressure injury and pressure injury category ($n = 460$).

Device type	n	Time-to-DRPI (days) Md (IQR, range)	PI category					
			Stage 1	Stage 2	Stage 3	Unstageable	SDTI	Mucosal
Endotracheal tube	255	3 (1–5, 0–18), NR = 5	10	33	1	4	11	196
High-flow banal prongs	43	4 (3–5, 0–10), NR = 1	10	12		10	9	2
Indwelling urinary catheter	31	8 (4.5–11, 0–19), NR = 2	3	1				27
Nasogastric tube	30	4 (2–9, 0–38), NR = 1	1	4		3	2	20
BiPAP/NIV mask	23	2.5 (0–5.25, 0–10), NR = 1	7	5		7	4	
Nasal prongs	10	3 (2.75–5.5, 1–13)	4	2			4	
TED stocking	10	5 (2.5–18, 1–24)	8	1			1	
Tracheostomy tube	10	19 (6–21, 6–23), NR = 1		4	2	1	1	2
Saturation probe	10	3 (3–8.5, 3–19), NR = 1					10	
Saturation probe – forehead	7	6 (3–6, 3–14)	1			1	5	
Foot splint	7	(3.25–20.5, 1–31), NR = 1	1	1			5	
Faecal management system	5	4 (3–9, 3–11)		4			1	
Orogastric tube	5	4 (3–7, 2–9)		1			2	2
Arterial line	3	9 (range 9–30)	3					
ECMO cannula	3	23 (range 8–23)	1				2	
Incontinence pad	2	NR = 2	1				1	
Central venous pressure line	1	7					1	
ECG lead	1	5		1				
Foot pump	1	4					1	
ICC	1	1	1					
Oral temperature probe	1	NR = 1						1
Tubing (other)	1	NR = 1				1		
Total	460	4 (2–6, 0–3), NR = 18	51	69	3	27	59	251

BiPAP = biphasic positive airway pressure, ECG = electrocardiogram, NR = device insertion date not recorded, NIV = non-invasive ventilation, SDTI = suspected deep tissue injury, TED = thrombo-embolic deterrent.

Table 6
Patient ($n = 413$), disease and treatment factors associated with pressure injury.

Factors % (n)		Missing n	Patients with non-DRPI only	Patients with DRPI only	Patients with both non-DRPI and DRPI	Significance p
Patient factors mean (SD)	Age	0	63.0 (15.6)	60.4 (17.6)	57.7 (14.0)	0.078
	Body mass index	52	28.4 (7.4)	28.8 (6.9)	29.9 (7.6)	0.371
	APACHE II admission score	2	20.7 (7.3)	18.9 (6.6)	21.8 (7.4)	0.004
	APACHE 3 J admission score	2	79.6 (28.5)	70.3 (25.6)	82.4 (28.4)	< 0.001
	SOFA admission score	6	8.7 (3.4)	8.2 (3.1)	10.1 (3.7)	< 0.001
Disease factors % (n)	Diabetes	4	39.0 (46/118)	21.6 (46/213)	29.5 (23/78)	0.003
	Hypotension	4	12.7 (15/118)	9.4 (20/213)	12.8 (10/78)	0.554
	Cardiovascular disease	2	66.1 (78/118)	51.2 (110/215)	61.5 (48/78)	0.022
	Peripheral vascular disease	4	16.1 (19/118)	6.6 (14/213)	7.7 (6/78)	0.015
	Sepsis during admission	15	47.8 (55/115)	36.9 (76/206)	77.9 (60/77)	< 0.001
Treatment factors % (n)	Ventilated during admission	5	88.9 (104/117)	91.1 (194/213)	93.6 (73/78)	0.531
	IV sedation during admission	5	88.9 (104/117)	91.1 (194/213)	91.2 (74/78)	0.352
	IV vasopressor during admission	5	88.9 (104/117)	87.3 (186/213)	96.2 (75/78)	0.092
	ECMO during admission	6	13.7 (16/117)	9.0 (19/212)	28.2 (22/78)	< 0.001
	IABP during admission	5	18.8 (22/117)	14.6 (31/213)	23.1 (18/78)	0.211
	VAD during admission	5	8.5 (10/117)	2.8 (6/213)	7.7 (6/78)	0.053

APACHE = Acute Physiology and Chronic Health Evaluation, DRPI = device-related pressure injury, ECMO = extracorporeal membrane oxygenation, IABP = intraortic balloon pump, IV = intravenous, SOFA = Sequential Organ Failure Assessment, VAD = ventricular assist device.

Table 7
ICU treatment factors associated with pressure injuries ($n = 757$).

Treatment factor		Non-DRPI $n = 296$	DRPI $n = 461$	Significance p
Ventilation	[1]Ventilated at time of PI, % (n)	75.2 (221/294)	72.9 (333/457)	0.484
	[1]Ventilated days prior to PI, mean (SD)	6.9 (7.3)	4.9 (5.8)	< 0.001
IV sedation	[1]Sedated at time of PI, % (n)	60.2 (177/294)	63.7 (291/457)	0.338
	[1]IV sedated days prior to PI, mean (SD)	5.7 (5.1)	4.3 (4.5)	< 0.001
IV vasopressor	[2]Receiving IV vasopressor at time of PI, % (n)	66.1 (195/295)	58.4 (267/457)	0.035
	[2]IV vasopressor days treated prior to PI, mean (SD)	6.1 (5.8)	4.1 (4.9)	< 0.001
ECMO	[1]ECMO treatment at time of PI, % (n)	19.0 (56/295)	10.3 (47/456)	< 0.001
	[1]ECMO days treated prior to PI, mean (SD)	1.9 (3.9)	0.6 (1.7)	0.018
IABP	[2]IABP treatment at time of PI, % (n)	12.2 (36/295)	7.0 (32/457)	0.015
	[2]IABP days treated prior to PI, mean (SD)	1.1 (2.5)	0.6 (1.7)	0.001
VAD	[2]VAD treatment at time of PI, % (n)	9.8 (29/295)	3.5 (16/457)	< 0.001
	[2]VAD days treated prior to PI, mean (SD)	1.0 (3.0)	0.4 (3.2)	. 010

[1] Missing $n = 6$, [2]Missing $n = 5$.

In the largest study undertaken to date, in which global prevalence of ICU-acquired PI point prevalence was found to be 16.2 % [8], although the number of devices attached to each patient was recorded [9], DRPIs were not and thus their prevalence was unable to be calculated. Several systematic reviews have been conducted to estimate DRPI incidence and prevalence in ICU. In the earliest systematic review, pooled incidence was reported as 3.9 % (95 % CI 0–16.7 %) in 4 studies, with pooled prevalence of 6.5% (95 % CI 2.0–8.6 %) reported across 7 studies [26]. More recently, Jia et al. [19] estimated a pooled DRPI incidence of 14.7 % (95 % CI 9.7–19.6 %) across 10 studies and a pooled DRPI prevalence of 19.0 % (95 % CI 13.6–24.3 %) across 9 studies. In the latest *meta*-analysis of DRPI incidence, pooled incidence in ICU was reported as 19.0 % (95 % CI 12.4–25.6 %) across an ICU subset of 17 studies [27]. In terms of global benchmarks, our study and earlier studies [9,16] indicate that DRPI incidence compares favourably in Australia.

The majority of ICU-acquired DRPIs in our study were caused by ETTs or the methods used to secure them, as shown in other studies [17,18,28–30], with most injuries occurring on the lips. Furthermore, the median time from ETT insertion until DRPI occurrence was only 3 days, with 54 % occurring within this timeframe. In our study, most ETT-related DRPIs were caused by ETT tapes (50.0 %) or the tube itself (36.7 %). These data provide a clear clinical indicator of where effective preventative interventions would be most likely to result in significant reductions in overall ICU-acquired PI incidence. Indeed, in the study ICU, there is potential to reduce ETT-related DRPIs with greater use of ETADs rather than traditional methods of securement using tapes. In the study ICU, work unit guidelines for ETT management indicate that ETADs should be used for patients who are expected to be ventilated for 24 h or more, and should be considered for patients with suspected cerebral neurological insult due to prolonged cardiac/respiratory arrest, stroke or heady injury; and facial swelling or lip/mouth pressure injuries. However, the unit's guideline for prone positioning states that ETADs are contra-indicated and ETT tapes should be used. Repositioning of ETTs is not done routinely, and is a two-person procedure, which is performed only following the written order of a medical officer. Hydrocolloid patches (Duoderm™) around the corners of the mouth and foam over the ETT tapes are used routinely, with ETT tapes changed at least daily. Most ETT-related DRPIs (76.8 %) were mucosal membrane injuries (lips, mouth, tongue). From the patient's perspective, it is somewhat fortunate that mucosal injuries heal relatively quickly compared to skin injuries [31] once pressure from the relevant device is relieved.

Stabilisation of the ETT is the most effective individual intervention to prevent DRPI with the use of ETADs reducing ETT-related PIs by around a half [32]. Several types of ETAD are available, with some incorporating a bite-block. In a relatively small study, Sun et al. [33] investigated three ETT fixation methods. Although they found a bite-block fixation device to be superior to an adhesive tape method, when the two methods were alternated on a daily basis the latter approach was superior in maintaining the ETT position. However, no differences were found in DRPIs between the three methods. In another study, two types of bite-block ETAD were compared: a traditional ETAD with device contact in the perioral area and a novel device with contact in the cheek facial area [34]. The incidence of DRPI was significantly lower with the novel device (7.8 % versus 33.3 %; $p = 0.001$), which was related to an absence of mucosal PIs on the lips. In a prospective observational study, 80 % of intubated patients developed a DRPI, however virtually all ETTs (99 %) were secured using tapes [35]. In that study, most (56 %) ETT-related DRPIs occurred within 3–4 days.

Several care bundles that are designed to prevent DRPI [36] as well as several general PI prevention bundles [37] include ETT-related interventions. In one bundle [38], use of an ETAD is specified in preference to ETT tapes and in the InSPiRE bundle [39] use of either tapes or an ETAD is advised but no rationale is provided for the choice of one or the other. However, whilst several bundles indicate that device fixation is fundamental to prevent PIs, the method of ETT securement is often not described e.g., the SKINCARE bundle [40] or is described using ETT tapes [41]. Several bundles indicate that the ETT should be repositioned regularly, although the frequency ranges from 2-hourly [41] to 6-hourly [38] or 12-hourly [39] or "more frequently than twice daily" [40]. In their systematic review, Moser et al. [32] concluded that there was no benefit to repositioning the ETT more frequently than 12-hourly, however this was based on the review of only two studies, of which one had a paediatric sample. In terms of positioning the ETT, in their study of the biomechanical effects of the ETT, Amrani and Gefen [42] concluded that neither the centre nor the side of the mouth was better but suggested that prophylactic use of cushioning pads was beneficial. However, there are many types of padding or cushioning dressings available and research into their efficacy is still in its early stages [43]. In general, the practical measures to prevent any type of DRPIs i.e., proper device selection, positioning and regular skin inspection [44] apply to the prevention of ETT-related DRPIs.

In our study, the mean APACHE II score of patients who developed an ICU-acquired PI was 20. Scores of $\geq$ 20 are associated with high mortality [45]. In terms of ICU case-mix, more severely ill patients are at greater risk of PI, especially those who are compromised haemodynamically [46]. In a recent systematic review and *meta*-analysis several risk factors were significantly associated with DRPI in ICU [47]. These included older age, higher APACHE II and SOFA scores and use of vasoconstrictors. These were amongst several factors investigated in our study. We found injury severity (APACHE II, APACHE 3 J, and SOFA admission scores) was significantly lower and a smaller proportion had diabetes in patients with DRPI compared to those with non-DRPI. However, there was no significant difference in age or vasopressors use between these groups. We also found that the incidence of cardiovascular disease, peripheral vascular disease and sepsis was lower in those with DRPI. However, the number of days treatment with ventilation, sedation, vasopressors, ECMO, IABP, and VAD was significantly less in those with DRPI. Further analysis of all ICU patients, including those that did not develop ICU-acquired PI, is required to determine the association of these factors with DRPI.

Limitations

As with all retrospective studies there is potential for missing data as well as human error in the original data entry. The PI data were collected across COVID pandemic years, which in Australia was from March 2020 until February 2022, therefore there is potential for patterns and incidence of DRPIs to have been influenced by this predominantly respiratory disease. In this context, due to limited data availability, the association between prone ventilation and ETT tape-related DRPI was not investigated; this should be considered for further research. Furthermore, it is possible that some ICU-acquired PIs may not have been reported via the clinical incident monitoring system and there was also potential for the PI category to change between the time it was reported to the time it was validated, although this was not apparent in our analysis. Also, estimates of time-to-PI are crude, as they are based on whole day measures. Finally, our results are historical and were derived from a single ICU, thus they are not generalisable to other settings.

Conclusions

The results from this study present a detailed analysis of DRPI in ICU, which can be used to benchmark these injuries in other ICUs nationally and internationally. The study shows a predominance of ETT-related DRPIs, which provides a clear focus for preventative interventions. In the main, the severity of DRPIs was lower than that of non-DRPIs, with the majority being mucosal and Stage 1 PIs. Factors associated with DRPI development are similar to those reported in other studies, however the results indicate that DRPIs tend to develop more quickly than non-DRPIs, emphasising the importance of early preventative intervention.

Ethical statement

Formal ethics approval was received from The Prince Charles Hospital Ethics Committee (reference: HREC/2021/QPCH/80804). Access to patient records for the purpose of the study was granted under section 284 of the Public Health Act (reference: PHA 80804.2).

CRediT authorship contribution statement

Paul Fulbrook: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Jacob Butterworth:** Writing – review & editing, Writing – original draft, Project administration, Investigation, Data curation.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.iccn.2025.103955.

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