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Prevalence, associated factors and outcomes of pressure injuries in adult intensive care unit patients: the DecubICUs study

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Abstract

Purpose: Intensive care unit (ICU) patients are particularly susceptible to developing pressure injuries. Epidemiologic data is however unavailable. We aimed to provide an international picture of the extent of pressure injuries and factors associated with ICU-acquired pressure injuries in adult ICU patients.

Methods: International 1-day point-prevalence study; follow-up for outcome assessment until hospital discharge (maximum 12 weeks). Factors associated with ICU-acquired pressure injury and hospital mortality were assessed by generalised linear mixed-effects regression analysis.

Results: Data from 13,254 patients in 1117 ICUs (90 countries) revealed 6747 pressure injuries; 3997 (59.2%) were ICU-acquired. Overall prevalence was 26.6% (95% confidence interval [CI] 25.9–27.3). ICU-acquired prevalence was 16.2% (95% CI 15.6–16.8). Sacrum (37%) and heels (19.5%) were most affected. Factors independently associated with ICU-acquired pressure injuries were older age, male sex, being underweight, emergency surgery, higher Simplified Acute Physiology Score II, Braden score < 19, ICU stay > 3 days, comorbidities (chronic obstructive pulmonary disease, immunodeficiency), organ support (renal replacement, mechanical ventilation on ICU admission), and being in a low or lower-middle income-economy. Gradually increasing associations with mortality were identified for increasing severity of pressure injury: stage I (odds ratio [OR] 1.5; 95% CI 1.2–1.8), stage II (OR 1.6; 95% CI 1.4–1.9), and stage III or worse (OR 2.8; 95% CI 2.3–3.3).

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Conclusion: Pressure injuries are common in adult ICU patients. ICU-acquired pressure injuries are associated with mainly intrinsic factors and mortality. Optimal care standards, increased awareness, appropriate resource allocation, and further research into optimal prevention are pivotal to tackle this important patient safety threat.

Keywords: Decubitus epidemiology, ICU, Pressure injury, Pressure ulcer, Outcome, Risk factors, Morbidity, Mortality

Introduction

Pressure injuries are localised lesions to the skin and/or underlying tissues due to pressure or pressure combined with shear [1, 2]. Often occurring at bony prominences, they can develop anywhere on the body. Predisposing factors include limitations in activity/mobility, deficiencies in nutrition and skin moisture, inadequate perfusion, and the use of mechanical devices that exert pressure on the skin [3, 4]. Frequently incorrectly considered a specific problem of long-term residents, they may develop as quickly as between the first hour and 4–6 h after sustained loading [5]. An international classification categorises the injuries into stages I–IV, Unstageable, and Suspected Deep Tissue Injury according to the extent of the tissue damage (Online Resource_2) [1, 2].

Pressure injuries cause pain and disability, compromise the quality of life [6], and extend the length of hospital stay by an average of 5–8 days per pressure injury [7]. By increasing the need for care resources they are a major economic burden for healthcare systems worldwide [8–10]. In the United States, the incremental hospital cost per patient of treating hospital-acquired pressure injuries is estimated at about US$10,708 and might exceed US$26.8 billion at the national level [11].

Patients residing in the intensive care unit (ICU) are extremely prone to developing pressure injuries due to their inherent immobility, haemodynamic instability, poor tissue perfusion and oxygenation, and to a plethora of complexly interacting intrinsic and extrinsic risk factors [12–14]. Additionally, they are highly exposed to medical devices [15]. Finally, medical and technological advances have generated a substantial ICU population of geriatric patients and long-term residents whose risk of developing pressure injuries might even be higher [16–18].

Despite the severity of the problem and the considerable unfavourable impact of these lesions on patient outcomes, patient care, and health economics, research interest in pressure injuries in the ICU population has remained restricted.

As a result, clear insight into the global epidemiology of pressure injuries in ICUs is still lacking [19]. A recent systematic review and meta-analysis on their occurrence in adult ICU patients found 10 studies published between 2002 and mid-2017 reporting cumulative incidences, and 12 providing prevalence data only [20]. Moreover, the included studies' outcomes showed large variability. Cumulative incidence ranged from 3 to 39.3%, prevalence from 11.5 to 32.7%. These large differences cannot currently be explained due to a lack of large study cohorts capable of dealing with the clinical heterogeneity that is typical for the ICU setting, and with variations in the availability of healthcare resources worldwide.

The objective of this study was to provide an up-to-date picture of the extent and factors associated with pressure injuries in a large, geographically diverse cohort of adult ICU patients. More specifically, we aimed to identify the overall and ICU-acquired prevalence according to geographic region and anatomical location; risk factors associated with ICU-acquired pressure injuries; and the association of pressure injuries with hospital mortality. We hypothesised that a number of the individual patient and ICU contextual factors will be associated with the development of pressure injuries in adult ICU patients.

Take-home message

Pressure injuries are common in adult ICU patients and ICU-acquired pressure injuries are associated with mainly intrinsic factors, and mortality. Increased clinical awareness, appropriate resource allocation, and further investigations into the pathophysiology of pressure injuries in critical illness and optimal prevention strategies for ICU patients are pivotal to tackle this important patient safety threat.

Methods

A full description is in Online Resource_3.

Study design and subjects

The Decubitus in Intensive Care Units study (DecubICUs) was a worldwide prospective, observational, 1-day point-prevalence study of pressure injuries among adult ICU patients with 12-weeks follow for survival status and length of hospital stay. All patients ≥ 18 years in ICU from 0:00 to 23:59:59 h on the study day were eligible; there were no exclusion criteria. DecubICUs was registered at ClinicalTrials.gov (NCT03270345).

Ethical approval

Overall, approval by established national, regional or local ethics committees and/or institutional review boards was granted.

Data collection

Data were collected on 15 May 2018. Alternative dates were set for Nigeria, Brazil and Libya due to delayed ethics approval. Anonymous patient data were collected by case report form. They encompassed demographic and admission data, and physiological data pertaining to the study day, including the severity of disease assessment by the Simplified Acute Physiology Score II (SAPS II) [21]. Pressure injury occurrence was measured by direct observation according to the international staging definitions [1, 2]. Pressure injury risk was assessed by the Braden scale that combines 6 subscales: mobility, activity, sensory perception, skin moisture, nutritional state, and friction/shear, with lower scores reflecting higher risk [22]. Follow-up data gathered were survival status, and length of ICU and hospital stay until hospital discharge or at 12 weeks following the study day (7 August 2018). The study protocol, including case and center report forms, is in Online Resource_4 and at https://www.esicm.org/research/trials/trials-group-2/decubicus/.

To maximise uniformity in reporting, we developed a training module with self-test on pressure injury staging (Online Resource_5) [1, 2] that was validated for content by 3 experts and published on the study website prior to study initiation. Registered participants were repeatedly encouraged to familiarise themselves with the module before data collection.

Data management

Quality and integrity of the reported data were checked. Missing, extreme or implausible values were returned to the local data collectors for review. Where data remained questionable, the primary investigators (SOL and SIB) made a final adjudication about study inclusion in mutual agreement. Missing values mutually judged eligible for inclusion were imputed with median values or deduced from other variables reported. Remaining missings were omitted from the analyses.

Statistical analyses

Analyses were performed at the patient level. Overall pressure injury prevalence was calculated as the proportion of the sample with at least one pressure injury on the study day, ICU-acquired prevalence as the proportion with at least one pressure injury acquired in ICU on the study day. Prevalence is reported as numbers (n) and percentages with 95% confidence intervals (CI). Continuous data are summarised by a median with interquartile range (IQR), categorical data as n (%). Univariate analyses used Chi square, Mann–Whitney U, and Kruskal–Wallis tests, as appropriate. Survival analysis was performed by Kaplan–Meier procedure (log-rank test). Associations with ICU-acquired pressure injuries were examined by generalized linear mixed-effects regression analysis with logit link function and a random effect for country. All variables were included following an exploratory approach, irrespective of univariate analyses results. As analyses did not focus on a prediction but on the identification of associations, feature selection was not applied, particularly as the risk of overfitting was minimised given the limited number of covariates ($n=24$ for pressure injury occurrence, $n=22$ for hospital mortality) and the adequate dataset size ($n=13{,}254$). Results are reported as odds ratios (OR) with 95% CIs.

Statistical analysis was performed using IBM SPSS 24.0 (IBM Corp., NY, US) and R statistical software 3.6.1 [23].

Results

Hospitals and patients

We recruited 1117 ICUs in 90 countries (6 continents). Most were mixed medical-surgical units ($n=729$; 65.2%) and in university hospitals ($n=675$; 60.4%). Median (IQR) hospital and ICU capacities were 600 (329–1035) and 13 (8–20) beds, respectively; 1005 (89.9%) data collectors had studied a training module on pressure injury staging, of which 920 (82.3%) the module developed for this project. Participation rates and ICU characteristics are in Online Resources_6 and 7, respectively.

Data from 13,254 patients were eligible for analysis. Their demographic characteristics are in Table 1, completeness of data in Online Resource_8.

Prevalence

We identified 6747 pressure injuries in 3526 patients, of which 3997 were ICU-acquired (59.2%; 2145 patients). Overall, 2081 patients had 1 pressure injury, 653 patients had 2, 411 had 3, and 381 had >3 pressure injuries; and 1284 patients had 1, 398 had 2, 243 had 3, and 220 had >3 ICU-acquired pressure injuries. Injuries were acquired before ICU admission in 1381 patients; developed in the ICU in 1922; and 233 patients developed injuries both before and during ICU stay.

Table 2 reports the overall and ICU-acquired prevalence across the 6 continents. A detailed breakdown per Stages and continents is in Online Resource_9. The overall prevalence was 26.6% (95% CI 25.9–27.3) with 18.0% (95% CI 17.3–18.6; $n=2383/13{,}254$) of stage II or worse. Overall stage II prevalence was 11.4% (95% CI 10.9–11.9),

stage III prevalence 4.2% (95% CI 3.9–4.6), and stage IV prevalence 2.0% (95% CI 1.7–2.2). Prevalence of Unstageable and Suspected Deep Tissue Injuries was 2.1% (95% CI 1.9–2.4) and 2.3% (95% CI 2.1–2.6), respectively.

ICU-acquired prevalence was 16.2% (95% CI 15.6–16.8), with 11.0% (95% CI 10.5–11.5) of stage II or worse. ICU-acquired stage II prevalence was 7.5% (95% CI 7.1–8); stage III prevalence 3.2% (95% CI 2.9–3.5), and stage IV prevalence 1.7% (95% CI 1.5–1.9). ICU-acquired prevalence of Unstageable and Suspected Deep Tissue Injuries was 2% (95% CI 1.7–2.2) and 2% (95% CI 1.8–2.3), respectively.

ICUs from low and lower-middle-income economies, where the mean percentage of gross national income spent on healthcare is least, reported the highest overall prevalence of pressure injuries (40.7%, 95% CI 36.7–44.8) and of ICU-acquired pressure injuries (27.7%, 95% CI 24.1–31.5; Online Resource_10).

The sacral region and heels were the most affected anatomical sites, accounting for 37 and 19.5% of all pressure injuries, respectively. Figure 1 shows numbers (percentages) of overall and ICU-acquired pressure injuries at the most affected body locations. A comprehensive overview of all body locations according to pressure injury staging is in Online Resource_11.

Factors associated with ICU-acquired pressure injuries

Generalized linear mixed-effects regression analysis identified the following factors as independently associated with ICU-acquired pressure injuries: older age, male sex, being underweight, admission due to emergency surgery, decreasing Braden scores, increasing ICU stay, chronic obstructive pulmonary disease, immunodeficiency, renal replacement therapy, mechanical ventilation on ICU admission, higher SAPS II score, and being in a low or lower-middle-income economy, with strongest, gradually increasing associations with worsening Braden scores and increasing length of ICU stay before the study day, respectively ($n = 12{,}533$; Table 3).

Hospital mortality

Overall hospital mortality was 22.5% (95% CI 21.8–23.3; $n = 2929/12\ 989$). Following adjustment for demographics and morbidity data, severity of pressure injury showed a gradually increased association with hospital mortality: OR 1.31 (95% CI 1.1–1.55) for stage I, OR 1.66 (95% CI 1.41–1.95) for stage II, and OR 2.31 (95% CI 1.96–2.71) for stage III or worse, i.e. stage IV, Unstageable, or Suspected Deep Tissue Injury ($n = 11\ 889$; Online Resource_12). Figure 2 reports survival distribution for patients with increasing severity of pressure injuries (i.e., no pressure injury, stage I, stage II, and stage III or worse; Log-rank test: $p < 0.001$).

Discussion

In this point-prevalence study encompassing 1117 ICUs in 90 countries across 6 continents and involving 13,254 adult patients, we found an overall pressure injury prevalence of 26.6% and an ICU-acquired prevalence of 16.2%. Although the prevalence was highest in low and lower-middle-income economies, our findings suggest that pressure injuries remain a considerable burden for healthcare systems worldwide, and highlight the necessity of additional efforts in patient safety initiatives.

These observational data confirm and reinforce previous findings resulting from meta-analysis [20]. Additionally, they are complementary to findings from systematic reviews aiming at determining risk factors for pressure injuries in ICU patients [12, 24–26]. These identified a broad range of factors including age, length of ICU stay, diabetes, mechanical ventilation, vasopressor support, hypotension, and cardiovascular disease, and suggest that an interplay of these factors increases the probability of pressure injury development. Our data, albeit resulting from cross-sectional research and thereby only representing the study day, are suggestive for associating pressure injury in ICU with a patient profile characterised by high vulnerability, as evidenced by the following findings. First, the occurrence of pressure injuries was associated with the Braden score, which summarises essential conditions that gradually contribute to a high-risk profile characterised by being bedridden, malnourished, incontinent, and with limited ability to react on or sense pain [22]. These conditions are characteristic for a majority of ICU patients and mirror an overall vulnerability level. Second, older age was independently associated with pressure injury occurrence. The steadily increasing proportion of very old ICU residents constitutes an overt influx of high-risk patients given the accumulation of chronic comorbidities, nutritional deficiencies, immobility, and aging skin [17, 18]. Third, an association was found with organ support (mechanical ventilation and renal replacement therapy), which implies a high severity of acute illness. Finally, this high-vulnerability profile is completed by the finding that patients who resided > 12 days in ICU before the study day had a 7.5-fold increased risk of ICU-acquired pressure injury compared to patients with a short ICU stay (≤ 3 days).

As such, our data suggest that the large majority of factors associated with pressure injury in ICU patients appear to be intrinsic or unmodifiable. This is in line with the unanimous agreement of experts that pressure injuries can be unavoidable in haemodynamically unstable or critically ill/injured individuals [27]. Our findings need validation, preferably in longitudinal studies. Prospective high-resolution data from smaller samples might

Table 1 Characteristics of included patients

Characteristic	All patients (*n* = 13,254; 100%)[a]	No pressure injuries (*n* = 9728; 73.4%)[a]	Pressure injuries (*n* = 3526; 26.6%)[a]	ICU-acquired pressure injuries (*n* = 2145; 16.2%)[a]
Age, years (M, IQR)	64 (51–74)	63 (50–74)	66 (54–75)	65 (53–74)
Sex (male)	8184 (61.8)	5923 (60.9)	2261 (64.1)	1414 (65.9)
Body Mass Index class[b]				
Underweight (< 18.5)	680 (5.1)	446 (4.6)	234 (6.6)	134 (6.2)
Normal weight (18.5–24.9)	5287 (39.9)	3944 (40.5)	1343 (38.1)	759 (35.4)
Pre-obesity (25–29.9)	4420 (33.3)	3259 (33.5)	1161 (32.9)	733 (34.2)
Obesity class I (30–34.9)	1713 (12.9)	1259 (12.9)	454 (12.9)	305 (14.2)
Obesity class II (35–40)	690 (5.2)	501 (5.2)	189 (5.4)	129 (6)
Obesity class III (> 40)	464 (3.5)	319 (3.3)	145 (4.1)	85 (4)
Mechanical ventilation on ICU admission	7369 (55.6)	5000 (51.4)	2369 (67.2)	595 (27.8)
Type of admission				
Medical	6501 (49)	4499 (46.2)	2002 (56.8)	1114 (51.9)
Elective surgery	29 (22.5)	2521 (25.9)	457 (13)	288 (13.4)
Emergency surgery	2609 (19.7)	1866 (19.2)	743 (21.1)	522 (24.3)
Trauma and burns	1066 (8.8)	842 (8.7)	324 (9.1)	221 (10.3)
Comorbidities				
Acquired Immune Deficiency Syndrome	56 (0.4)	35 (0.4)	21 (0.6)	16 (0.7)
Chronic Obstructive Pulmonary Disease	1663 (12.5)	1058 (10.9)	605 (17.2)	368 (17.2)
Malignancy	1509 (11.4)	1093 (11.2)	416 (11.8)	246 (11.5)
Cancer, solid tumour	1089 (8.2)	812 (8.3)	277 (7.9)	167 (7.8)
Metastatic cancer	378 (2.9)	280 (2.9)	98 (2.8)	47 (2.2)
Haematologic cancer	233 (1.8)	147 (1.5)	86 (2.4)	55 (2.6)
Immunocompromised	968 (7.3)	633 (6.5)	335 (9.5)	206 (9.6)
Corticosteroid therapy	449 (3.4)	271 (2.8)	178 (5)	106 (4.9)
Immunosuppression	444 (3.3)	279 (2.9)	165 (4.7)	107 (5)
Chemotherapy	313 (2.4)	228 (2.3)	85 (2.4)	55 (2.6)
Cirrhosis	433 (3.3)	314 (3.2)	119 (3.4)	60 (2.8)
Diabetes	2842 (21.4)	1913 (19.7)	929 (26.3)	534 (24.9)
Heart failure	1752 (13.2)	1132 (11.6)	620 (17.6)	373 (17.4)
Impaired mobility	1680 (12.7)	1067 (11)	613 (17.4)	311 (14.5)
Malnutrition	651 (4.9)	359 (3.7)	292 (8.3)	138 (6.4)
Peripheral vascular disease	662 (5)	408 (4.2)	254 (7.2)	146 (6.8)
Renal failure	1416 (10.7)	898 (9.2)	518 (14.7)	320 (14.9)
Simplified Acute Physiology Score II category[c]				
≤ 23	3473 (26.2)	2985 (30.7)	488 (13.8)	304 (14.2)
24–33	3335 (25.2)	2616 (26.9)	719 (20.4)	431 (20.1)
34–44	2955 (22.3)	1973 (20.3)	982 (27.9)	595 (27.7)
≥ 45	3491 (26.3)	2154 (22.1)	1337 (37.9)	815 (38.0)
Braden score category[d]				
Very high risk (≤ 9)	1448 (10.9)	849 (8.8)	599 (17)	53 (2.5)
High risk (10–12)	3928 (29.6)	2491 (25.8)	1437 (40.8)	365 (17)
Moderate risk (13–14)	2474 (18.8)	1743 (18.1)	731 (20.8)	463 (21.6)
Mild risk (15–18)	3689 (27.8)	3039 (31.5)	650 (18.5)	878 (41)
No risk (19–23)	1635 (12.3)	1534 (15.9)	101 (2.9)	383 (17.9)
Length of stay in ICU prior to study day (M, IQR)	4 (1–12)	3 (1–9)	10 (4–25)	13 (5–29)
Length of stay in ICU (M, IQR)	11 (4–28)	8 (3–21)	22 (10–46)	27 (13–52)
Length of stay from ICU admission to hospital discharge (M, IQR)	19 (9–40)	16 (8–33)	31 (15–57)	36 (19–62)

Table 1 (continued)

Characteristic	All patients (*n* = 13,254; 100%)[a]	No pressure injuries (*n* = 9728; 73.4%)[a]	Pressure injuries (*n* = 3526; 26.6%)[a]	ICU-acquired pressure injuries (*n* = 2145; 16.2%)[a]
Length of stay in hospital after study day (M, IQR)	12 (6–27)	10 (5–23)	17 (7–35)	19 (8–36)
Patients still in ICU 3 months after study day	178 (1.3)	129 (1.3)	49 (1.4)	30 (1.4)
Patients still in non-ICU ward 3 months after study day	781 (5.9)	531 (5.5)	250 (7.1)	171 (8)
Deceased during hospital stay	2929 (22.1)	1663 (17.1)	1266 (35.9)	812 (37.9)
28-days mortality	1751 (13.2)	1149 (11.8)	606 (17.2)	340 (15.9)

Results are expressed as number (percentages) if not differently indicated

ICU intensive care unit, *M* median, *IQR* interquartile range

[a] Totals may not sum to 13,254, 9728, 3526 and 2145, respectively, owing to missing values; an overview of the completeness of data is in Online Resource_8

[b] Body Mass Index is body weight in kilograms divided by body height in meters squared

[c] Range of possible scores is 0–163; a higher SAPS II score indicates a higher severity of disease and acute illness; scores are categorized according to the sample's quartiles

[d] Range of possible scores is 6–23

Table 2 Overall and ICU-acquired pressure injury prevalence according to continents

	All *n* = 13,254	Europe *n* = 5632	North America *n* = 1507	Latin, Central and South America *n* = 1040	Asia *n* = 4424	Africa *n* = 246	Oceania *n* = 405
	Number of patients (percentage) 95% confidence interval						
Overall prevalence	3526 (26.6) 25.9–27.3	1630 (28.9) 27.8–30.1	344 (22.8) 20.8–25	365 (35.1) 32.2–38.1	1047 (23.7) 22.4–25	84 (34.2) 28.5–40.1	56 (13.8) 10.8–17.5
ICU-acquired prevalence	2145 (16.2) 15.6–16.8	1124 (20) 18.9–21	200 (13.3) 11.7–15.1	237 (22.8) 20.3–25.4	495 (11.2) 10.3–12.2	52 (21.1) 16.5–26.7	37 (9.1) 6.7–12.3
Proportion ICU-acquired prevalence (%)	60.8	69.0	58.1	64.9	47.3	61.9	66.1

Results are expressed as number of patients (percentages) and 95% confidence interval if not differently indicated. Online Resource_9 reports more detailed information distributed for distinct pressure injury Stages

ICU intensive care unit

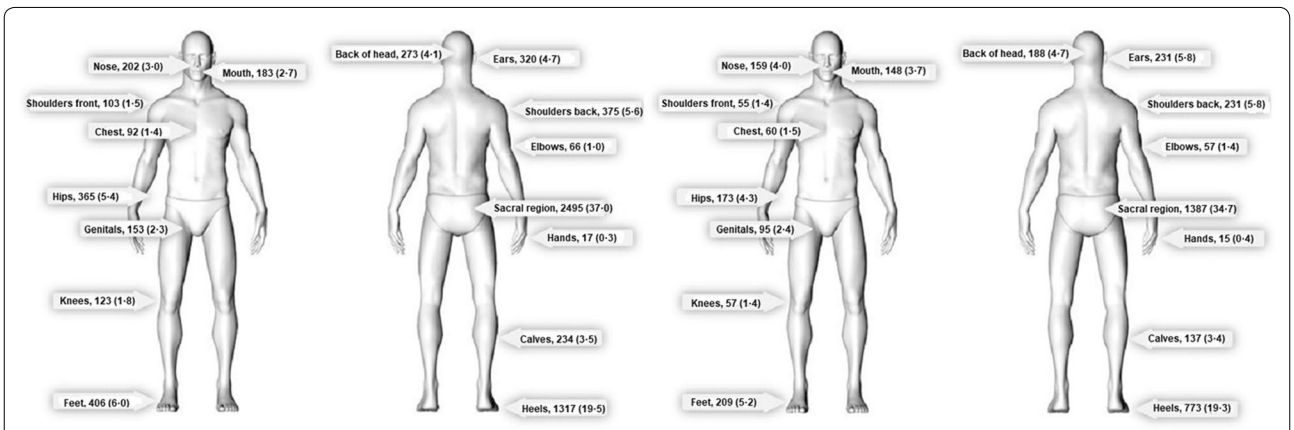

Fig. 1 Anatomical locations of pressure injuries (most affected body sites). Left: Numbers (percentages) of overall pressure injuries — total number of pressure injuries = 6764. Right: Numbers (percentages) of intensive care unit-acquired pressure injuries — total number of pressure injuries = 3997

Table 3 Factors independently associated with ICU-acquired pressure injury

Variable	Odds ratio	95% confidence interval
Admission type: medical	1.15	0.94–1.4
Admission type: elective surgery	1.02	0.8–1.29
Admission type: emergency surgery	1.28	1.04–1.58
Age	1.005	1.0007–1.009
Male sex	1.21	1.08–1.36
Body Mass Index		
18.5–24.9: normal weight	Reference	
< 18–5: underweight	1.58	1.23–2.01
25–29.9: pre-obesity	1.03	0.9–1.17
≥ 30: obesity	0.98	0.84–1.14
Risk of pressure injury		
Braden score 19–23: no risk	Reference	
Braden score 15–18: mild risk	2.91	1.81–4.68
Braden score 13–14: moderate risk	5.23	3.25–8.42
Braden score 10–12: high risk	6.52	4.07–10.44
Braden score ≤ 9: very high risk	9.72	6.01–15.71
Acquired immune deficiency syndrome	1.52	0.74–3.11
Cirrhosis	0.89	0.65–1.22
Chronic obstructive pulmonary disease	1.24	1.03–1.49
Diabetes	1.05	0.92–1.2
Heart failure	1.07	0.92–1.25
Immunocompromised	1.27	1.04–1.55
Malignancy	0.95	0.8–1.14
Peripheral vascular disease	1.19	0.95–1.51
Days in ICU before study day		
0–3 days	Reference	
4–6 days in ICU before study day	2.28	1.90–2.74
7–9 days in ICU before study day	3.57	2.91–4.37
10–12 days in ICU before study day	4.12	3.29–5.17
> 12 days in ICU before study day	7.51	6.42–8.78
Mechanical ventilation on admission	1.26	1.11–1.43
Sedation	0.95	0.82–1.09
Muscle relaxant use	1.08	0.83–1.41
Vasopressor use	1.04	0.91–1.2
Renal replacement	1.34	1.14–1.58
Simplified Acute Physiology Score II score	1.006	1.002–1.01
Number of patients per nurse	0.91	0.83–0.99
Economy[a]		
High-income economy	Reference	
Upper-middle income economy	1.09	0.65–1.85
Low- + lower-middle income economy	1.82	1–3.29

[a] Economy: categorised according to the 2016 World Bank classification (https://data.worldbank.org/indicator/SH.XPD.CHEX.GD.ZS)

also identify additional modifiable factors not sought in this study. A hint that these may exist is the lower prevalence reported in Asia where increased awareness may have been prompted by previous large-scale initiatives on this topic. Until such data is generated, the variables we identified can at least be used to flag patients who might benefit from greater vigilance for pressure injuries. Also research into pressure injury pathophysiology and prevention specifically directed towards the heterogeneous ICU population is recommended.

Another factor independently associated with pressure injury was being in a low or middle-low income

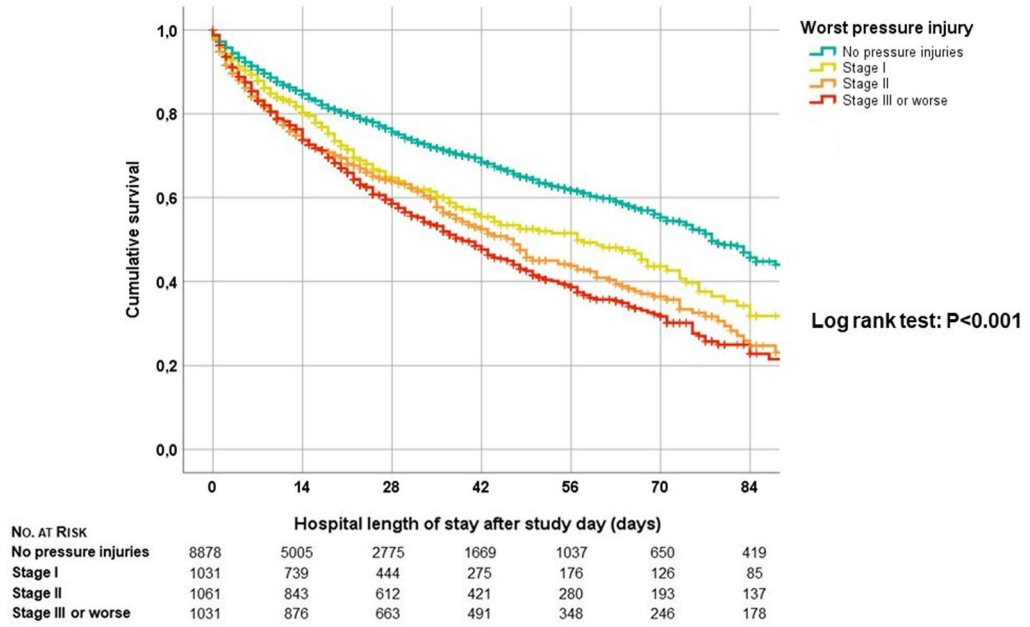

Fig. 2 Kaplan–Meier estimates of overall survival according to pressure injury status on the study day among adult intensive care unit patients. Green line indicates patients without pressure injuries; yellow line indicates patients whose worst pressure injury is of stage I; orange line indicates patients whose worst pressure injury is stage II; red line indicates patients whose worst pressure injury is stage III or worse (i.e. stage IV or Unstageable or Suspected Deep Tissue Injury). Tick marks indicate censored data (hospital discharge before 12 weeks). Log-rank test: $p < 0.001$

economy ICU. Limited availability of human and material resources may contribute to this finding, as the mean percentage of gross national income spent on healthcare in these economies is less than half as compared with high-income economies (4.9% versus 10.3%). Additionally, pressure injury prevention might not be a healthcare priority in developing countries.

Manzano and co-workers [28] identified pressure injury as a significant independent predictor of mortality in mechanically ventilated patients (adjusted hazard ratio 1.28; 95% CI 1.003–1.65; $p = 0.047$). The mortality associated with pressure injuries remains however unclear. As their occurrence often mirrors a generally debilitated condition and high severity of acute illness, an association with mortality seems reasonable. However, our regression analysis demonstrated a gradual increase in mortality with increasing severity of pressure injuries despite adjustment for these covariates. Even though this does not imply causality, this observation calls for clinical concern towards patients presenting with pressure injuries or those at high-risk for developing such complications.

Stage I pressure injuries are generally considered reversible if promptly identified and appropriately managed [13] and, therefore, often excluded from scientific reports [19]. They were nevertheless shown to be prone to deterioration, as in 6 Dutch acute care hospitals where 22.1% worsened to a deeper lesion [29]. In line with several earlier prevalence reports [29], the majority of pressure injuries in our study were of stage I (38.1%). These currently often underreported injuries, however, emerged from our analyses as independently associated with hospital mortality, which calls for considering these lesions as full quality indicators and for the standardized recording of this data in institutional and research reports.

This study has limitations. The cross-sectional design might have resulted in bias toward patients who have long ICU stays [30]. Since the length of stay is associated with pressure injury risk, the reported prevalence might not be representative for the entire ICU population. Our data only represents a snapshot at the study day and cannot account for potentially influencing factors such as staffing levels. Data on pressure injuries on mucosal surfaces have not been collected as these are not staged by the international staging system [4]. Not all geographic regions are well-represented, thus impeding globally generalized results. As pressure injuries might be considered as a result of suboptimal care, fear of criticism or institutional censure may have hampered objective reporting. If so, the actual prevalence might be higher than the rates identified. Accurate assessment of pressure injury staging is challenging and data collectors were not required to be qualified tissue viability experts.

Despite our efforts to obtain consistency in reporting using a well-documented data collection procedure and providing a training module, variability and errors in staging may have occurred. Given the scale of the study, it was however not feasible to assess the validity of the data using digital photographs. Nevertheless, the error resulting from our approach will if anything have led to random error in estimations, rather than a systematic error. We were unable to doublecheck the self-reported number of participants who indicated having studied the training module, which may be prone to social desirability bias. As we requested to report the number of 'nurses' on the study day, without further definition, we do not know whether assistant-nurses were also reported and included in the calculation of the number of patients-per-nurse. The unexpected association of this variable with pressure injury also needs further exploration. There is a view that Suspected Deep Tissue Injuries should not be included in epidemiological studies because it is unclear how many are actual deep tissue injuries that convert to pressure injuries. Their number was however small and unlikely to have substantial impact, if any, on the estimated prevalence. Finally, our study may be prone to random observer errors as data collectors depended on the reliability of patient files to determine whether a pressure injury was ICU-acquired.

The major strength is that it is the first to present a worldwide picture of the epidemiology of pressure injuries in adult ICU patients and to map a high-risk profile based on a large global sample. It may act as an incentive for tackling this patient safety issue and provide local and regional baseline data for quality improvement programmes. Furthermore, pressure injuries staging was assessed by the gold standard of skin inspection by trained outcome assessors, and the study used a rigorous protocol with clear attention to detail in standardising the data collection process.

Conclusions

This observational study identified a quarter of ICU patients with pressure injuries albeit with considerable regional variation in prevalence. However, approximately 60% of the patients developed these lesions in ICU irrespective of the regional prevalence. As pressure injuries are a common complication and a substantial burden for healthcare systems worldwide, their prevention deserves increased clinical awareness and appropriate resource allocation. Besides, further investigations into the pathophysiology of pressure injuries in critical illness and into optimal prevention strategies for ICU patients are pivotal to tackle this important patient safety threat.

Electronic supplementary material
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Author contributions
SOL and SIB prepared the first draft. SOL, SIB and MD analysed the data. GF managed study registrations and the online platform for data collection. SJB, WC, AKK, and LS provided first internal reviewer feedback. All authors provided data, developed models, reviewed results, provided guidance on methods, and reviewed the manuscript. SOL, SIB and MD finalised the manuscript on the basis of comments from all authors. All authors approved the final version. SOL, SIB, and GF had full access to all the data in the study. SOL and SIB had final responsibility for the decision to submit for publication.

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Availability of data and material
Study protocol, statistical analysis plan, and informed consent forms will be shared upon request with any researcher. Local DecublCUs investigators have the right to use the data collected from their respective units. National data can be obtained and used by the DecublCUs National Representatives upon proof of written consent from the local investigators. The complete DecublCUs database is only transferred to the primary investigators, SOL and SIB. They cannot share the database as they are bound to a broad variety of Data User Agreements. Information requests are to be addressed to stijn.blot@ugent.be and sonia.labeau@hogent.be.

Compliance with ethical standards

Conflicts of interest
Received honoraria or grants outside the submitted work: Ashish K. Khanna (Medtronic, Philips North America, Edwards Lifesciences, Zoll Medical, La Jolla pharmaceuticals, and Retia Medical). Stijn I. Blot (Pfizer, 3M). Leif Saager (Medtronic, Merck, The 37 Company, Ferrer Deutschland). For the other authors, there are no conflicts of interest.

Code availability
Not applicable.

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