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Exploring the impact of traumatic injury on mortality: An analysis of the certified cause of death within one year of serious injury in the Scottish population

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ABSTRACT

Background: Few studies effectively quantify the long-term incidence of death following injury.
The absence of detailed mortality and underlying cause of death data results in limited understanding and a potential underestimation of the consequences at a population level. This study takes a nationwide approach to identify the one-year mortality following injury in Scotland, evaluating survivorship in relation to pre-existing comorbidities and incidental causes of death.
Study Design: This retrospective cohort study assessed the one-year mortality of adult trauma patients with an Injury Severity Score ≥ 9 during 2020 using the Scottish Trauma Audit Group (STAG) registry linked to inpatient hospital data and death certificate records. Patients were divided into three groups: trauma death, trauma-contributed death, and non-trauma death. Kaplan-Meier curves were used for survival analysis to evaluate mortality, and cox proportional hazards regression analysed risk factors linked to death.
Results: 4056 patients were analysed with a median age 63 years (58–88) and male predominance (55.2 %). Falls accounted for 73.1 % of injuries followed by motor vehicle accidents (16.3 %) and blunt force (4.9 %). Extremity was the most commonly injured region overall followed by chest and head. However, head injury prevailed in those who died. The registry demonstrated a one-year mortality of 19.3 % with 55 % deaths occurring post-discharge. Of all deaths reported, 35.3 % were trauma deaths, and 47.7 % were trauma-contributed deaths. These groups accounted for over 70 % of mortality within 30 days of hospital admission and continued to represent the majority of deaths up to 6 months post-injury. Patients who died after 6 months were mainly the result of non-traumatic causes, frequently circulatory, neoplastic, and respiratory diseases (37.7 %, 12.3 %, 9.1 %, respectively). Independent risk factors for one-year mortality included a GCS ≤ 8, modified Charlson Co-morbidity score >5, Injury Severity Score >25, serious head injury, age and sex.
Conclusion: With a one-year mortality of 19.3 %, and post-discharge deaths higher than previously appreciated, patients can face an extended period of survival uncertainty.
As mortality due to index trauma lasted up to 6 months post-admission, short-term outcomes fail to represent trauma burden and so cogent survival predictions should be avoided in clinical and patient settings.

Introduction

Accounting for approximately 8 % of global deaths annually[1], traumatic injury is recognised as a significant public health challenge and cause of death worldwide. Current literature focuses on in-hospital and 30-day mortality following trauma in accordance with the Utstein criteria[2] for trauma analysis. However, several studies evaluating trauma systems have demonstrated a persistent increased risk of mortality for years following injury[3–10].

Over a 14-year period, Davidson et al. reported a 2.7 % increase in

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cumulative death rate post- discharge despite in-hospital deaths decreasing by 3.1 %[9]. A further study by Kuorikoski and colleagues[8] outlined the long-lasting effects of major blunt trauma with repercussions persisting 12 years after index hospitalisation, and mortality rates over double the general population average. Consequently, the classic trimodal distribution of trauma mortality described by Trunkey and colleagues[11] has come under question in recent years. Santry et al. reported that of the 67 % of individuals surviving their index hospitalisation, 6.6 % died within the first year of discharge which correlates with a fourth peak in a 'quadrimodal' pattern of mortality[6]. Therefore, the current short-term outcome measures used in reports may be viewed as insufficient to appreciate the substantial long-term impact of injury on a patient, health system and society, and its implications that justify investment in trauma systems.

Throughout the literature the underlying cause of death is a commonly omitted variable; difficulties with follow-up, data linkage, and the absence of standardised cause of death certification[6-10,12,13] hinders the full analysis and evaluation of trauma burden on society. In the year following injury, loss of life as a direct consequence of trauma has been documented between 4 %–33 %[3–5]. Claridge et al. demonstrated that death within the first year of injury was most likely related to trauma, whilst chronic diseases are shown to have a more prevalent influence on the population, in particular the elderly cohort, in the years thereafter[4].

As existing studies are primarily based in level one trauma centres, a gap exists for a large- scale study to measure and quantify the long-term implications of injury. We aimed to identify the true one-year mortality of adult patients who sustained severe injury in Scotland, and to evaluate survivorship in relation to other comorbidities and incidental causes of death.

Study objectives

The primary objective of this study was to assess the one-year mortality rate in the adult population following a traumatic injury in Scotland. Secondary outcomes included 30-day outcome, 6-month outcome, all-cause one year mortality following injury, and risk factors associated with death.

Methods

Study design

This was a retrospective multicentre observational study of trauma patients who were admitted to hospital for a serious injury (ISS $\geq$ 9) in Scotland between January 1, 2020, and December 31, 2020. A retrospective analysis of prospectively collected clinical data from the Scottish Trauma Audit Group (STAG)[14] national trauma registry was completed. This included eligible patients admitted to any of the 28 hospitals with an emergency department in Scotland as per criteria found on the STAG website[15]. In cases of trauma recidivism, whereby a patient has multiple admissions during the study time period, the index admission was utilised if criteria were satisfied.

Throughout this study trauma refers to a physical injury to the body from an extrinsic force, and its subsequent sequelae.

Specific Criteria for this study were as follows:

Inclusions

- Patients admitted during the 2020 calendar year and entered into the STAG audit

Exclusions

- Patients < 16 years of age
- ISS < 9
- Pre-hospital death
- Burns, drowning, hanging and/or poisoning
- Isolated upper or lower limb injury
- Pathological fracture(s)

Patient injuries were coded in accordance with the Abbreviated Injury Scale (AIS)[19], enabling calculation of the Injury Severity Scores (ISS)[20]. Deaths were ascertained by linking the STAG 2020 registry cohort with inpatient hospital data (SMR01)[16,17] and the appropriate certified cause of death records as previously described. Cause of death was documented according to the international classification of diseases, tenth revision, clinical modification codes (ICD10)[18].

Study participants were divided into 3 separate groups to determine the potential factors linked to death:

- Group 1: Trauma death
- Group 2: Trauma-contributed death
- Group 3: Non-trauma death

All included patients had one primary underlying cause of death listed on their death certificate with up to ten contributary causes. If an injury code was detailed as the underlying cause of death or one of the contributary causes on the death certificate, participants were placed into Group 1 or Group 2 respectively. If injury was not coded, the patient was categorised as a Non-trauma death.

Data linkage

Fig. 1 details the process of data linkage between non-survivors in the e-STAG database with their respective death certificate information from the National Records of Scotland using Community Health Index (CHI) numbers. The majority of deaths were linked using a patient's Unique Patient Identifier (UPI), with 1 % (n = 41) linked requiring manual look-up. Two individuals could not be successfully linked to their underlying cause of death using either method, and therefore they were excluded from the final analysis.

Data analysis

Continuous variables were reported as mean values and standard deviations if normality was demonstrated, with comparisons using a two-tailed t-test. Otherwise, variables were presented as median values with interquartile range. Categorical variables were reported as numbers and percentages, with comparisons using the Chi-squared test.

Kaplan-Meier curves were produced to outline the crude death rate within one year of trauma in the overall dataset, and within the 3 assigned subgroups. Based on these empirical survival functions, the death rates of each group were compared and tested for significance using log rank tests. Cox proportional hazards regression analysis was used to assess the association between potential risk factors and survival including age, sex, presence of a serious head trauma (AIS > 3) and comorbidities using the modified Charlson Co-morbidity Index (mCCI). Graphs of the negative log of the estimated survivor function against time, and the log of the negative log of the estimated survivor function against log time were used to test for non-proportionality. All variables demonstrating univariate significance were included in the final multivariate model. Group analyses were conducted to examine the impact of trauma recidivism.

Significance was declared when p-values from two-sided tests was < 0.05. Data analysis was performed using IBM SPSS statistics version 24.0 for Windows (IBM, Inc, Somers, NY).

Missing data

As this study collected patient data upon hospital admission and death over a one-year period, missing data were anticipated due to loss

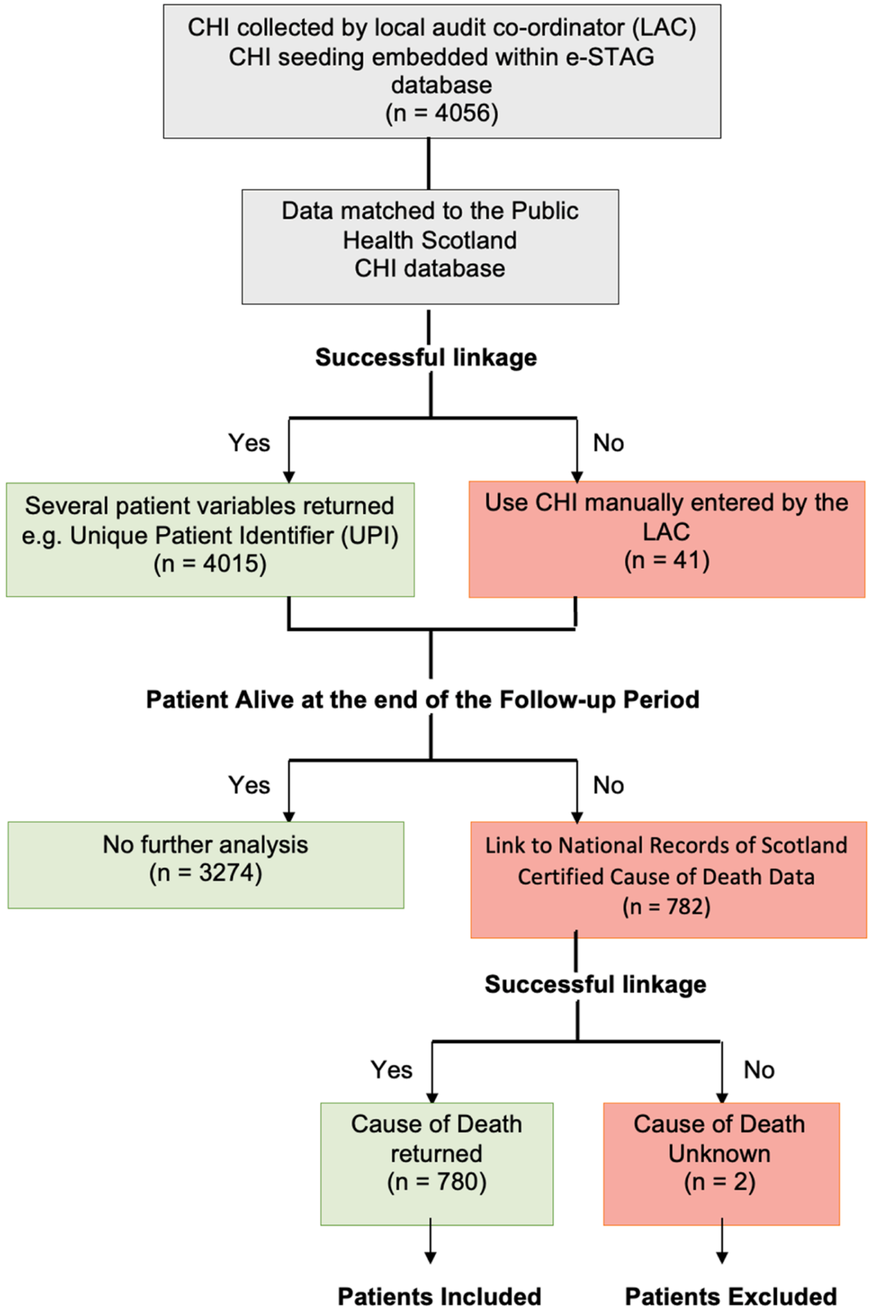

Fig. 1. Flow chart displaying the process of data linkage between the Scottish Trauma Audit Group (STAG) database and the National Records of Scotland. *CHI: Community Health Index number, LAC: Local audit co-ordinator, ISD: Information Services Division, UPI: Unique patient identifier.*

to follow-up. Not all patients met the primary outcome measure of death within one year and so right censoring became apparent which was appropriately accounted for in the Kaplan Meier curves.

Ethical conduct of the study

Ethical approval was granted by the STAG Steering Group and Public Health Scotland's Data Protection team. All health data and information collected was handled and managed in accordance with the General Data Protection Regulation (GDPR) and the Data Protection Act 2018. Data was fully anonymised prior to release.

Patient and public involvement

Patients and the public were not involved in the study's design, conduct, or reporting.

Results

During the study period, the STAG trauma registry comprised of 5932 patients. Of these, 4056 (68.4 %) adults had an Injury Severity Score (ISS) $\geq$ 9 and were subsequently included in the study. There were 30 patients with two trauma incidents and therefore they had multiple entries in the registry database; the most recent admission was selected for inclusion if criteria were met. Patient inclusion is illustrated in Fig. 2. Within the overall cohort, 782 (19.3 %) patients died within a year of index trauma hospitalisation, with 429 (54.8 %) dying post-discharge.

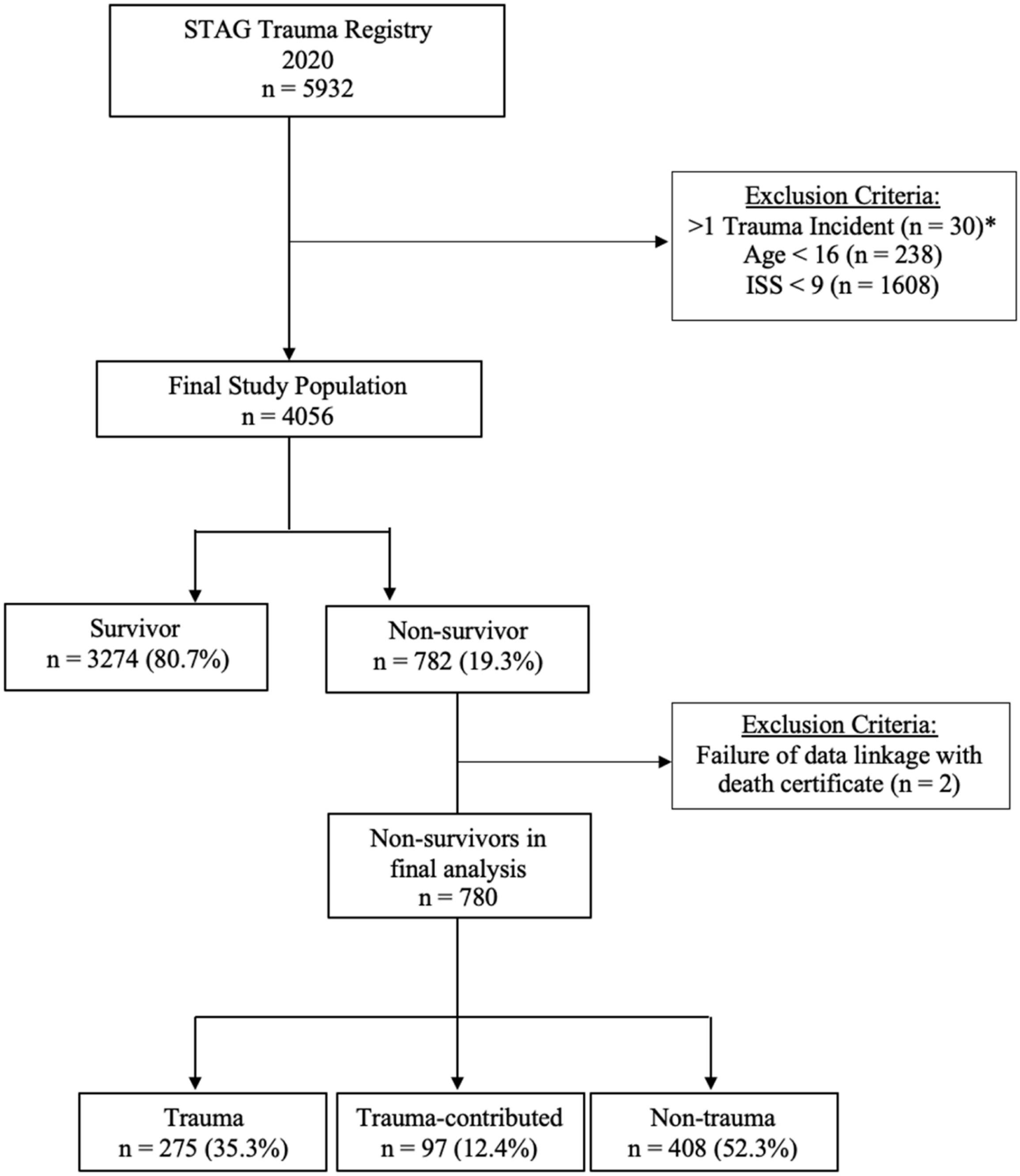

Fig. 2. Flow diagram of patient inclusion and subsequent patient groups.
** 30 patients had two trauma incidents accounting for 60 incidents in the database. The most recent trauma admission for the 30 patients was included in the study.*

Study group characteristics

Patient demographics are illustrated in Table 1. The median age of the trauma population was 63 (IQR 49, 80) and the patients were predominantly male (55.2 %). The most common mechanism of injury was a fall, which accounted for 73.1 % of injuries in the study population, followed by motor vehicle accidents (16.3 %) and other blunt force injuries (4.9 %).

Overall, patients had a median ISS of 10 (IQR 9, 16); 73 % of patients sustained a moderate injury, whilst 8.7 % of patients sustained a very severe injury with an ISS > 25.

1047 (25.8 %) of the registered trauma patients obtained a Head AIS > 3, of whom 8.9 % died within the follow-up period. The median length of hospital stay was 9 days with a mean of 11.6 days (SD 8.9).

When comparing demographics between survivors and non-survivors, there was no significant difference in Sex, Scottish Index of Multiple Deprivation (SIMD) and Age.

73 % (570) non-survivors were > 65 years old with a median age of 80 (64, 87). They had often sustained a more severe head injury (46% vs 21 %, $p < 0.001$), and had more profound injuries with a total ISS > 25 (19.8% vs 6.0 %, $p < 0.001$).

Cause of death determination

When examining the underlying cause of death in the overall study population, the highest incidence of mortality resulted from falls (60.4 %), followed by motor vehicle accidents (14.5 %) and exposure to an unspecified factor (10.9 %). Of all patients with a fall-related injury

Table 1
Demographics, physiology and injury characteristics of STAG 2020 adult trauma registry patients.

	Trauma registry (n = 4056)		Survivor (n = 3274)		Non-survivor (n = 782)		P -value
Demographics							
Male, n (%)	2239	(55.2)	1828	(55.8)	411	(52.6)	0.117
Age, n (%)							
≤ 45	888	(21.9)	824	(25.2)	64	(8.2)	< 0.001
46 - 55	507	(12.5)	456	(13.9)	51	(6.5)	
56 - 65	808	(19.9)	711	(21.7)	97	(12.4)	
66 - 75	543	(13.4)	449	(13.7)	94	(12.0)	
76 - 85	731	(18.0)	500	(15.3)	231	(29.5)	
> 85	579	(14.3)	334	(10.2)	245	(31.3)	
SIMD Quintile, n (%)*							
1	1084	(26.7)	889	(27.2)	195	(24.9)	0.172
2	915	(22.6)	725	(22.1)	190	(24.3)	
3	712	(17.6)	560	(17.1)	152	(19.4)	
4	651	(16.1)	538	(16.4)	113	(14.5)	
5	578	(14.3)	459	(14.0)	119	(15.2)	
Unknown	116	(2.9)	103	(3.1)	13	(1.7)	
Physiology							
GCS ≤ 8, n (%)	241	(5.9)	100	(3.1)	141	(18.0)	< 0.001
Mean Arterial Pressure, mean (± SD)	88.3	(±36.3)	88.5	(±35.5)	87.3	(±39.8)	0.412
Modified Charlson Comorbidity, n (%)*	1311	(32.3)	1220			(11.6)	< 0.001
0	1766	(43.5)	1426	(37.3)	91	(43.5)	
1 - 5	955	(23.5)	611	(43.6)	340	(44.0)	
> 5	24	(0.6)	17	(18.7)	344	(0.9)	
Unknown				(0.5)	7		
(continued): Demographics, physiology, injury severity and characteristics of STAG 2020 adult trauma registry patients							
	Trauma registry (n = 4056)		**Survivor** (n = 3274)		**Non-survivor** (n = 782)		**P - value**
Injury Characteristics							
Mechanism of Injury, n (%)							< 0.001
Moving vehicle accident	660	(16.3)	602	(18.4)	58	(7.4)	
Fall	2964	(73.1)	2293	(70.0)	671	(85.8)	
Crushing force	18	(0.4)	17	(0.5)	1	(0.1)	
Mechanical threat to breathing	1	(0.0)	1	(0.0)	0	(0.0)	
Penetrating force	106	(2.6)	95	(2.9)	11	(1.4)	
Blunt force	197	(4.9)	181	(5.5)	16	(2.0)	
Blast	4	(0.1)	4	(0.1)	0	(0.0)	
Shot	2	(0.0)	2	(0.1)	0	(0.0)	
Other	19	(0.5)	16	(0.5)	3	(0.4)	
Unknown	57	(1.4)	42	(1.3)	15	(1.9)	
Not Recorded	28	(0.7)	21	(0.6)	7	(0.9)	
ISS, n (%)*							
9 −15	2959	(73.0)	2501	(76.4)	458	(58.6)	< 0.001
16 - 25	745	(18.4)	576	(17.6)	169	(21.6)	
> 25	352	(8.7)	197	(6.0)	155	(19.8)	
Serious Injury per body region (AIS ≥ 3), n (%)							
Head and neck	1047	(25.8)	686	(21.0)	361	(46.2)	< 0.001
Face	32	(0.8)	28	(0.86)	4	(0.51)	0.412
Chest	1143	(28.2)	946	(28.9)	197	(25.2)	< 0.001
Abdomen	167	(4.5)	147	(4.5)	20	(2.6)	0.081
Extremity	1539	(37.9)	1314	(40.1)	225	(28.8)	< 0.001
External	13	(0.3)	10	(0.31)	3	(0.38)	0.001
Spinal	342	(8.4)	273	(8.3)	69	(8.8)	0.025

* Percentages may not equal 100 due to rounding.

(2964), 10.6 % died within 30 days ($p < 0.001$) with a median age of 80 (IQR, 67–87). Of those who died, 372 (47.7 %) had an injury code on their death certificate, with 275 (35.3 %) trauma deaths and 97 (12.4 %) trauma-contributed deaths reported. In the remaining Non-trauma group, the leading causes of death were circulatory disease (37.7 %), neoplasms (12.3 %) and respiratory disease (9.1 %). When compared to the overall Scottish population, neoplasms (26 %) and circulatory disease (24 %) were the two most frequent causes of death, followed by COVID-19, which remained lower in the trauma registry population (9.5% vs 5.9 % respectively). Table 2 outlines the underlying causes of death for the trauma registry population, the non- trauma group and the 2020 Scottish population according to ICD-10.

In the Trauma group, the median time from admission to death was 4 days (IQR 1, 9); patients were younger (median 76 years), had lower consciousness levels (38.2 % with GCS ≤ 8, $p < 0.001$), greater incidences of serious head injury (57.1 %, $p < 0.001$) and sustained more severe injuries overall with 42.2 % demonstrating an ISS > 25 compared to 7.2 % and 7.6 % in Group 2 and 3 respectively (Table 3).

Long-Term mortality outcomes

4056 patients underwent a 365-day follow-up period from index trauma hospitalisation. Non-survivors demonstrated a cumulative mean survival of 78.5 days (95 % CI, 71.5 – 85.6) and median survival of 30 days (IQR 4, 121) following traumatic injury using Kaplan-Meier analysis. There was no significant difference demonstrated between male and female patients ($p = 0.2$) using the log-rank test but significance was evident between those of different ISS categories ($p < 0.001$) as detailed

Table 2
Cause of Death distribution for the STAG 2020 Trauma Registry population and Non-trauma group compared to the overall Scottish population in 2020[[21]].

Cause of Death (ICD10)	Deceased Scottish Population 2020 $N = 63{,}859$*		Deceased Trauma Registry Population $N = 780$		Non-Trauma Group $N = 408$	
Neoplasms, n (%)	16,659	(26.1)	58	(7.4)	50	(12.3)
Infectious disease, n (%)	753	(1.2)	11	(1.4)	10	(2.5)
Circulatory system disease, n (%)	15,332	(24.0)	177	(22.7)	154	(37.7)
Respiratory system disease, n (%)	5466	(8.6)	47	(6.0)	37	(9.1)
Endocrine, nutritional, and metabolic disease, n (%)	1478	(2.3)	10	(1.3)	8	(2.0)
Disease of blood / blood-forming organs, n (%)	130	(0.2)	2	(0.3)	2	(0.5)
Mental or Behavioural disorder, n (%)	4247	(6.7)	33	(4.2)	26	(6.4)
Nervous system and sense organs	4126	(6.5)	28	(3.6)	18	(4.4)
Digestive system disease, n (%)	3371	(5.3)	33	(4.2)	25	(6.1)
Disease of skin and subcutaneous tissue, n (%)	185	(0.3)	2	(0.3)	2	(0.5)
Musculoskeletal or Connective tissue, n (%)	410	(0.6)	7	(0.9)	5	(1.2)
Genitourinary system disease, n (%)	1035	(1.6)	9	(1.2)	8	(2.0)
Congenital malformation, n (%)	137	(0.2)	2	(0.3)	0	(0.0)
External cause of morbidity and mortality, n (%)	3691	(5.8)	297	(38.1)	19	(4.7)
COVID-19, n (%)	6048	(9.5)	46	(5.9)	26	(6.4)
Other ‡, n (%)	790	(1.2)	18	(2.3)	18	(4.4)

*Adjusted for inclusion criteria excluding pregnancy and perinatal disease.
† Percentages may not equal 100 due to rounding.
‡ Other includes ICD-10 codes for symptoms and signs not otherwise classified (R00-R99).

Table 3
Characteristics of non-survivors stratified by cause of death group.

	Trauma ($n = 275$)	Trauma-contributed ($n = 97$)	Non-trauma ($n = 408$)
Age, y, median (IQR)	76 (58, 86)	81 (73, 88)	82 (67, 87)
Male sex,%	59.6	49.5	48.8
ISS,%			
9 - 15	33.8	80.4	70.3
16 - 24	24.0	12.4	22.1
≥ 25	42.2	7.2	7.6
Head AIS ≥ 3,%	57.1	25.8	43.4
GCS on admission,%			
≤ 8	38.2	6.2	7.4
> 8	60.7	92.8	91.9
Unknown	1.1	1.0	0.7
Mean Arterial Pressure, mean ± SD	100 ± 24	97.8 ± 22	101 ± 20
Comorbidity Score, median (IQR)	4 (1, 7)	6 (3, 9)	6 (3, 10)
LOS, median (IQR)	4 (1, 9)	12 (5, 24)	11 (5, 19)
Days to death, median (IQR) *	4 (1, 14)	37 (6, 27)	93 (26, 218)

* Kaplan Meier Curve analysis.

in Fig. 3.

The overall trauma registry population demonstrated a 24-hour mortality of 3 %, with a 30-day, 180- day and 1-year mortality of 9.7 %, 15.9 % and 19.3 %, respectively.

The trauma and trauma-contributed death groups accounted for 72.6 % of mortality within 30 days of admission; these two groups continued to account for the majority of deaths up to 6 months from injury according to death certificate data. In contrast, patients who died after 6 months died more frequently from non-traumatic causes. A comprehensive breakdown of death distribution stratified by subgroup is illustrated in Table 4.

In the Trauma group, the median survival was 4 days (IQR, 1 – 14 days) following injury compared to 37 days (IQR 6, 72 days) for the Trauma-contributed group and 93 days (IQR, 26, 218 days) for the Non-trauma group ($p < 0.001$). Overall median survival of the three groups was reported as 30 days (IQR 22, 38 days). Kaplan-Meier analysis for the three subgroups is conveyed in Fig. 4.

Risk factors for death within one year of trauma admission

In survival analyses of the overall study population, Age, ISS, Head injury AIS > 3, Modified Charlson Co-morbidity Index (mCCI) > 1, and a GCS < 13 were statistically significant univariable predictors of one-year mortality following serious injury (Table 5). In multivariable analyses, a GCS ≤ 8 during admission (HR 8.92, 95 % CI 7.03–11.32) illustrated a strong statistically significant and clinically relevant risk factor for mortality at one year with more than eight times the mortality risk of an independent subject. An ISS > 25 was also deemed an independent risk factor for death (HR 2.52, 95 % CI 1.99–3.64, $p < 0.001$) and was associated with a poorer prognosis in the overall study population.

Subgroup analysis: trauma recidivism

30 patients experienced more than one trauma incident during the study period of whom 5 were excluded from subgroup analysis as their most recent trauma admission failed to meet the ISS ≥ 9 criteria.

Of these 25 patients with trauma recidivism, 17 (68 %) were male with a median age of 64 years (IQR, 50–77). Cox regression conveyed repeated episodes of trauma as a statistically significant univariable risk factor for death at one year (HR 2.1, 95 % CI 1.1- 4.0, $p = 0.029$) compared to the overall trauma population studied. Trauma recidivists had a median length of stay of 12 days (IQR, 6–21) and reduced mean survival of 261 days compared to 311 in the overall dataset, but this was not statistically significant ($p = 0.25$).

Discussion

Accurate trauma mortality and morbidity statistics are crucial in understanding the significance of injury burden on society and ensuring optimal trauma care and rehabilitation. Current literature surrounding trauma mortality is limited regarding certified cause of death. This is the first comprehensive national data linkage study performed in Scotland describing one-year mortality following a serious injury. This study's unique use of death certificate data categorises patients according to their underlying cause of death, with an additional trauma-contributed death category not previously defined.

Early deaths due to trauma predominate, as observed in previous studies[3,6,12]. With a median survival of 30 days, this is an appropriate survival outcome measure for trauma analysis of severely injured patients in support of other studies[3]. However, a substantive increase in mortality exists after discharge, with almost a quarter of trauma and trauma-contributed deaths occurring after 30 days. Rather than simply reporting results after 30 days, a set of additional measures are required to adequately describe the lasting impact on life and healthcare resource.

Deaths continue to occur regardless of the timing of trauma, emphasising short-term mortality benchmarks as a poor reflection of the true burden injury poses. Previous studies have demonstrated that older patients with chronic medical conditions, and reduced physiological reserve, are less likely to recover quickly from injury compared to

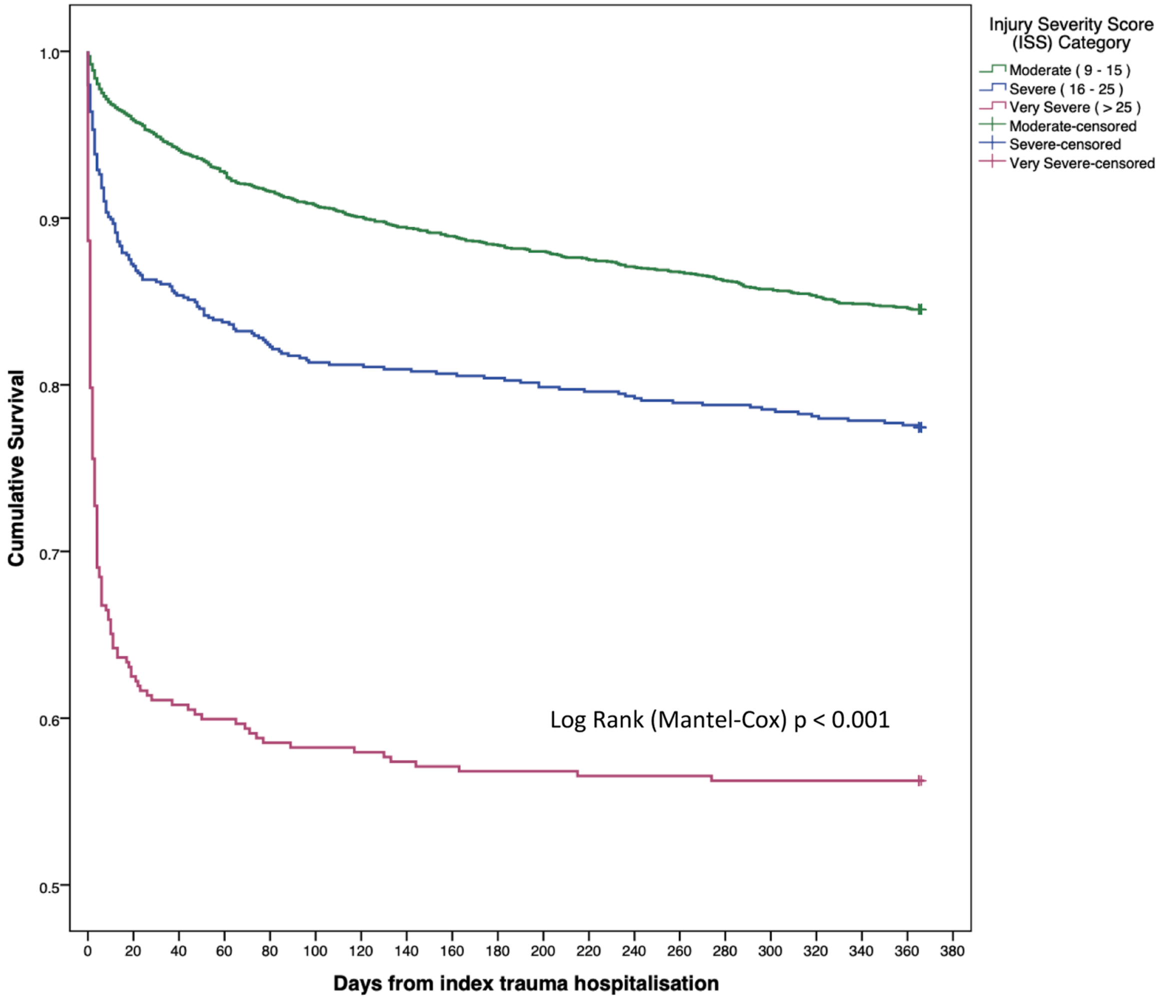

Fig. 3. Kaplan-Meier survival curve demonstrating the one-year survival of the 2020 STAG cohort of traumatically injured adult patients stratified by ISS.

Table 4
Cumulative time to death and location stratified by cause of death subgroups compared to overall cohort of non-survivors.

Timing, n (%)	Trauma (n = 275)		Trauma-contributed (n = 97)		Non-trauma (n = 408)		Non-survivors (N = 782[†])	
24 h	91	(33.1)	6	(6.2)	24	(5.9)	122	(15.6)
30 - day	239	(86.9)	45	(46.4)	107	(26.2)	393	(50.3)
180 - days	269	(97.8)	93	(95.9)	280	(68.6)	644	(82.4)
365 - days	275	(100)	97	(100)	408	(100)	782	(100)
Location, n (%)[*]								
In-hospital	226	(82.2)	38	(39.2)	83	(20.3)	349	(44.6)
Post-discharge	46	(16.7)	59	(60.8)	324	(79.4)	429	(54.8)
Unknown	3	(1.1)	0	(0.0)	1	(0.2)	4	(0.5)

[*] Percentages may not equal 100 due to rounding.
[†] Two non-survivors could not be linked to underlying cause of death and therefore are not included in Groups 1 – 3.

younger individuals of different injury patterns [22,23]. Current literature has reported mortality rates in older patients as high as 52.4 % within a year from index trauma [24], yet uncertainty remains regarding the significance of the trauma itself, or in fact its subsequent sequalae on function, cognition, mobility and increased frailty risk.

With often fragmented outpatient care, greater attention should be placed on the development and integration of trauma support services and rehabilitation programmes post-discharge; this is an often neglected, but critical component of comprehensive trauma care [25–27]. The overriding causes of death, out-with trauma, in our patient cohort matched that of the general Scottish population during 2020 [21] including neoplasms, cardiovascular disease and COVID-19. A more comprehensive statistical analysis of the data would be required to test the significant variance in age and sex. Performing a separate analysis of men and women in appropriate age brackets would better reflect the study populations. Following hospitalisation and the systemic insult of injury, patients often become deconditioned and have a reduced physiological reserve upon discharge; this results in a population at greater risk of morbidity and mortality than recognised. Compelling evidence exists demonstrating a correlation between organised trauma systems, rehabilitation and a reduction in mortality risk [28,29]; if extended to an outpatient setting, this may have the potential to further reduce trauma

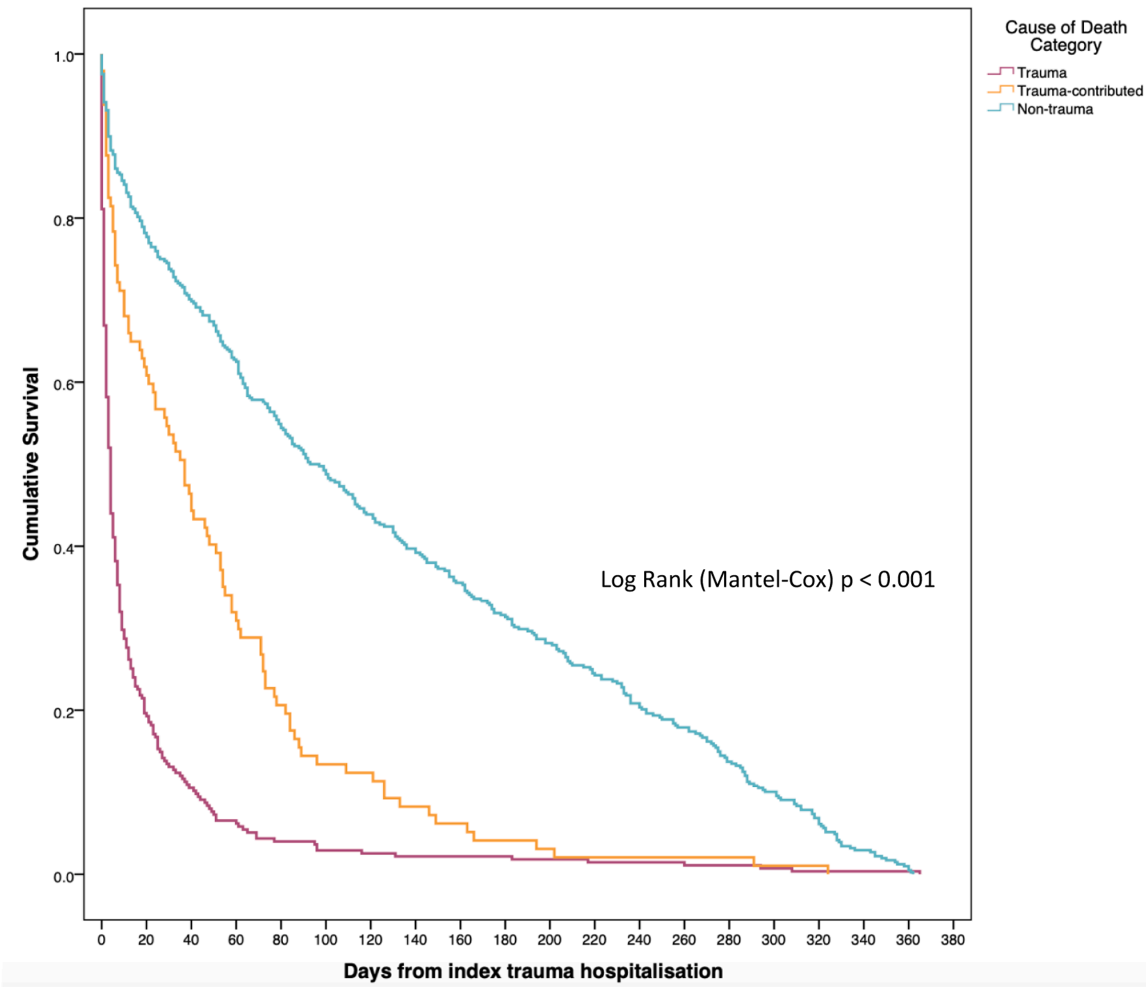

Fig. 4. Kaplan-Meier survival curve of the 2020 STAG cohort of traumatically injured adult patients who died within 365 days post-trauma hospitalisation stratified by underlying cause of death subgroup: Trauma, Trauma-contributed and Non-trauma.

Table 5
Cox regression survival analysis output of the risk factors associated with one year mortality following traumatic injury hospitalisation.

	Univariable Coefficient (B)	HR	95 % CI	p-value	Multivariable Coefficient (B)	HR	95 % CI	p-value
Male sex	−0.089	0.92	0.80–1.05	0.216	0.16	1.17	1.01–1.37	0.033
Age (years)	0.039	1.04	1.03–1.04	< 0.001	0.04	1.05	1.04–1.05	< 0.001
ISS Category								
9–15 (ref)	0.46	1.58	1.32–1.88	< 0.001	0.35	1.42	1.17–1.72	< 0.001
16–25	1.39	4.02	3.35–4.82	< 0.001	0.92	2.52	1.99–3.20	< 0.001
> 25				< 0.001				< 0.001
Head AIS ≥ 3	1.08	2.94	2.56–3.39	< 0.001	0.22	1.25	1.05–1.49	0.012
GCS Score								
13–15 (ref)	1.17	3.21	2.51–4.11	< 0.001	1.03	2.79	2.15–3.64	< 0.001
9–12	1.93	6.85	5.70–8.25	< 0.001	2.19	8.92	7.03–11.32	< 0.001
3–8				< 0.001				< 0.001
Modified Charlson Co-morbidity Index								
0 (ref)	1.08	2.94	2.33–3.71	< 0.001	0.71	2.03	1.60–2.60	< 0.001
1–5	1.80	6.09	4.79–7.61	< 0.001	1.14	3.14	2.46–4.01	< 0.001
> 5				< 0.001				< 0.001

and trauma-contributed deaths.

A multitude of limitations are placed on rehabilitation access related to need, injury type, age, and geography both during the study and in pre-COVID times. In the absence of a national rehabilitation network, these services remain sparse throughout the UK, with significant variations in practice. The military service has exhibited exceptional outcomes with rigorous rehabilitation programmes, demonstrated at the Defence Medical Rehabilitation Centre (DMRC)[30], Stanford Hall, with improvements in function, pain, quality of life and mental health for service users. If applied nationally, early, and intensive rehabilitation may improve patient outcomes whilst reducing societal costs incurred through ongoing long-term NHS treatment, social care use and work and education absences. The extension of these services to the wider NHS population may therefore prove beneficial on a systemic and societal scale. Due to the sparse services existing pre-COVID, it is not believed the pandemic further impacted our results from this perspective.

Furthermore the number of trauma registry patients in this study has not significantly deviated from previous years despite changes to every day routine during the COVID-19 period. The mechanisms of injury detailed in this study are largely consistent with pre-COVID times. Falls remained the most common injury and cause of death at all time points in our study in line with previously published literature[5,22,31]. With a slight 3–9 % increase in falls incidence compared to STAG annual reports from 2017 – 2019[32–34], motor vehicle accidents reduced by 2 – 5 % in our study. This mechanism change may have potentially reduced the overall mortality expected in our population. Giudici et al.[35] document similar injury patterns during the pandemic with a 10 % increase in admissions from unintentional falls, and a 25 % reduction due to motor vehicle accidents ($P < 0.05$). No further changes were evident in our data compared to pre-COVID years other than injury location, with a greater proportion of injuries occurring within the home compared to previously published data. These patterns likely reflect reduced car usage and lockdown restrictions imposed during this timeframe.

As our data consists primarily of older age groups, one must consider the increased risk of deconditioning and reduced community healthcare access in this cohort. Impacting mobility, cognition and concurrent health surveillance, this may have played a role in the increased incidence of falls and subsequent hospital admissions. With a notable contribution to mortality, fall-associated factors such as frailty, polypharmacy, and sarcopenia[24,36] may also play an influential role in our data. However, this remains unmeasured and highly speculative. A recent report by *Pecheva* et al.[36] using data from the Trauma Audit and Research Network (TARN) illustrated a significant relationship between frailty and mortality amongst major trauma patients over the age of 60. Those with a high frailty score experienced twice the mortality risk at one year compared to those with low frailty scores (51% vs 26.2 %, $p < 0.001$).

Strengths and limitations

Published literature on trauma mortality primarily focuses on level 1 trauma centres[4,7,10,13] which tend to have a more significant proportion of younger patients than lower-level trauma centres introducing a degree of bias. In contrast, our study utilises detailed information on patient demographics, injury characteristics, and hospital outcomes throughout the country, eliminating geographical bias. Attaining high-quality certified cause of death records is a well-established challenge in trauma literature. This report obtained high calibre death certificate data from the National Records of Scotland, which undergoes independent appraisal by Health Improvement Scotland [37].

The study's retrospective nature has resulted in several inherent constraints. Only factors recorded within the registry database could be explored, whilst other health factors such as smoking status, and frailty scores were unavailable despite potential significance. A finite number of variables were analysed, in accordance with current literature, via Cox regression, and several crucial parameters may be absent. We did not wish to create a prediction model but aimed to identify risk factors of late mortality. With a large study population, minor differences can appear statistically significant. Therefore, when interpreting our findings clinical significance should be taken into consideration before drawing any conclusions. Length of hospital stay is a commonly used factor in other studies [4-6,9], but as this is only recorded in the database for a maximum of 30 days, it may be biased towards those who die early, and so it was excluded alongside ITU admission and ventilation.

Like other studies[6,12,13], deaths in the pre-hospital setting are excluded due to stringent inclusion criteria imposed by STAG. This introduces a degree of systematic error in ascertaining severe trauma cases, especially when out-of-hospital deaths contribute a significant burden to trauma mortality, accounting for one-third of Scottish trauma deaths in 2016[38]. This limitation may underestimate the total number of trauma deaths in the population, further strengthening the conclusions drawn. However, many pre-hospital deaths are a result of unsurvivable injuries and or occurred in difficult circumstances for ambulance service transportation, restricting quantification. Geographical, patient and injury-related characteristics may reduce the comparability of our findings to those of other populations. Therefore, to inform clinical practice and trauma recovery schemes, there remains a need for greater exploration of the underlying causes of death in this patient cohort across different nations, with varying health care policies and systems. Further effort should be made to include pre-hospital deaths and exploration of functional outcome measures after a serious injury. This study did not investigate these key factors, which could supplement our understanding of patient prognosis and mortality risks. Despite limitations, this study may aid clinicians in understanding the emerging phenomenon of the quadrimodal distribution of trauma mortality.

Conclusion

With a 30-day and 365-day trauma mortality of 9.7 % and 19.3 %, respectively, our novel approach to data linkage addresses previous challenges faced when acquiring accurate trauma mortality statistics. Two important conclusions can be drawn from this study.

First, an extended period of survival uncertainty has been exhibited in this patient population with mortality due to index trauma lasting up to 6 months post-hospitalisation. Short-term survival outcomes are therefore not reflective of trauma burden and so cogent survival predictions should be avoided in the clinical and patient setting.

Second, over 65 s represent the bulk of deaths in the trauma population as seen in previous years; in the absence of concrete frailty data, further studies are required to appropriately delineate a valid connection between frailty and trauma mortality.

CRediT authorship contribution statement

Hannah A Craig: Formal analysis, Writing – original draft, Writing – review & editing. **David J Lowe:** Writing – review & editing. **Angela Khan:** Conceptualization, Project administration. **Martin Paton:** Data curation, Resources. **Malcolm WG Gordon:** Conceptualization, Project administration, Writing – review & editing.

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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