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Severe trauma with associated pelvic fractures: The impact of regional trauma networks on clinical outcome

Nikolaos K. Kanakaris [a,b], Omar Bouamra [c], Fiona Lecky [c,d], Peter V. Giannoudis [a,b,*]

[a] LEEDS Major Trauma Centre, Leeds Teaching Hospitals NHS Trust, Leeds, United Kingdom
[b] Academic Department of Trauma and Orthopaedics, School of Medicine, University of Leeds, United Kingdom
[c] Trauma Research and Audit Network, University of Manchester, 3rd Floor Mayo Building, Salford Royal NHS Foundation Trust, Salford, United Kingdom
[d] Centre for Urgent and Emergency Care REsearch (CURE), Health Services Research Section, School of Health and Related Research, University of Sheffield, United Kingdom

A R T I C L E I N F O

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A B S T R A C T

Lately, the care of severely injured patients in the United Kingdom has undergone a significant transformation. The establishment of regional trauma networks (RTN) with designated Major Trauma Centers (MTCs) and satellite hospitals called Trauma Units (TUs) has centralized the care of severely injured patients in the MTCs.

Pelvic fractures are notoriously linked with hypovolemic shock or even death from excessive blood loss. The aim of this prospective cohort study is to compare the profile of severely injured patients with combined pelvic fractures and their mortality between two different distinct eras of an advanced healthcare system. Anonymized consecutive patient records submitted to TARN UK between 2002 and 2017 by NHS England hospitals were analyzed. Records of patients without a pelvic fracture, or with isolated pelvic fractures (no other serious injury with abbreviated injury scale AIS >2) were excluded.

All patients with known outcomes were included and were divided into 2 distinct periods (pre-RTN era: between January 2002 and March 2008 (control group); and RTN era April 2013 to June 2017 (study group)). Data from the transition period from April 2008 to March 2013 were excluded to minimize the effect of variations between the developing networks and MTCs during that era. Overall, the study group included 10,641 patients, whereas the control group was 3152 patients, with a median age of 52.4 and 35.1 years and an ISS of 24 and 27 respectively. A systolic blood pressure below 90mmHg was observed in 7.2% of patients in the study group and 10.4% in the control group. A significant increase of the median time to death (from 8hrs to 188hrs) was observed between the two eras. The cumulative mortality of severely injured patients with pelvic fractures decreased significantly from 17.8% to 12.4% ($p<0.0001$).

The recorded improvement of survivorship in the subgroup of severely injured patients with a pelvic fracture (32% lower in the post-RTN than in the pre-RTN period: OR 1.32 (95% CI 1.21 – 1.44), following the first 5 years of established regional trauma networks in NHS England, is encouraging, and should be attributed to a wide range of factors that translate to all levels of trauma care.

Introduction

Over the last decade, the care of severely injured patients in the United Kingdom has undergone a significant transformation.[1,2] Central to this change is the development of a comprehensive trauma system first in England (between 2008 and 2013) and later in the rest of the nations. [3,4]

The establishment of regional trauma networks with designated Major Trauma Centers – MTCs and satellite hospitals called Trauma Units (TUs) has centralized the care of severely injured patients in the MTCs. Twenty-seven such hospitals across England, four in Scotland and one in each of Wales and Northern Ireland were upscaled to the level of specialist trauma hospitals (level 1) with 24/7 readiness to receive all severely injured patients directly from the place of the accident even if that meant bypassing nearby smaller units and emergency departments.

The rationale was summarized in the motto “right care, right place,

* Corresponding author at: Academic Department of Trauma and Orthopaedics, School of Medicine, University of Leeds, Leeds General Infirmary, Clarendon Wing, Level D, LS13EX, Leeds, West Yorkshire, United Kingdom.
E-mail address: pgiannoudi@aol.com (P.V. Giannoudis).

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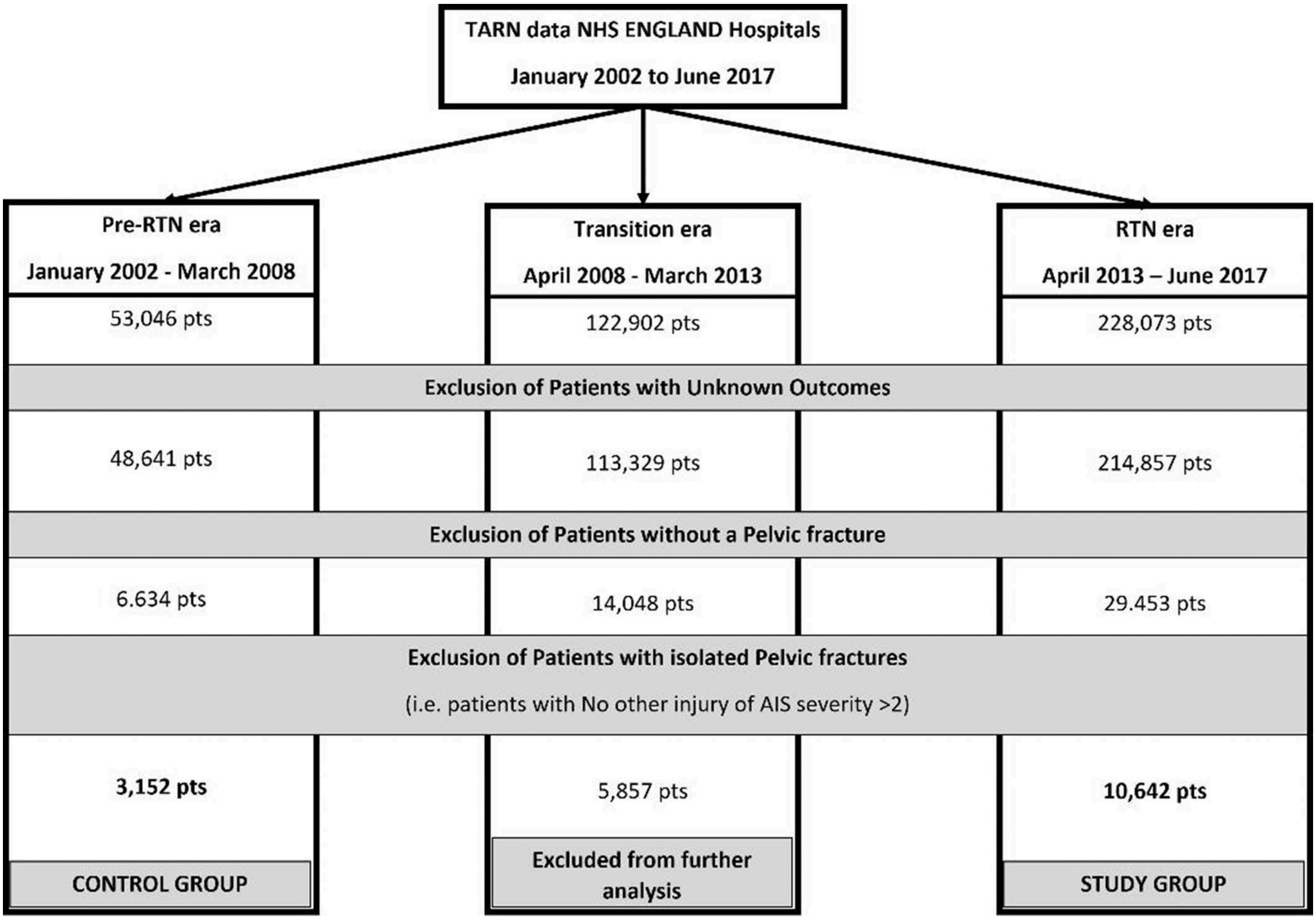

Fig. 1. Flowchart of patient selection from the TARN registry apply the study specific criteria.

at the right time". [5] Noteworthy, the allocation of additional resources and restructuring of the in-hospital major trauma-related services is heavily data-driven.[5] The role of the pre-existing Trauma Audit and Research Network (TARN) registry in this transformation has been crucial. TARN is the largest trauma registry in Europe. For the last 30 years progressively all trauma-receiving hospitals (MTCs and TUs) across England and Wales submit validated data via a secure web-based system. [6]

Complex pelvic fractures (PFXs) are usually the result of high-energy mechanisms, represent a classic paradigm of severe trauma, and have reported mortality ranging between 15–30%. [7–9] Pelvic fractures are notoriously linked with hypovolemic shock or even death from excessive blood loss. The sources of bleeding are multiple and often located distant from the pelvic ring in more than 90% of all such cases.[8,10,11] Exsanguinating trauma deaths are considered to a large extent as potentially preventable, therefore have become the center of attention of extensive clinical research which has led to a wide spectrum of developments. [12,13] A number of these (i.e. boast guidelines [14], hypotensive resuscitation [15], massive transfusion protocols [16], early intravenous administration of tranexamic acid [17,18], use of pre-hospital pelvic binders [19], trialing of the resuscitation balloon occlusion of the aorta - REBOA [20]), have been introduced in parallel to the regional major trauma networks and the structural reforms of the UK trauma system.

The aim of this prospective cohort study is to compare the profile of severely injured patients with combined pelvic fractures and their mortality between two different distinct eras of an advanced health care system.

Patients and methods

Anonymized consecutive patient records submitted to TARN UK between 2002 and 2017 by NHS England hospitals were analyzed. The TARN database inclusion criteria are trauma patients of any age who:

- are admitted to high dependency unit / intensive care, or for 72 h or more, or died at the hospital.
- are transferred into the hospital for specialist care.
- are transferred to another hospital for specialist care or for an intensive care bed.

AND

- whose isolated injuries meet a set of criteria. [6]

Records of patients without a pelvic fracture, or with isolated pelvic fractures (no other serious injury with abbreviated injury scale AIS >2) were excluded. [21] All patients with known outcomes were included and were divided into 2 distinct periods (pre-RTN era: between January 2002 and March 2008 (control group); and RTN era April 2013 to June 2017 (study group)). Date from the transition period April 2008 to March 2013 were excluded to minimize the effect of variations between the developing networks and MTCs during that era.

Demographics, mechanism of injury, associated injuries, injury severity score and patient physiology parameters at presentation together with performed diagnostic, resuscitative and surgical interventions, as well as the clinical outcome of these PFXs patients collected from the TARN database. All injuries were classified according

Table 1
Comparison between the general characteristics of severely injured patients with pelvic fractures between the two different time periods.

General Characteristics	RTNStudy group	Pre-RTNControl group	*p*-values*
Overall Number of patients	10,642	3152	
Male	6400 (60.1%)	2168 (68.8%)	***<0.0001***
Age, median (IQR)	52.4 (30.1-77.7)	35.1 (21.45-53.65)	***<0.0001***
Mechanism of Injury			
RTA	5516 (51.8%)	2418 (76.7%)	***<0.0001***
Fall > 2m	2317 (21.8%)	468 (14.8%)	***<0.0001***
Fall < 2m	2507 (23.6%)	117 (3.7%)	***<0.0001***
Shooting/Stabbing	37 (0.3%)	11 (0.3%)	0.991
Blow(s)	86 (0.9%)	15 (0.5%)	0.055
Other	179 (1.7%)	123 (3.9%)	***<0.0001***
Position in the vehicle (Only for RTA N=7934)			
Driver	1349 (24.5%)	749 (31.0%)	***<0.0001***
Passenger	651 (11.8%)	389 (16.1%)	***<0.0001***
Pedestrian	1631 (29.6%)	629 (26.0%)	***0.0012***
Motorcyclist	1288 (23.4%)	478 (19.8%)	***0.0004***
Pedal cyclist	482 (8.7%)	90 (3.7%)	***<0.0001***
Other Position/Not recorded	115 (2.1%)	83 (3.4%)	***0.0004***
Physiology data			
ED SBP <90	761 (7.2%)	328 (10.4%)	***<0.0001***
ED SBP 90 - 110	1690 (15.9%)	505 (16%)	0.8491
ED SBP>110	7268 (68.3)	1726 (54.8%)	***<0.0001***
ED SBP, median (IQR)	128 (110-146)	124 (105-142)	***<0.0001***
ED GCS, median (IQR)	15 (14-15)	15 (13-15)	0.9999
ED SBP not recorded	923 (8.7%)	593 (18.8%)	***<0.0001***
ED GCS not recorded	1987 (18.7%)	874 (27.7%)	***<0.0001***
Anatomic injuries			
ISS, median (IQR)	24 (13-34)	26 (17-36)	***0.0003***
Head AIS >2	3143 (29.5%)	1051 (33.3%)	***<0.0001***
Abdomen AIS >2	1419 (13.3%)	536 (17.0%)	***<0.0001***
Thorax AIS >2	5721 (53.8%)	1633 (51.8%)	0.0539
Spine AIS >2	1438 (13.5%)	176 (5.6%)	***<0.0001***
Other particular injuries			
Liver-Spleen	1379 (13.0%)	527 (16.7%)	***<0.0001***
Long bones	4711 (44.3%)	1655 (52.5%)	***<0.0001***
Urogenital	795 (7.5%)	401 (12.7%)	***<0.0001***
Open Fractures	1507 (14.2%)	1040 (33.0%)	***<0.0001***
Mortality overall	1164 (12.4%)	504 (17.8%)	***<0.0001***
Hours to death, median (IQR)	188 (21-593)	8 (2-307)	***<0.0001***

AIS: abbreviated injury scale; ED: emergency department; GCS; Glasgow coma scale; IQR: interquartile range; ISS: injury severity score; RTC: road traffic accident; RTN: regional trauma network; SBP: systolic blood pressure.
**p*-values adjusted using Bonferroni correction.

to the Abbreviated Injury Scale (AIS) as to their anatomic description and severity. TARN records the cumulative 3-month mortality, but also uses the 30-day mortality for prediction of outcome calculations.

Statistical comparison between the different periods and analysis of the accumulated data was performed using *p*-values were obtained by Chi-square when the variables were categorical and by Bonnet-Price test on medians when they were continuous. Logistic regression analysis for the odds of survival between the two groupds (pre-RTN and post-RTN) was performed. using the ISS, the GCS, the age, gender and their interactions as predictors of survival.

Results

The control group (pre-RTN era) refers to a period of 74 months whilst the study group (RTN era) to a period of 50 months. Overall data of 376,827 injured patients were screened according to the selection criteria of this study. Further analysis was performed for 13,794 patients with PFXs and associated severe injuries (10,641 versus 3152 in the study and control cohorts), as presented at the study flowchart (Fig. 1). The occurrence of PFXs was on average 2239 *vs.* 756 per year in the study and control periods respectively.

The demographic, mechanism of injury, associated injuries and other descriptive features between the two eras are presented in Table 1. A progressive temporal increase of the median age was observed in all subgroups of trauma patients within the TARN registry (Fig. 2), associated with a reduction in male preponderance (60.1% in the study cohort versus 68.8% in the control). This aligns with the fact that falls (both from a height and lower level) became increasingly prevalent as a cause of PFX in the study period; however, RTCs remain the predominant causal mechanism. Overall injury severity and patterns of injury were similar in both cohorts (ISS 24 within the study period versus 26 in the control period), with the commonest associated injuries being those to thorax, long bone and head. Open fractures and urogenital injuries were more prevalent in the control period whereas spinal injuries were more prevalent in the study period (Table 1).

The different interventions and inhospital acute diagnostic and surgical measures employed also differed between the study and control groups. Some like the use of tranexamic acid, or of pelvic binders in the period before 2008 were not recordable as they were introduced in general later. Others like the prompt involvement of a consultant leading the trauma team, early CT scans, use of blood products for resuscitation, and employment of endovascular interventions were significantly increased at the period after 2013. A measurable decrease of emergency laparotomies, length of hospital stay was also identified during the latter period (Table 2).

The cumulative mortality of severely injured patients with a pelvic fracture has decreased from 17.8% in the study period to 12.4% in the control period ($p< 0.0001$). The logistic regression for odds of survival using ISS, GCS, age, gender and their interaction and period (pre- and post-RTN) as predictors showed that the adjusted odds of survival are 32% higher in the post-RTN than in the pre RTN period: OR 1.32 (95% CI 1.21 – 1.44). Furthermore, we observed also a significant increase in the median time to death (from 8hrs to 188hrs) for these severely injured patients between the two eras. Similarly, the mortality has improved when subgroups of patients were analyzed as for example PFXs patients with associated open fractures (from 20.7% to 12.3%), or with associated injuries to different organs or body regions. The subgroup of patients with the highest mortality 56.4% (those with pelvic fractures and head and thoracic and abdominal injuries) also appears to have a better outcome (39.3%) in the recent system (Table 3).

Discussion

The clinical outcome of major trauma patients remains a multifactorial and challenging equation. The evolution of our understanding on trauma pathophysiology [22], the application of improved treatment strategies [23,24], advanced interventions [20,25,26], and modern preventive measures, all aim to reduce mortality and disability. There is ample of evidence on the important impact reforms of the overarching health system can have. [2,4,27,28] The present observational cohort study verifies the anticipated improved survivorship rates of multiple severely injured patients in UK following the establishment of regional trauma networks.

The example of PFXs with other associated severe injuries was selected to demonstrate the contrast between the two different healthcare eras, as one of the most challenging trauma clinical scenarios. Giannoudis et al in 2007 [9], using data of pelvic injured patients from the TARN registry (period between 1989 to 2001), have reported an overall mortality of 14.2% in 11,149 pelvic fracture patients with a median ISS of 9. They recognized that the subgroup of more severely injured (ISS>15) had even worse outcome, and that 95.2% of their non survivors had associated severe injuries in other body regions. The present study focuses into two subsequent time periods: one before the introduction of major trauma networks (RTNs) (control group), more than a decade after the 2007 Giannoudis et al paper [9]; and on an even more recent period (study group) that refers to the first 5 years of established RTNs across the whole NHS England. Furthermore, in order

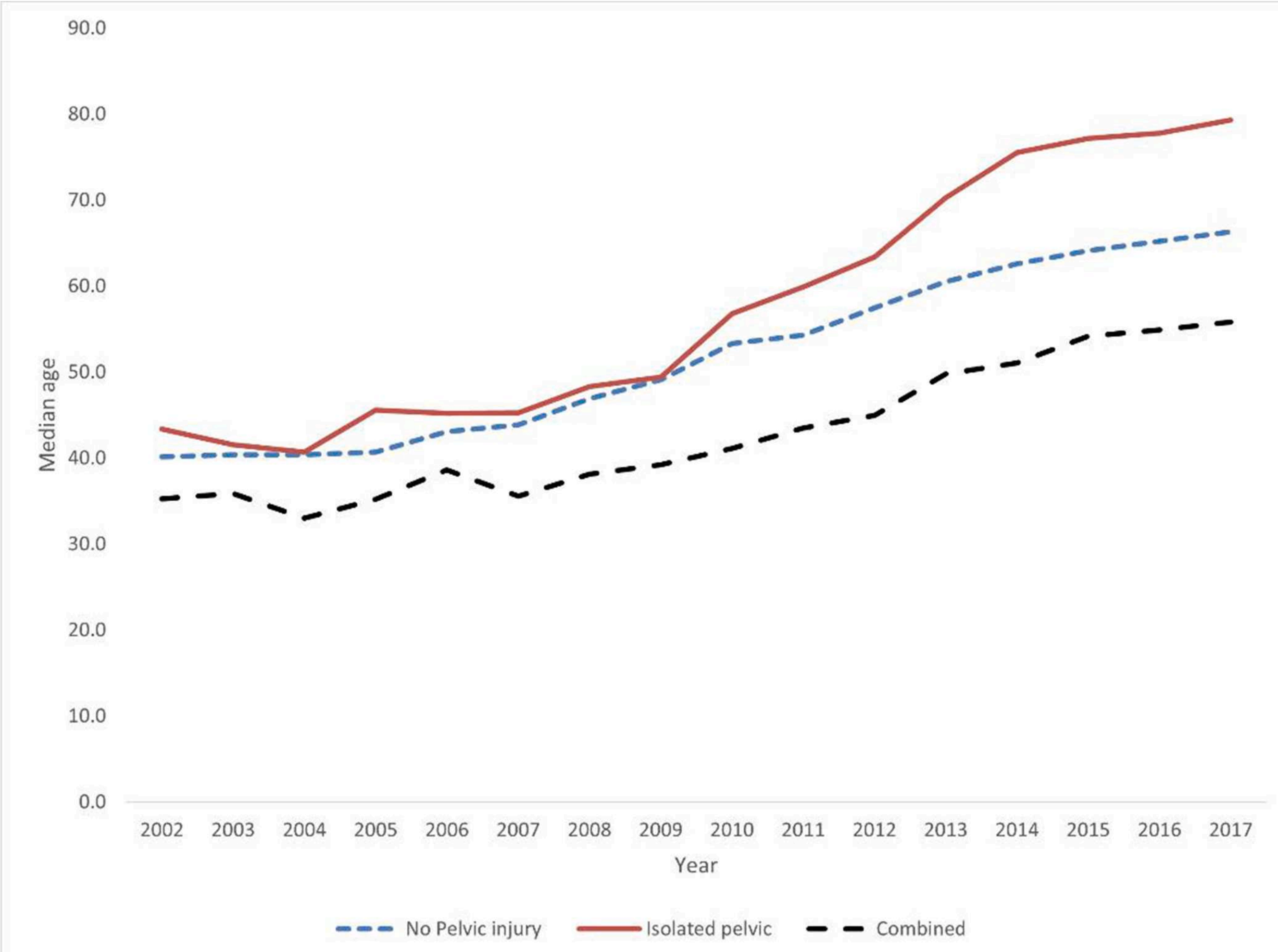

Fig. 2. Median age progressive changes through the years 2002–2017 in the TARN registry, divided between non pelvic injured, isolated pelvic injured and pelvic injured patients with combined other severe injuries with AIS>2.

to focus to the most complex of clinical scenarios that challenge modern trauma care, we excluded from this analysis patients with isolated pelvic/acetabular fractures. Therefore, the median ISS of this study was 24 and 27 for the study and control groups respectively.

The identified decreased mortality of 12.4% vs. 17.8% in this subgroup of multiple injured PFXs patients can be attributed to a series of changes that have been implemented in the previously criticized British trauma care. [4,5] These include large scale changes from the level of the national health care system, to interventions at the level of bed-side patient care. In this study, the more recent patient group (2013 to 2017), was managed to a large degree according to the BOAST guidelines [14,29], whilst the quality of TARN data during this period are more inclusive as all MTCs and most TUs are obliged to submit their cases to the registry. This explains the significant difference in the numbers of recorded PFXs between the two periods (10,642 *vs.* 3152), as the overall incidence of PFXs has not increased (12.9% *vs.* 12.5%). The improvement in the quality of submitted data to the registry is also indirectly evident by the significant decrease (p <0.0001) of missing information in the registry between the two periods (i.e., missing SBP (8.7% *vs.* 18.8%) and missing GCS values (18.7% *vs.* 27.7%)).

In comparison to the period of 2002 to 2008, a wide range of new protocols and interventions have been gradually adopted in contemporary trauma care within NHS England. In between others, prehospital medicine has evolved [30,31], trauma readiness has significantly improved [32], haemostatic hypotensive resuscitation for blunt trauma [15,33], use of pelvic binders [19], tranexamic acid [34], and massive hemorrhage protocols have been implemented at different stages within the study period of 2013 to 2017. Most certainly, the structural reform of trauma care since 2012, the additional resources allocated to acute services, together with the close monitoring of performance of all trauma-receiving hospitals using publicly available key indicators in the TARN registry, are cumulatively responsible for the significant increase in survivorship especially for the most severely injured of trauma patients. [1,35] The same effect was verified in this study using the cohort of PFXs with other associated severe injuries (Fig. 3), a recognized good model for quality control in trauma care. [7,8,10,11,36]

Even in this cohort of severely injured PFXs, significant changes on its demographics have been identified between the two eras. The median age has steadily increased over the analyzed time period of the last 15 years (Fig. 2). This has translated also to the higher ratio of female victims in this cohort of PFXs (from 31.2% to 40%). The effect of ageing of the population in the developed countries has been previously recognized as a significant modifier of modern trauma care. [37–39] Since 2018, awareness of the special needs of this elderly major trauma population has increased, whilst early assessment of patients' frailty and active involvement of geriatricians to the major trauma wards is established over the last few years in the UK trauma system and has become one of the TARN key performance indicators of good practice. [40,41]

The current study is limited mostly due to the discrepancy in the volume and quality of data between the different periods in the database. These have been significantly improved following the reformation

Table 2
Interventions and process measures between the recorded pelvic fracture patients with associated severe injuries between the years 2002 and 2017 represent the two eras of the trauma health system of NHS England.

	RTNStudy group2017	Pre-RTNControl group2002	Magnitude of change (95% CI) *p-value*
Resuscitation			
Blood units, median (IQR)	4.6 (2 - 8.2)	2 (2 - 2)	2.6 (2 – 4) ***<0.0001***
TXA, n (%)	410 (29.7%)	0 (0%)	29.7 (27.3 - 32.1) ***<0.0001***
Consultant in ED within 30 minutes, n (%)	831 (60.2%)	175 (31%)	29.1 (24.5 - 33.8) ***<0.0001***
Imaging			
FAST scan, n (%)	55 (4%)	0 (0%)	4 (2.9 – 5) ***<0.0001***
X-ray, n (%)	1026 (74.3%)	425 (75.4%)	-1.1 (-5.3 - 3.2) *0.626*
Ultrasound, n (%)	100 (7.2%)	79 (14%)	-6.8 (-9.9 - -3.6) ***<0.0001***
Peritoneal lavage, n (%)	(0%)	(0%)	-
CT, n (%)	1108 (80.2%)	281 (49.8%)	30.4 (25.8 - 35.0) ***<0.0001***
CT head, n (%)	813 (58.9%)	157 (27.8%)	31.0 (26.5 - 35.6) ***<0.0001***
CT thorax, n (%)	776 (56.2%)	99 (17.6%)	38.6 (34.6 - 42.7)
CT abdo, n (%)	825 (59.7%)	156 (27.7%)	32.1 (25.6 - 36.6)
Emergency Surgery			
Internal operation*, n (%)	65 (4.7%)	61 (10.8%)	-6.1 (-8.9 - -3.3) ***<0.0001***
External operation**, n (%)	373 (27%)	75 (13.3%)	13.7 (10.1 - 17.4) ***<0.0001***
Specific operation***, n (%)	34 (2.5%)	1 (0.2%)	2.2 (1.4 - - 3.2) ***<0.0006***
Embolisation, n (%)	17 (1.2%)	0 (0%)	1.2 (0.6 – 1.8) ***0.008***
Hospital stay			
ICU stay, n (%)	530 (38.4%)	284 (50.4%)	-12.0 (-16.8 - -7.1) ***<0.0001***
Interventional radiology, n (%)	37 (2.7%)	0 (0%)	2.7 (1.8 – 3.5) ***0.0001***
LOS, median (IQR)	14 (7 - 25)	17 (7 - 33)	-3 (-5.0 - -1.0) ***0.003***
LOS ICU, median (IQR)	5 (2 - 13)	5.5 (2 - 13)	-0.5 (-2.1 - 1.1) *0.531*

AIS: abbreviated injury scale; CI: confidence interval; CT: computerised tomography; ICU: intensive care unit; IQR: interquartile range; hrs: hours; LOS: length of stay; n: number; RTN: regional trauma network; TXA: tranexamic acid.
* Damage control Laparotomy, repair of intraperitoneal bladder rupture, fasciotomies.
** Fracture manipulation, traction, pelvis external fixation.
*** Fracture internal fixation, primary open reduction internal fixation.

of the trauma system in the UK. Since 2012, all MTCs and progressively over the last 10 years most of the TUs consistently submit complete and high quality entries to the registry. Unfortunately, this improvement does not affect the control group of this cohort analysis. However, the large number of PFXs cases in this study (>13,000) and the strict TARN methodology of scrutiny of the data they receive before their approval and incorporation to the registry, does minimize selection biases. Therefore, these results do represent the reality of trauma care these patients have received. Another limitation of this study is the TARN specific selection criteria, which exclude prehospital deaths or delayed trauma related deaths from the registry and also from this study. However, the 30-day mortality is generally accepted as very good outcome measure especially after blunt major trauma. [42] Lastly, the clinical and functional outcome of the majority of these patients that survive their injuries was not available to our analysis, although very important for having a complete picture of the quality of provided care between the two periods. This was mainly, because it was out of scope of this analysis, and also because patient reported outcome measures have only recently been incorporated to the TARN registry.

Table 3
Outcome comparison between the two different cohorts representing two different eras of management of seriously injured (major trauma) patients with pelvic fractures in NHS England.

	RTNStudy group		Pre-RTNControl group		*p*-values*
	Alive	Dead	Alive	Dead	Dead
Age, median, (IQR)	51.8 (29.9 - 73.9)	71.05 (42.5 - 85.05)	34.6 (22.1 - 50.5)	44.8 (25.05 - 71.2)	***<0.0001***
ISS, median, (IQR)	20, (13 - 32)	36 (25 - 50)	24 (16 - 33)	41 (30 - 50)	***0.0021***
Pelvic AIS Severity					
3	5946 (89.1%)	729 (10.9%)	1083 (84.4%)	200 (15.6%)	***<0.0001***
4	1551 (85.8%)	257 (14.2%)	1199 (82.9%)	247 (17.1%)	***0.0148***
5	713 (80%)	178 (20%)	54 (48.6%)	57 (51.4%)	***<0.0001***
Associated Severe Injuries					
Head	2071 (75.2%)	684 (24.8%)	626 (66.8%)	311 (33.2%)	***<0.0001***
Thorax	4155 (84.2%)	780 (15.8%)	1118 (75.1%)	371 (24.9%)	***<0.0001***
Abdomen	972 (79.3%)	254 (20.7%)	342 (70.7%)	142 (29.3%)	***0.0001***
Spine	1074 (86.2%)	172 (13.8%)	135 (84.4%)	25 (15.6%)	*0.5322*
Long bones	3685 (89.3%)	440 (10.7%)	1248 (83%)	255 (17%)	***<0.0001***
Other injuries in particular					
Liver-Spleen	957 (80%)	239 (20%)	327 (67.6%)	157 (32.4%)	***<0.0001***
Head &Thorax & Abdomen	182 (60.7%)	118 (39.3%)	58 (43.6%)	75 (56.4%)	***<0.0001***
Urogenital	557 (82%)	122 (18%)	271 (75.1%)	90 (24.9%)	***<0.0001***
Open fractures	1351 (87.7%)	156 (12.3%)	848 (79.3%)	192 (20.7%)	***<0.0001***

AIS: abbreviated injury scale; IQR: interquartile range; RTN: regional trauma network.
**p*-values were obtained by Bonnet-Price test on the median for continuous variables and Chi-square test for categorical variables

Conclusions

The improvement of patients' outcome remains the goal of all clinicians and professionals in all health care systems. Major trauma patients represent a small part proportionally of hospital admissions, but at the same time one of the most complex multispecialty clinical challenges. The recorded improvement of survivorship in the subgroup severely injured patients with a pelvic fracture, following the first 5 years of established regional trauma networks in NHS England, is encouraging, and should be attributed to a wide range of factors that translate to all levels of trauma care.

Declaration of Competing Interest

The authors declare no conflict of interest in relation to the content of this manuscript.

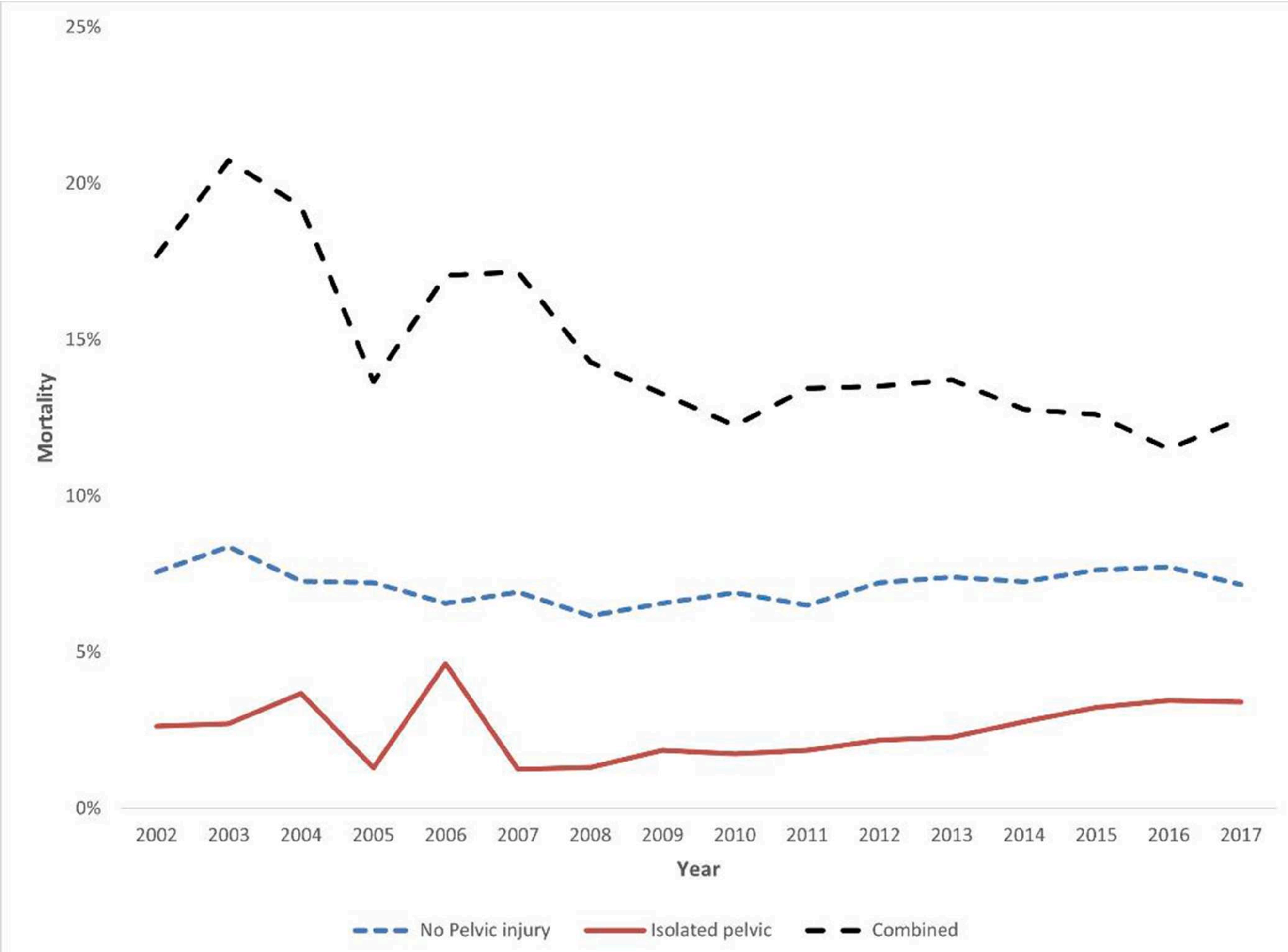

Fig. 3. Evolution of mortality changes through the years 2002–2017 in the TARN registry, divided between non pelvic injured, isolated pelvic injured and pelvic injured patients with combined other severe injuries with AIS>2.

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