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Mortality after hospital admission for trauma in Norway: A retrospective observational national cohort study

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ABSTRACT

Background: National quality data for trauma care in Norway have not previously been reported. We have therefore assessed crude and risk-adjusted 30-day mortality in trauma cases after primary hospital admission on national and regional levels for 36 acute care hospitals and four regional trauma centres.
Methods: All patients in the Norwegian Trauma Registry in 2015–2018 were included. Crude and risk-adjusted 30-day mortality was assessed for the total cohort and for severe injuries (Injury Severity Score ≥16), and individual and combined effects of health region, hospital level, and hospital size were studied.
Results: 28,415 trauma cases were included. Crude mortality was 3.1% for the total cohort and 14.5% for severe injuries, with no statistically significant difference between regions. Risk-adjusted survival was lower in acute care hospitals than in trauma centres (0.48 fewer excess survivors per 100 patients, $P<0.0001$), amongst severely injured patients in the Northern health region (4.80 fewer excess survivors per 100 patients, $P = 0.004$), and in hospitals with <100 trauma admissions per year (0.65 fewer excess survivors than in hospitals with ≥100 admissions, $P = 0.01$). However, the only statistically significant effects in a multivariable logistic case mix-adjusted descriptive model were hospital level and health region. Case-mix adjusted odds ratio for survival for severely injured patients directly admitted to a trauma centre vs. an acute care hospital was 2.04 (95% CI 1.04–4.00, $P = 0.04$), and if admitted in the Northern health region vs. all other health regions was 0.47 (95% CI 0.27–0.84, $P = 0.01$). The proportion of cases admitted directly to the regional trauma centre in the sparsely populated Northern health region was half of that in the other regions (18.4% vs. 37.6%, $P<0.0001$).
Conclusion: Differences in risk-adjusted survival for severe injuries can to a large extent be attributed to whether patients are directly admitted to a trauma centre. This should have implications for planning of transport capacity in remote areas.

Background

Trauma is a major cause of death and disability worldwide, and is the leading cause of life-years lost in people under the age of 44 years in high-, middle- and low-income countries [1]. Norway is a sparsely populated Scandinavian country [2]. It is amongst the highest-ranking countries in the Human Development Index and in terms of per-capita income, with universal and decentralised health care and a comprehensive social security system [3]. Here, traumatic deaths accounted for almost half of deaths in people under the age of 45 years in 2015–2018

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[4].

The Norwegian national trauma system consists of four health regions, each with a single regional trauma centre and several acute care hospitals. In 2013 there were approximately 7000 annual trauma team activations (TTA) in Norwegian hospitals for admitting potentially seriously injured patients, 4500 in acute care hospitals and 2500 in trauma centres [5].

To date, no complete assessment of mortality after injury in Norway has been published. Thus, it is not known whether patients admitted to an acute care hospital have different mortality from those admitted directly to a trauma centre, whether differences in mortality exist between health regions, and which severe injuries are most frequent amongst non-survivors. In this study we therefore aimed to describe any such differences of importance to the development of regional and national trauma services.

Methods

Design

The study is a retrospective observational cohort study on prospectively collected data provided by the Norwegian Trauma Registry (NTR). We adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement for cohort studies [6].

Study setting

The mainland of Norway covers an area of 385,178 km^2 and had 5165,000 inhabitants in the index year of 2015 [2]. The Norwegian trauma system model consists of four regional trauma systems, each with one regional trauma centre and several acute care hospitals (Fig. 1). The regional trauma centres are similar to the level I and II trauma

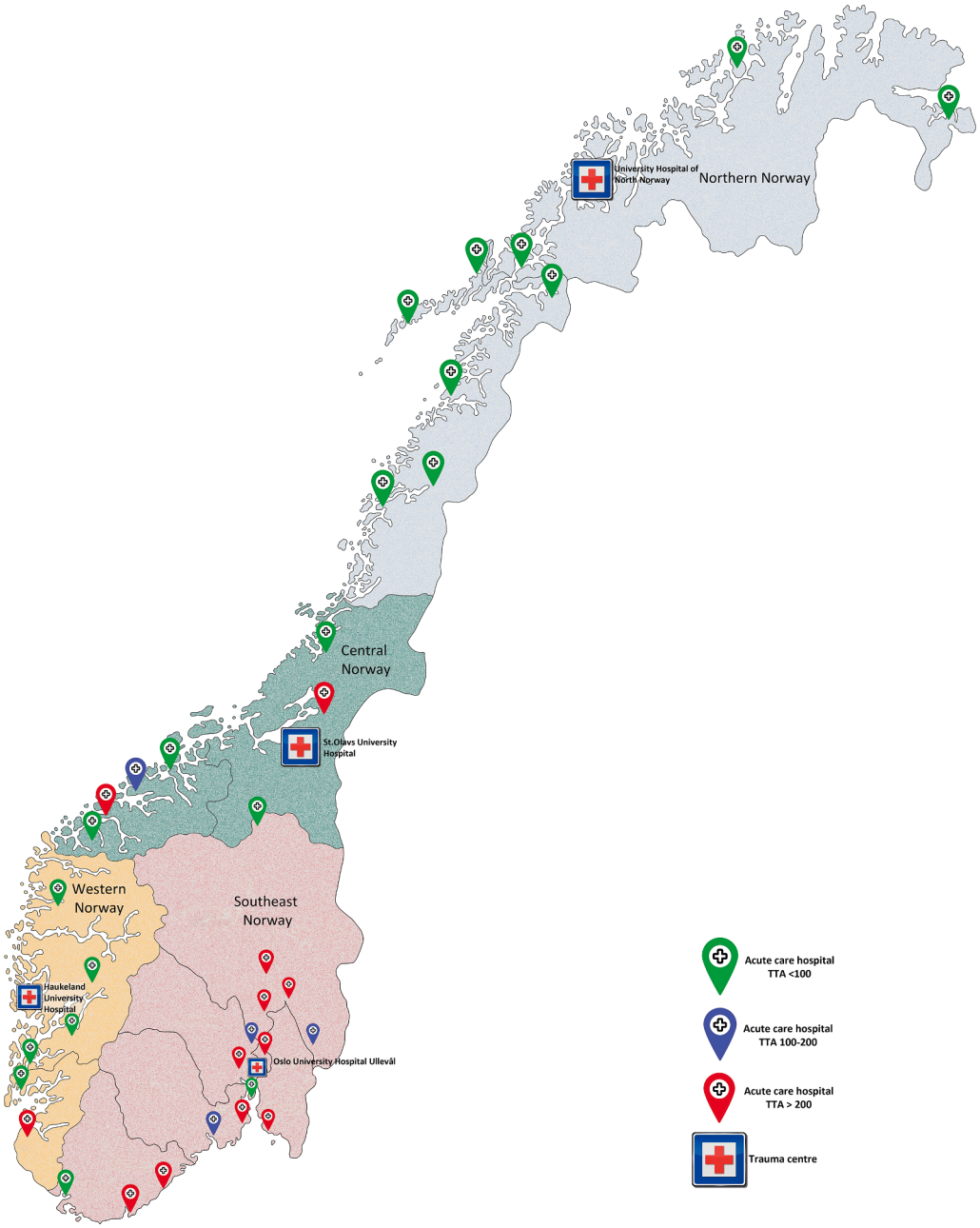

Fig. 1. Map of mainland Norway with health regions, trauma centres and acute care hospitals. Acute care hospitals are colour coded according to number of trauma team activations (TTA) per year.

centres described by the American College of Surgeons - Committee on Trauma (ACS-COT) [7]. The 36 acute care hospitals all have 24-hour general surgical services and the capabilities to stabilise trauma patients before transfer to the trauma centre if needed [5]. The majority of the acute care hospitals are similar to the level III centres described by ACS-COT [7]. However, the range of medical specialities offered in acute care hospitals varies from general surgery only to almost all specialties offered in a trauma centre. Patients with severe traumatic injuries are recommended managed in hospitals with neurosurgical expertise [8], which is only available in the regional trauma centres and in one large acute care hospital. At the time of the study, no external accreditation system existed for the two hospital levels.

Norway has an extensive and uniform ambulance service, which includes a 19-aircraft helicopter emergency service (HEMS) manned with anaesthesiologists and 9 ambulance planes, in addition to car and boat ambulances, all with readiness 24 h a day [9]. All ambulance services adhere to the national trauma plan and have identical requirements for staffing and training.

The Norwegian national trauma plan

The Norwegian National Trauma Plan was implemented in 2007 and updated in 2016 [10]. The trauma plan has specific requirements to e.g., equipment, skills, competence and readiness from the first responders at the site of the accident, transport, acute care hospitals, trauma centres, and rehabilitation. Its goal is to provide health service with good and equal quality despite differences in geography, time of day and year, and severity of injuries. It also requires all hospitals admitting trauma patients to have the same criteria for TTA.

Norwegian trauma registry (NTR)

The NTR has collected national data since 01.01.2015 [11]. It includes all patients admitted with TTA, as well as all patients with penetrating injury to the head, neck, torso and extremities proximal to elbow or knee, all patients with New Injury Severity Score (NISS) >12, and all patients with a head injury with Abbreviated Injury Score (AIS) severity code ≥ 3, regardless of TTA. The NTR excludes patients with chronic subdural haematoma without any other trauma-related injuries and patients with injuries from drowning, inhalation and asphyxia without concomitant trauma, unless they were admitted with TTA. Patients without TTA who fulfil the inclusion criteria are identified from hospital charts. Association for the Advancement of Automotive Medicine (AAAM) certified registrars in each hospital enter all data and classify all injuries according to The Abbreviated Injury Scale (AIS) 2005 Update 2008 [12]. The NTR has a coverage of 100% of hospitals admitting trauma patients and >85% of individual trauma patients [13].

Inclusion criteria

All patients admitted in a Norwegian hospital in the period 01.01.2015–31.12.2018 and registered in the NTR were eligible for inclusion.

Variables

Primary outcome was 30-day mortality after first admission to hospital, by hospital, hospital level and health region, assessed with three different methods: total mortality, mortality for patients with Injury Severity Score (ISS) ≥ 16 [14], and excess survivors per 100 patients (W statistic) [15]. Each patient was assigned a value corresponding to gained or lost fractional life by subtracting that patient's calculated probability of survival from the actual outcome, where 1 represented survival and 0 death. Excess survivors per 100 in a patient group was calculated as the mean (with 95% confidence interval) of this value multiplied by 100. Probability of survival was calculated according to the NORMIT 2 model [16], which is based on anatomical injury represented as NISS, physiological derangement as Triage Revised Trauma Score (T-RTS, the unweighted sum of the individual Revised Trauma Score components), comorbidity according to pre-injury American Society for Anaesthesiologists Physical Status Classification System (ASA-PS) score, and age as a continuous variable [17,18]. Survival status at 30 days was obtained by the NTR from patient records and the Norwegian National Population Register. The other variables consisted of demographic data including pre-injury ASA-PS score, all individual AIS codes, overall anatomical injury severity quantified as ISS and NISS [19], and data on hospital level and health region.

Trauma cases were constructed from separate records for individual hospital stays. Each trauma case in the NTR has a unique numeric identifier which follows that patient across all hospital stays. A patient will be assigned a new unique identifier for each new trauma case. Records from individual hospital stays constituting a trauma case were sorted according to dates and times for admission and discharge and merged. Admission hospital characteristics and T-RTS values were obtained from the first hospital in a case, whereas pre-injury ASA-PS, mechanism of injury, AIS codes, ISS and NISS were obtained from trauma centre stays when they existed, or else from the first hospital stay. Total length of ICU and hospital stay was summed across individual hospital stays in a case.

Statistical analyses

Data analysis was undertaken with JMP Pro 16.2.0 and 17.1.0 (SAS Institute, Cary, NC). Missing data were not imputed. Fisher's Exact test and Wilcoxon Rank Sums test were used to assess differences between groups of patients.

Effects of a set of explanatory variables on survival were evaluated in generalized linear mixed models (JMP Pro 17.1) with 30-day survival as binary response variable and hospital for primary admission as random effect. Fixed effects were the primary admission hospital's health region (Northern vs. all other health regions), level (trauma centre vs. acute care hospital), and average number of primary trauma admissions with ISS ≥ 16 per year in the study period. Case-mix adjustment was performed on a per-patient basis by including as a fixed effect the value of the linear predictor from the NORMIT 2 model [16], computed from the individual patient's actual values. Results are reported for the whole population, and for the subgroups ISS <16 and ISS ≥ 16.

Effect sizes and odds ratios (OR) from logistic regression analyses as well as excess survivors per 100 patients are reported with 95% confidence intervals (CI), all other results are reported as count with% or as median with 25th and 75th percentile if not otherwise stated. Statistical significance was assumed for two-tailed $P < 0.05$.

Ethics

The study was approved by the Regional Patient Data Protection Officer at the University Hospital of North Norway Tromsø (Ref. No. 2017/0687) and the Regional committee for medical and health research ethics North (Ref. No. 2018/991). All patients included in the NTR receive written information about the NTR, including the opportunity to apply for access to their recorded data and the possibility to anonymise their data.

Results

Records from 33,428 hospital stays in four trauma centres and 36 acute care hospitals constituting 32,004 trauma admissions were provided from the NTR (Fig. 2). Cases without coded injuries or without known 30-day survival status were excluded, leaving a total of 28,415 included trauma cases.

Characteristics of the total case population and split by health region are given in Table 1. There was a clear overweight of males, cases

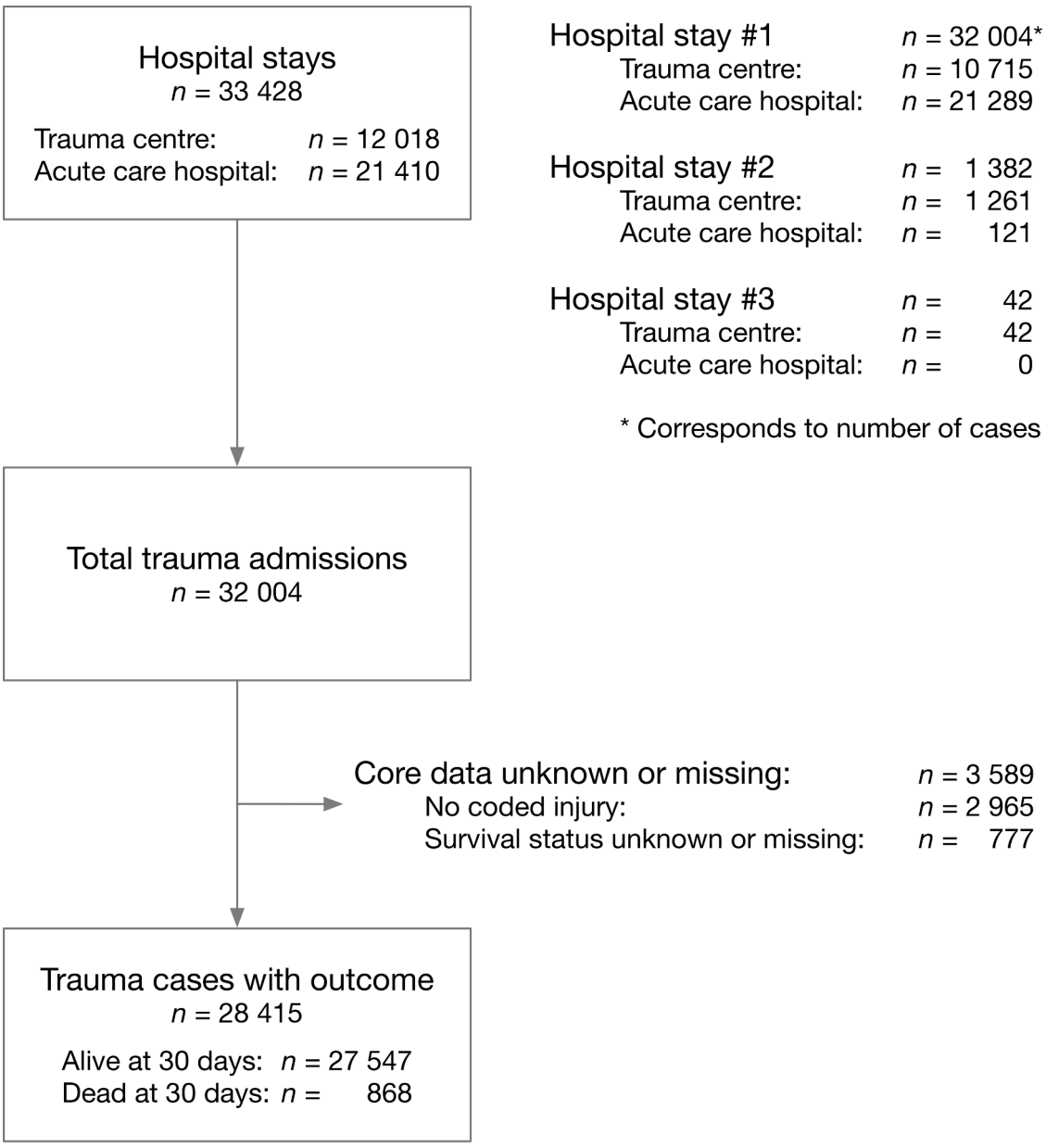

Fig. 2. STROBE flow diagram for trauma case inclusion.

without pre-injury comorbidity, blunt injuries, low injury severity, and primary admissions to acute care hospitals. Crude mortality rate was 3.1% for the total population, 1.0% for cases with ISS <16, 14.5% for ISS ≥16, 0.9% for NISS <16, and 10.2% for NISS ≥16. There was no statistically significant difference in crude mortality rate between regions ($P = 0.53$ for total population, $P = 0.38$ for ISS ≥16, $P = 0.19$ for NISS ≥16). Other differences between health regions were small, except for Northern Norway where the proportion of cases admitted directly to the regional trauma centre was half of that in the other regions (18.4% vs. 37.6%, $P < 0.0001$). For the total population, the number of excess survivors per 100 patients was –0.85 in Northern Norway vs. –0.06 in the other regions combined, but the difference was not statistically significant ($P = 0.42$). However, amongst severely injured patients (ISS ≥16) excess survivors was 4.80 lower in Northern Norway (–6.32 vs. –1.52, $P = 0.004$).

Data were further split by hospital level for the primary admission (Table 2). For the total national trauma population, trauma centres had 0.48 more excess survivors per 100 primary admitted patients than acute care hospitals (0.20 vs. –0.28, $P < 0.0001$), but differences in excess survivors amongst the acute care hospitals and amongst the regional trauma centres were small and not statistically significant. For severely injured patients (ISS ≥16), the difference between trauma centres and acute care hospitals increased to 3.13 (–0.24 vs. –3.37, $P < 0.0001$). As for the total population, there were no statistically significant differences between trauma centres. However, excess survivors amongst severely injured patients admitted to acute care hospitals in Northern Norway was 5.88 lower than in the other regions combined (–8.72 vs. –2.84, $P = 0.0006$).

Excess survivors were also analysed per hospital for primary admission (Fig. 3A). Variability between hospitals increased with smaller hospital size, as was expected due to increased uncertainty of the estimates. However, there also seemed to be a tendency for smaller hospitals to deviate towards lower number of excess survivors. This was confirmed when number of excess survivors was analysed according to broader hospital size groups (Fig. 3B). Hospitals with on average fewer than 100 primary trauma admissions per year had 0.65 fewer excess survivors per 100 patients than hospitals with 100 cases or more per year (–0.68 vs. –0.03, $P = 0.01$). All hospitals in Northern Norway

Table 1
Characteristics of the study population, national and by health region.

	National	South-Eastern	Western	Central	Northern
Demographics					
Trauma cases (n)	28,415	17,631	4882	4096	1806
Sex (M: F) (n)	19,285: 9130	11,972: 5659	3339: 1543	2709: 1387	1265: 541
(%)	67.9: 32.1	67.9: 32.1	68.4: 31.6	66.1: 33.9	70.0: 30.0
Age (years)	40 (21–60) [435]	40 (21–59) [330]	40 (22–59) [103]	39 (21–60) [0]	41 (22–61) [2]
Comorbidity					
Pre-injury ASA-PS 1: 2: 3: 4: 5 (n)	18,239: 6976: 2523 : 155: 1 [521]	11,261: 4329: 1714 : 133: 1 [193]	2857: 1356: 522 : 18: 0 [129]	2798: 936: 195 : 3: 0 [164]	1323: 355: 92 : 1: 0 [35]
(%)	65.4: 25.0: 9.0 : 0.6: 0.0	64.6: 24.8: 9.8 : 0.8: 0.0	60.1: 28.5: 11.0 : 0.4: 0.0	71.2: 23.8: 5.0 : 0.1: 0.0	74.7: 20.0: 5.2 : 0.1: 0.0
Mechanism of injury					
Blunt: Penetrating (n)	26,444: 1473 [498]	16,489: 1003 [139]	4540: 211 [131]	3771: 169 [156]	1644: 90 [72]
(%)	94.7: 5.3	94.3: 5.7	95.6: 4.4	95.7: 4.3	94.8: 5.2
Anatomical injury					
ISS (score)	5 (1–10)	5 (1–10)	5 (2–10)	5 (1–10)	5 (2–10)
ISS ≥16 (n)	4357	2703	774	617	263
(%)	15.3	15.3	15.9	15.1	14.6
NISS (score)	6 (2–14)	5 (2–14)	6 (2–14)	6 (2–14)	8 (2–14)
NISS ≥16 (n)	6688	4188	1118	955	427
(%)	23.5	23.8	22.9	23.3	23.6
Admission level					
Directly to Trauma centre: Acute care hospital (n)	10,336: 18,079	6490: 11,141	1669: 3213	1844: 2252	333: 1473
(%)	36.4: 63.6	36.8: 63.2	34.2: 65.8	45.0: 55.0	18.4: 81.6
Hospital stay					
Hospital LOS (days)	2 (2–5) [8]	2 (2–5) [0]	2 (2–6) [8]	2 (2–5) [0]	2 (2–6) [0]
ICU LOS (days)	2 (1–2)	2 (1–2)	2 (1–4)	1 (1–2)	1 (1–2)
ICU stay (n)	16,521	12,731	1099	1624	1067
(%)	58.1	72.2	22.5	39.6	59.1
30-day survival					
Total population					
Alive: Dead (n)	27,547: 868	17,093: 538	4721: 161	3983: 113	1750: 56
(%)	96.9: 3.1	96.9: 3.1	96.7: 3.3	97.2: 2.8	96.9: 3.1
ISS ≥16					
Alive: Dead (n)	3727: 630	2308: 395	656: 118	541: 76	222: 41
(%)	85.5: 14.5	85.4: 14.6	84.8: 15.2	87.7: 12.3	84.4: 15.6
NISS ≥16					
Alive: Dead (n)	6006: 682	3764: 424	989: 129	872: 83	381: 46
(%)	89.8: 10.2	89.9: 10.1	88.5: 11.5	91.3: 8.7	89.2: 10.8
Age >65					
Alive: Dead (n)	5009: 582	3063: 355	844: 105	761: 83	341: 39
(%)	89.6: 10.4	89.6: 10.4	88.9: 11.1	90.2: 9.8	89.7: 10.3
Case-mix adjusted outcome*					
Excess survivors, total	-0.11 (-0.26 – 0.05) [1431]	-0.04 (-0.23 – 0.16) [846]	-0.06 (-0.45 – 0.32) [260]	-0.15 (-0.57 – 0.28) [239]	-0.85 (-1.48 – -0.22) [86]
Excess survivors, ISS ≥16	-1.82 (-2.63 – -1.01) [487]	-1.92 (-2.93 – -0.91) [285]	-1.18 (-3.06 – 0.71) [90]	-0.17 (-2.43 – 2.09) [89]	-6.32 (-9.85 – -2.79) [23]

Numbers are median (quartiles) or number (%) of primary admitted trauma cases with documented outcome, if not otherwise stated. Numbers in brackets denote cases where data is missing or documented as unknown. ISS, Injury Severity Score; NISS, New Injury Severity Score; LOS, length of stay; ICU, intensive care or high-dependency unit. *Excess survivors per 100 patients (95% confidence interval), only calculated when all relevant variables were available.

reported <100 primary trauma admissions per year, accounting for 10 of the 21 Norwegian hospitals in this category. The ISS body region with the most frequent serious injuries (AIS severity code ≥3) in non-survivors was Head or neck, followed by Chest (Table 3). There were no major systematic differences between health regions or hospital levels.

Logistic regression was utilised to explore individual and combined effects of potential determinants for 30-day survival (Table 4). All analyses were performed with hospital as random effect, to account for correlation between results from the same hospital.

Statistically significant effects on the total population could generally be attributed to effects on severely injured patients (ISS ≥16), and the only statistically significant effects in the case mix-adjusted descriptive model incorporating all potential determinants were health region and hospital level. Case-mix adjusted odds ratio for survival for severely injured patients admitted in the Northern health region vs. all other health regions was 0.47 (95% CI 0.27 to 0.84, $P = 0.01$), and for direct admission to a trauma centre vs. an acute care hospital 2.04 (95% CI 1.04 to 4.00, $P = 0.04$).

Discussion

This assessment of the combined effects of hospital level, hospital size, and health region on risk-adjusted mortality in a uniform national trauma system is also the first report of risk-adjusted mortality based on the total Norwegian trauma population.

During 2015–2018, 3.1% of primary admitted cases died within 30 days after injury. Deaths amongst severely injured patients with ISS ≥16 amounted to 14.5%, and amongst those with NISS ≥16 to 10.2%. There was a markedly lower risk-adjusted survival for patients admitted to acute care hospitals vs. trauma centres, in particular for severely injured patients, and for patients admitted to hospitals with few primary trauma admissions. Risk-adjusted survival was particularly low amongst severely injured patients in Northern Norway, where most hospitals are small and the proportion of cases admitted directly to the regional trauma centre was half of that in the other regions. In a multivariable case mix-adjusted descriptive model, the only statistically significant effects on 30-day survival were health region and level of the primary admission hospital.

Although inclusion criteria and coverage for national trauma registries differ substantially, comparisons of crude mortality rates for serious injuries are feasible as long as outcome definitions are compatible. The Swedish trauma registry (SWETRAU) includes all patients received with

Table 2
Characteristics of the study population by level of first hospital, national and by health region.

First admission	National Trauma centre	Acute care hospital	South-Eastern Trauma centre	Acute care hospital	Western Trauma centre	Acute care hospital	Central Trauma centre	Acute care hospital	Northern Trauma centre	Acute care hospital
Demographics										
Trauma cases (n)	10,336	18,079	6490	11,141	1669	3213	1844	2252	333	1473
Sex (M: F) (n)	7211: 3125	12,074: 6005	4535: 1955	7437: 3704	1206: 463	2133: 1080	1230: 614	1479: 773	240: 93	1025: 448
(%)	69.8: 30.2	66.8: 33.2	69.9: 30.1	66.8: 33.2	72.3: 27.7	66.4: 33.6	66.7: 33.3	65.7: 34.3	72.1: 27.9	69.6: 30.4
Age (years)	39 (22–59) [317]	40 (21–60) [118]	39 (22–59) [316]	41 (21–60) [14]	40 (23–59) [0]	40 (22–59) [103]	41 (22–61) [0]	37 (19–60) [0]	39 (21–60) [1]	41 (22–61) [1]
Comorbidity										
Pre-injury ASA-PS 1: 2: 3: 4: 5 (n)	6552: 2410: 1030: 93 : 0 [251]	11,687: 4566: 1493: 62 : 1 [270]	4014: 1525: 850: 85: 0 [16]	7247: 2804: 864: 48: 1 [177]	1041: 436: 88: 7 : 0 [97]	1816: 920: 434: 11: 0 [32]	1287: 363: 68: 0 : 0 [126]	1511: 573: 127: 3 : 0 [38]	210: 86: 24: 1 : 0 [12]	1113: 269: 68: 0 : 0 [23]
(%)	65.0: 23.9: 10.2: 0.9: 0.0	65.6: 25.6 : 8.4: 0.3 : 0.0	62.0: 23.6 : 13.1: 1.3 : 0.0	66.1: 25.6 : 7.9: 0.4 : 0.0	66.2: 27.7 : 5.6: 0.4 : 0.0	57.1: 28.9 : 13.6: 0.3 : 0.0	74.9: 21.1 : 4.0: 0.0 : 0.0	68.2: 25.9 : 5.7: 0.1 : 0.0	65.4: 26.8 : 7.5: 0.3 : 0.0	76.8: 18.6 : 4.7: 0.0 : 0.0
Mechanism of injury										
Blunt: Penetrating (n)	9334: 759 [243]	17,110: 714 [255]	5920: 570 [0]	10,569: 433 [139]	1488: 82 [99]	3052: 129 [32]	1635: 87 [122]	2136: 82 [34]	291: 20 [22]	1353: 70 [50]
(%)	92.5: 7.5	96.0: 4.0	91.2: 8.8	96.1: 3.9	94.8: 5.2	95.9: 4.1	94.9: 5.1	96.3: 3.7	93.6: 6.4	95.1: 4.9
Anatomical injury										
ISS (score)	5 (2–14)	5 (1–9)	5 (1–14)	5 (1–9)	5 (2–14)	5 (2–10)	8 (2–14)	4 (1–9)	9 (4–14)	5 (1–10)
ISS ≥16 (n)	2260	2097	1411	1292	364	410	409	208	76	187
(%)	21.9	11.6	21.7	11.6	21.8	12.8	22.2	9.2	22.8	12.7
NISS (score)	9 (2–17)	5 (2–12)	8 (1–17)	5 (2–12)	9 (2–17)	6 (2–12)	9 (3–17)	4 (2–12)	10 (4–17)	6 (2–13)
NISS ≥16 (n)	3292	3396	2054	2134	505	613	616	339	117	310
(%)	31.8	18.8	31.6	19.2	30.3	19.1	33.4	15.1	35.1	21.0
Hospital stay										
Hospital LOS (days)	3 (2–7) [0]	2 (2–5) [8]	3 (2–7) [0]	2 (2–5) [0]	3 (2–9) [0]	2 (2–5) [8]	3 (2–7) [0]	2 (1–4) [0]	4 (2–9) [0]	2 (2–5) [0]
ICU LOS (days)	2 (1–3)	1 (1–2)	2 (1–2)	1 (1–2)	4 (2–8)	2 (1–3)	3 (2–9)	1 (1–2)	3 (1–8.25)	1 (1–2)
ICU stay (n)	6103	10,418	5498	7233	255	844	284	1340	66	1001
(%)	59.0	57.6	84.7	64.9	15.3	26.3	15.4	59.5	19.8	68.0
30-day survival										
Total										
Alive: Dead (n)	9927: 409	17,620: 459	6214: 276	10,879: 262	1611: 58	3110: 103	1780: 64	2203: 49	322: 11	1428: 45
(%)	96.0: 4.0	97.5: 2.5	95.7: 4.3	97.6: 2.4	96.5: 3.5	96.8: 3.2	96.5: 3.5	97.8: 2.2	96.7: 3.3	96.9: 3.1
ISS ≥16										
Alive: Dead (n)	1937: 323	1790: 307	1192: 219	1116: 176	319: 45	337: 73	360: 49	181: 27	66: 10	156: 31
(%)	85.7: 14.3	85.4: 14.6	84.5: 15.5	86.4: 13.6	87.6: 12.4	82.2: 17.8	88.0: 12.0	87.0: 13.0	86.8: 13.2	83.4: 16.6
NISS ≥16										
Alive: Dead (n)	2952: 340	3054: 342	1821: 233	1943: 191	458: 47	531: 82	566: 50	306: 33	107: 10	274: 36
(%)	89.7: 10.3	89.9: 10.1	88.7: 11.3	91.0: 9.0	90.7: 9.3	86.6: 13.4	91.9: 8.1	90.3: 9.7	91.5: 8.5	88.4: 11.6
Age >65										
Alive: Dead (n)	9927: 409	17,620: 459	6214: 276	10,879: 262	1611: 58	3110: 103	1780: 64	2203: 49	322: 11	1428: 45
(%)	96.0: 4.0	97.5: 2.5	95.7: 4.3	97.6: 2.4	96.5: 3.5	96.8: 3.2	96.5: 3.5	97.8: 2.2	96.7: 3.3	96.9: 3.1
Case-mix adjusted outcome*										
Excess survivors, total	0.20 (-0.08 – 0.49) [767]	-0.28 (-0.46 – -0.10) [664]	0.25 (-0.11 – 0.61) [504]	-0.19 (-0.41 – 0.03) [342]	-0.02 (-0.71 – 0.67) [105]	-0.09 (-0.54 – 0.37) [155]	0.16 (-0.56 – 0.88) [133]	-0.39 (-0.89 – 0.12) [106]	0.63 (-0.66 – 1.92) [25]	-1.18 (-1.89 – -0.46) [61]
Excess survivors, ISS ≥16	-0.24 (-1.39 – 0.92) [348]	-3.37 (-4.50 – -2.24) [139]	-0.57 (-2.03 – 0.90) [215]	-3.24 (-4.64 – -1.84) [70]	-0.35 (-3.09 – 2.38) [55]	-1.85 (-4.46 – 0.75) [35]	0.90 (-1.98 – 3.78) [65]	-2.17 (-5.78 – 1.43) [24]	0.43 (-5.09 – 5.95) [13]	-8.72 (-13.04 – -4.40) [10]

Numbers are median (quartiles) or number (%) of primary admitted trauma cases with documented outcome, if not otherwise stated. Numbers in brackets denote cases where data is missing or documented as unknown. ISS, Injury Severity Score; NISS, New Injury Severity Score; LOS, length of stay; ICU, intensive care or high-dependency unit. *Excess survivors per 100 patients (95% confidence interval), only calculated when all relevant variables were available.

a trauma team and all patients with NISS ≥16 regardless of TTA. amongst their 9031 patients registered in 2019, the fraction with NISS ≥16 was 31.6% at university hospitals and 19.5% at other hospitals, remarkably close to trauma centres and acute care hospitals respectively in our material (Results and Table 2). Their crude 30-day mortality rate was also comparable to ours, 1.1% for patients with NISS <16 and 12.6% for those with NISS ≥16 [20]. The TARN data set for England for 2015, based on 52,422 trauma admissions, also has a comparable 30-day mortality rate at 15.7% for ISS ≥16 [21]. The National Trauma Data Bank for US non-paediatric hospitals in 2016, based on 861,888 admissions, has a mortality rate at 13.4% for ISS ≥16 [22]. However, this figure cannot be directly compared to our 30-day survival data, as deaths were only registered at hospital discharge or by definition if a patient was transferred to hospice care [23].

Risk-adjusted survival was lower in acute care hospitals in Northern Norway compared to the rest of the country. Most of those hospitals are fairly small, and we were able to demonstrate a relationship between hospital size and risk-adjusted survival. The relationship between hospital volume and survival for patients with ISS ≥16 has previously been studied in detail by others. A German study of a national cohort from

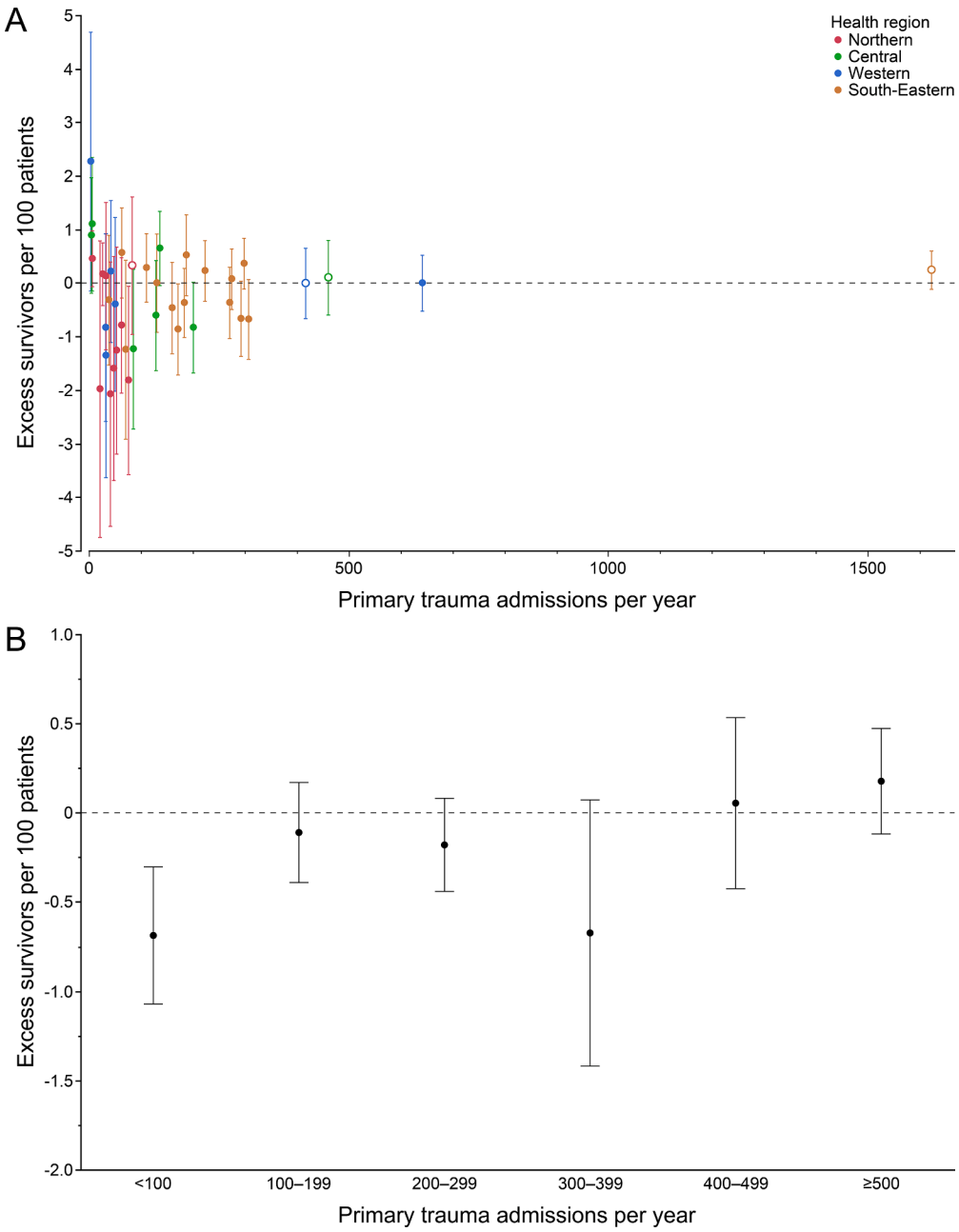

Fig. 3. Excess survivors per 100 primary admitted cases vs. hospital size. (A) Results from all individual hospitals, as a function of number of primary trauma admissions per year. Regions are colour coded; regional trauma centres are shown with open symbols. (B) Results aggregated according to hospital size category. Vertical bars represent 95% confidence intervals for the estimates.

2009 to 2013 found no clear cut-off value but suggested a volume of at least 40 severely injured patients per year to be beneficial for hospital survival, whereas a study from all English major trauma centres from 2013 to 2016 found no effect of volume on in-hospital mortality [24,25]. A systematic review concluded that a volume of more than 240 patients with ISS ≥16 per year, corresponding to the ACS-COT requirement for level I trauma centres, was significantly associated with lower in-hospital mortality [26]. In Norway, only the regional trauma centre for South-Eastern Norway (Oslo University Hospital Ullevål) is in this category.

Two recent Swedish studies have analysed risk-adjusted mortality after trauma [27,28]. Candefjord et al. found a similar difference in survival between admission at a trauma centre and a non-trauma centre as in our study. In apparent contrast to this, Strömmer et al. did not find a difference in mortality between trauma centre and non-trauma centre in patients without traumatic brain injury. Both studies are based on data from SWETRAU, but differences in patient inclusion and models for risk adjustment, including variables for physiology and comorbidity, might contribute to the divergent findings. Effects of hospital size and health region were also not assessed.

A recent systematic review concluded that there was a survival benefit for severely injured patients treated in level I trauma centres compared with patients treated in non-level I trauma centres, whereas there was no association between level of trauma care and in-hospital mortality for the general trauma population [29]. Thus, it is not surprising that our study demonstrated a similar association between hospital level and risk-adjusted 30-day mortality, both for the total population and the severely injured patients.

It is more surprising that hospital size was rendered insignificant in a multivariable descriptive model. A reasonable explanation for the lower

Table 3
30-day survival status for patients with serious injuries (AIS severity code ≥3) in the study population by body region and level of first hospital, national and by health region.

First admission	National Trauma centre	Acute care hospital	South-Eastern Trauma centre	Acute care hospital	Western Trauma centre	Acute care hospital	Central Trauma centre	Acute care hospital	Northern Trauma centre	Acute care hospital
ISS body region										
Head or neck	1968: 285	1527: 265	1361: 202	931: 147	237: 35	321: 63	301: 40	137: 27	69: 8	138: 28
Alive: Dead (n)										
(%)	87.4: 12.6	85.2: 14.8	87.1: 12.9	86.4: 13.6	87.1: 12.9	83.6: 16.4	88.3: 11.7	83.5: 16.5	89.6: 10.4	83.1: 16.9
Face	74: 10	49: 6	44: 7	41: 1	16: 1	4: 5	14: 1	3: 0	0: 1	1: 0
Alive: Dead (n)										
(%)	88.1: 11.9	89.1: 10.9	86.3: 13.7	97.6: 2.4	94.1: 5.9	44.4: 55.6	93.3: 6.7	100.0: 0.0	0.0: 100.0	100.0: 0.0
Chest	1401: 117	2075: 129	757: 73	1331: 67	255: 20	331: 37	340: 20	219: 14	49: 4	194: 11
Alive: Dead (n)										
(%)	92.3: 7.7	94.1: 5.9	91.2: 8.8	95.2: 4.8	92.7: 7.3	89.9: 10.1	94.4: 5.6	94.0: 6.0	92.5: 7.5	94.6: 5.4
Abdominal or pelvic contents	571: 27	683: 29	384: 20	443: 14	76: 5	109: 10	95: 1	77: 2	16: 1	54: 3
Alive: Dead (n)										
(%)	95.5: 4.5	95.9: 4.1	95.0: 5.0	96.9: 3.1	93.8: 6.2	91.6: 8.4	99.0: 1.0	97.5: 2.5	94.1: 5.9	94.7: 5.3
Extremities or pelvic girdle	778: 52	1143: 79	418: 28	670: 41	141: 8	233: 22	175: 12	122: 6	44: 4	118: 10
Alive: Dead (n)										
(%)	93.7: 6.3	93.5: 6.5	93.7: 6.3	94.2: 5.8	94.6: 5.4	91.4: 8.6	93.6: 6.4	95.3: 4.7	91.7: 8.3	92.2: 7.8
External	114: 33	118: 18	55: 13	72: 15	28: 9	20: 3	21: 10	18: 0	10: 1	8: 0
Alive: Dead (n)										
(%)	77.6: 22.4	86.8: 13.2	80.9: 19.1	82.8: 17.2	75.7: 24.3	87.0: 13.0	67.7: 32.3	100.0: 0.0	90.9: 9.1	100.0: 0.0

Numbers are primary admitted trauma cases with documented outcome. AIS, Abbreviated Injury Scale; ISS, Injury Severity Score.

Table 4
Potential determinants for survival.

	Individual explanatory variables, not case-mix adjusted			Individual explanatory variables, case-mix adjusted			All explanatory variables combined, case-mix adjusted		
	Effect size (95% CI)	OR (95% CI)	*P*	Effect size (95% CI)	OR (95% CI)	*P*	Effect size (95% CI)	OR (95% CI)	*P*
Total population									
Northern vs.	-0.11	0.80	0.27	-0.23	0.63	0.04	-0.23	0.64	0.04
All other health regions	(-0.31 – 0.09)	(0.53 – 1.20)		(-0.45 – -0.01)	(0.40 – 0.97)		(-0.44 – -0.01)	(0.41 – 0.99)	
Trauma centre vs.	-0.22	0.64	0.03	0.20	1.51	0.06	0.19	1.46	0.16
Acute care hospital	(-0.42 – -0.02)	(0.43 – 0.96)		(-0.01 – 0.42)	(0.97 – 2.33)		(-0.09 – 0.47)	(0.83 – 2.57)	
Primary admissions	-0.22	–	0.04	0.16	–	0.12	0.01	–	0.95
per year with ISS ≥16 (hundreds)	(-0.42 – -0.02)			(-0.06 – 0.39)			(-0.29 – 0.31)		
ISS 1–15									
Northern vs.	-0.02	0.96	0.88	-0.09	0.84	0.62	-0.06	0.88	0.74
All other health regions	(-0.31 – 0.27)	(0.53 – 1.72)		(-0.44 – 0.27)	(0.41 – 1.70)		(-0.44 – 0.31)	(0.42 – 1.88)	
Trauma centre vs.	-0.04	0.92	0.74	0.08	1.18	0.60	0	1.00	0.99
Acute care hospital	(-0.31 – 0.23)	(0.54 – 1.59)		(-0.26 – 0.42)	(0.60 – 2.32)		(-0.50 – 0.49)	(0.37 – 2.68)	
Primary admissions	-0.08	–	0.49	0.12	–	0.41	0.11	–	0.63
per year with ISS ≥16 (hundreds)	(-0.34 – 0.19)			(-0.21 – 0.44)			(-0.39 – 0.60)		
ISS ≥16									
Northern vs.	-0.07	0.86	0.49	-0.36	0.49	0.02	-0.38	0.47	0.01
All other health regions	(-0.28 – 0.13)	(0.57 – 1.31)		(-0.66 – -0.06)	(0.27 – 0.89)		(-0.66 – -0.09)	(0.27 – 0.84)	
Trauma centre vs.	0.04	1.08	0.68	0.32	1.88	0.04	0.36	2.04	0.04
Acute care hospital	(-0.16 – 0.23)	(0.73 – 1.58)		(0.03 – 0.60)	(1.06 – 3.33)		(0.02 – 0.69)	(1.04 – 4.00)	
Primary admissions	-0.03	–	0.71	0.23	–	0.11	-0.07	–	0.62
per year with ISS ≥16 (hundreds)	(-0.23 – 0.17)			(-0.07 – 0.52)			(-0.45 – 0.31)		

Results are shown for each individual explanatory variable separately, with and without case-mix adjustment (first and second column), and for all explanatory variables combined in a single case-mix adjusted model (third column). All results are from generalized linear mixed models with 30-day survival as dependant variable and primary admission hospital as random effect. Effect sizes and odds ratios (OR) are for survival after first admission, with 95% confidence intervals (CI) and *P* values. ISS, Injury Severity Score. Number of patients: Total $n = 28,415$ for values that are not case-mix adjusted (24,058 for ISS 1–15 and 4357 for ISS ≥16), total $n = 26,984$ for NORMIT 2 case-mix adjusted values (23,114 for ISS 1–15 and 3870 for ISS ≥16).

risk-adjusted survival in Northern Norway might thus be that a lower proportion of severely injured patients is admitted directly to the regional trauma centre. If this is the case, the most obvious way to increase survival would be to admit more patients directly to a trauma centre. The high mortality rate in patients with serious injuries in the Head or neck region supports this presumption, as specialised neurosurgical care is only provided in the trauma centres and a single additional acute care hospital. However, direct admission of more patients to a trauma centre is not a realistic alternative in a sparsely populated area such as Northern Norway. The time and distance necessary for road transport past the local hospital to a larger hospital or to the trauma centre is often far too long, and air ambulance transport cannot fully compensate this. A study of patient records from all 42,456 HEMS dispatches in Western Norway during 2004–2013 documented that 5.1% of all dispatches were cancelled due to bad weather conditions, particularly during low light conditions [30]. The number of hours of darkness during winter is far higher in Northern Norway, conceivably resulting in higher cancellation rates. Further, 3.5% of dispatches were cancelled due to competing missions. Giving higher priority to trauma patients might be beneficial for this patient group but would negatively influence

treatment of patients with other conditions unless air transport capacity is increased, e.g., by adding or moving existing HEMS bases [31].

There are several limitations in this study. A main limitation is the quality of NTR data. Although all hospitals in Norway admitting trauma patients deliver data to the NTR, not all provide data on patients without TTA. Undertriage has been identified as a risk factor for poorer outcome, but incomplete data in the present study makes assessment of undertriage unreliable. However, registration in the NTR of patients received with a trauma team is mandatory in all Norwegian hospitals, and moreover a recent validation study concluded that 29 of the 39 hospitals in the national trauma system systematically searched for undertriaged patients. Coverage and data completeness was 100% for patients received with a trauma team, and 92.2% when undertriaged patients were included [32]. For comparison, only 84% of Swedish hospitals reported data for 2017 as registration is voluntary, and an estimated 81% of all patients are included in the Swedish national trauma registry [27].

Any systematic errors resulting in study exclusion due to unknown or missing 30-day survival status might also influence apparent hospital performance. Although all trauma registrars are AAAM certified, there might be differences in coding practice between hospitals and even regions [33] which, e.g., could explain the apparent lower fraction of patients with comorbidity in Central and Northern Norway. Lower pre-injury ASA-PS would result in a higher expected number of survivors and consequently a lower number of excess survivors. The small number of patients in individual hospitals makes assessments on single hospitals uncertain, and except for Fig. 3 hospitals are grouped for assessment. Several other factors that also might influence outcome, e.g., prehospital time, transport distances, treatment, and transfers, were not assessed. Deviations from NORMIT 2 are also not unexpected, in particular for acute care hospitals since the model was developed based on patient data from a single regional trauma centre [34]. However, in addition to being the Level I trauma centre for the 3.1 million people in the South-Eastern health region, i.e., more than half the Norwegian population, the hospital is also the major trauma hospital for more than 660,000 citizens. In the present study, the hospital received 63% of patients directly admitted to a trauma centre, corresponding to 23% of the total study population (Table 2). Further, NORMIT 2 has been deemed well suited to predict survival in a Swedish trauma centre population irrespective of injury severity. Survival in a Swedish total national cohort was overestimated, which would be expected when seriously injured patients are not directly admitted to a trauma centre [34]. Lastly, due to the volume of patients received in the trauma centre for the South-Eastern health region, it would be expected to have major effects on the results of any regression model, consequently making interpretations more challenging. However, excluding it from the combined case-mix adjusted model (not shown) only results in minor changes and does not change any conclusions.

We have identified a lower survival rate for trauma patients admitted to small acute care hospitals with few TTAs located in the most rural parts of Norway. The obvious solution, to increase the proportion of severely injured patients who are transported directly to a trauma centre, is not always possible. Further research is necessary to identify and remedy other causes of the lower survival; e.g., possible differences in mechanism of injury, type and severity of injury, prehospital time and treatment, in-hospital treatment, and time to definitive treatment in the trauma centre.

Our results may be transferrable to other high-income countries with a developed health care system, long transport distances, and a trauma patient population dominated by blunt injuries.

Ethics approval and consent to participate

The study was approved by the Regional Patient Data Protection Officer at the University Hospital of North Norway Tromsø (Ref. No. 2017/0687) and the Regional committee for medical and health research ethics north (Ref. No. 2018/991). All patients included in the NTR and thus in this study receive written information about the NTR, including the opportunity to apply for access to the data recorded, and the possibility to anonymise their own data in the NTR.

Consent for publication

Not applicable.

Data availability

The data that support the findings of this study are de-identified patient records available from the NTR, but due to Norwegian legislation restrictions apply to their availability. The data was used under license for the current study and so are not publicly available. Data are however available from the authors upon reasonable request provided that permission is obtained from the North Norway Regional committee for medical and health research ethics and the NTR.

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Writing assistance

None.

CRediT authorship contribution statement

T Dehli: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Resources, Visualization, Writing – original draft. **T Wisborg:** Conceptualization, Formal analysis, Investigation, Project administration, Resources, Supervision, Visualization, Writing – review & editing. **LG Johnsen:** Conceptualization, Formal analysis, Investigation, Resources, Visualization, Writing – review & editing. **G Brattebø:** Conceptualization, Formal analysis, Investigation, Resources, Visualization, Writing – review & editing. **T Eken:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Supervision, Validation, Visualization, Writing – original draft.

Declaration of Competing Interest

Trond Dehli, Torben Wisborg, Guttorm Brattebø, Lars Gunnar Johnsen and Torsten Eken declare that they have no conflict of interests.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.injury.2023.110852.

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