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The Epidemiology of Traumatic Brachial Plexus Injuries in England and Wales—A 32-Year Review

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Background: Traumatic brachial plexus injuries (TBPI) are often devastating and life-changing and are thought to be becoming more prevalent. Several studies have investigated the epidemiology of TBPI in other countries (e.g., United States, Brazil); however, a similar analysis is yet to be undertaken in England and Wales. The aim of this cohort study was to determine the incidence and epidemiology of TBPI in England and Wales.

Methods: The Trauma Audit and Research Network database was reviewed to identify 1,297 eligible patients admitted with TBPI between 1990 and 2022. Patient demographics, injury mechanism, associated injuries, and outcomes were analyzed.

Results: The median age of patients with TBPI was 41 years, and 77% (n = 997) were male. There was a significant difference in age between male patients and female patients, with male patients aged younger than 18 years (confidence interval 14.4-21.3) at the time of injury. The predominant injury mechanism was vehicle collision (65%), with 62% riding motorcycle or quad bikes. The majority of other injuries resulted from falls less than 2 m (19%). Falls less than 2 m were particularly prevalent in patients aged older than 65 years, who represented 19% of the cohort. TBPI was commonly associated with other injuries (94%), predominately bony injuries including dislocations and fractures.

Conclusion: This is the first epidemiological study of TBPI within England and Wales. Vehicle incidents, particularly involving motorcycles, are the commonest cause of TBPI; however, there is a substantial cohort of elderly patients sustaining TBPI, often from falls. These findings may aid improved and earlier recognition of TBPI, enabling timely management.

Level of Evidence: Level III. See Instructions for Authors for a complete description of levels of evidence.

Introduction

Traumatic brachial plexus injuries (TBPI) hold devastating repercussions for the affected individual. Characterized by long-term severe physical disability, they can also precipitate chronic pain and psychological morbidity[1]. The societal and economic burden of TBPI not only affects the individual but extends to their family and wider community[2]. Direct healthcare costs are over £30,400 per patient[3], which is dwarfed by indirect costs of over £873,000 per patient, which are absorbed by the family[4]. Consequently, one in 3 patients with TBPI is at risk of catastrophic health expenditure, exceeding 40% of their postsubsistence income[5].

Recent epidemiological observations highlight a concerning trend. While TBPI are rare, estimated to occur in 1.2% of multitrauma cases[6], the incidence is thought to be increasing[7]. However, available evidence is outdated or not generalizable to England and Wales. In 1992, Goldie and Coates estimated that there were 400 to 500 closed supraclavicular lesions occurring annually in the United Kingdom[8]. More recently, the incidence has been estimated at 0.3 to 0.75 per 100,000/yr in Switzerland[9], 0.2 in Czech Republic and Slovenia combined[10], 0.8 in Scotland[11], and 1.75 in Brazil[12]. These figures carry inherent biases and largely emanate from specialist centers focused on surgical management, potentially underrepresenting actual prevalence, and spectrum of TBPI. The absence of reliable contemporary data and severity of these injuries are the rationale for this study.

The increasing frequency of TBPI combined with their life-changing effects supports the pressing need for national data collection and analysis in the United Kingdom. Recovery or reconstruction of function relies on prompt diagnosis and timely surgical intervention in specialist centers[13,14].

Disclosure: The **Disclosure of Potential Conflicts of Interest** forms are provided with the online version of the article (http://links.lww.com/JBJSOA/A778).

TABLE I Summary of Patient Demographics and Mechanism of Injury

Patient Demographics and Injury Mechanism	n	%
Gender		
Female	300	23
Male	997	77
Age of patient		
0-9 yr	12	1
10-19 yr	118	9
20-29 yr	296	23
30-39 yr	204	16
40-49 yr	208	16
50-59 yr	152	12
60-69 yr	116	9
70-79 yr	94	7
80+ yr	97	7
Mechanism of injury		
Road traffic accident	836	64
Fall <2 m	245	19
Fall >2 m	78	6
Penetrating injury	69	5
Other	69	5

Against this backdrop, the aim of this study was to characterize the incidence, epidemiological trends, and injury profiles of TBPI across England and Wales over the last 32 years. Through this, we aim to shed light on evolving patterns, potentially influencing future policy directives and clinical practices.

Materials and Methods

This cohort study was designed, executed, and reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) and the Standards for Reporting of Diagnostic Accuracy Studies (STARD) guidelines[15,16]. We used prospectively captured data held by the Trauma Audit and Research Network (TARN). Data regarding all patients with recorded TBPI in England and Wales between the database's inception in January 1990 and March 2022 were supplied on request and included in this study. The data set contained 166 duplicated entries due to submission from multiple hospitals (e.g., following transfer or repatriation), which were merged before analysis.

For data to be captured within TARN (Europe's most extensive trauma registry), patients must meet at least one of the following criteria: hospital stay 3 days or more, admission to critical care services, trauma resulting in death, or transfer for specialist or high-dependency care (excluding rehabilitation services). Only confirmed diagnoses are recorded by trained, experienced coders to ensure consistency[17].

We extracted data on patients' age, sex, geographical location, injury circumstances, transfer to hospital, concurrent injuries, complications, and 30-day mortality.

Statistical Methods

Data were analyzed using Stata/SE 17[18]. Skewed continuous variables are represented by the median and interquartile range (IQR) or geometric mean with 95% confidence interval (CI) as appropriate. Categorical variables are represented as counts and proportions and compared using χ^2 tests or Fisher exact tests if assumptions of the former were violated. A multivariable logistic regression model was used to explore whether age, sex, and injury mechanism were associated with cases of isolated TBPI vs. polytrauma cases. We use the term risk to describe the outputs of these regression models given that risk and odds are similar when the event is rare. CIs were generated to the 95% level (CI).

Ethical Approval/Data Storage

Existing ethical approval for anonymized registry data (Patient Information Advisory Group section 60) was used with data stored securely on a University of Manchester server[19].

Results

Patient Demographics

Overall, 1,297 patients with TBPI were identified. No patients were excluded as all had a coded TBPI and available data for variables of interest. The majority were male (997, 77%), while 300 (23%) were female. The median age was 41 years, with an IQR of 27 to 58 years. Notably, male patients with TBPI were on average 18 years younger than female patients (CI 14.4-21.3). Patient demographics and injury mechanism are summarized in Table I. The incidence of TBPI demonstrated an increasing trend over the 32-year period (Fig. 1).

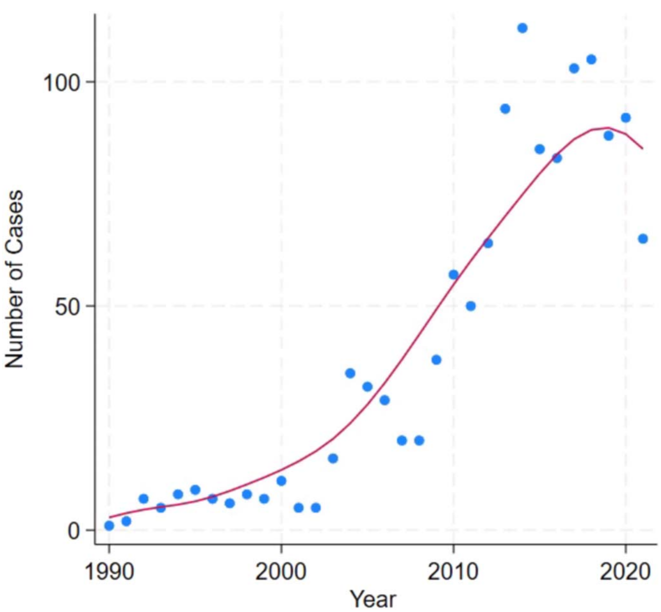

Fig. 1

Number of cases of TBPI reported per year between 1990 and 2021. TBPI = traumatic brachial plexus injuries.

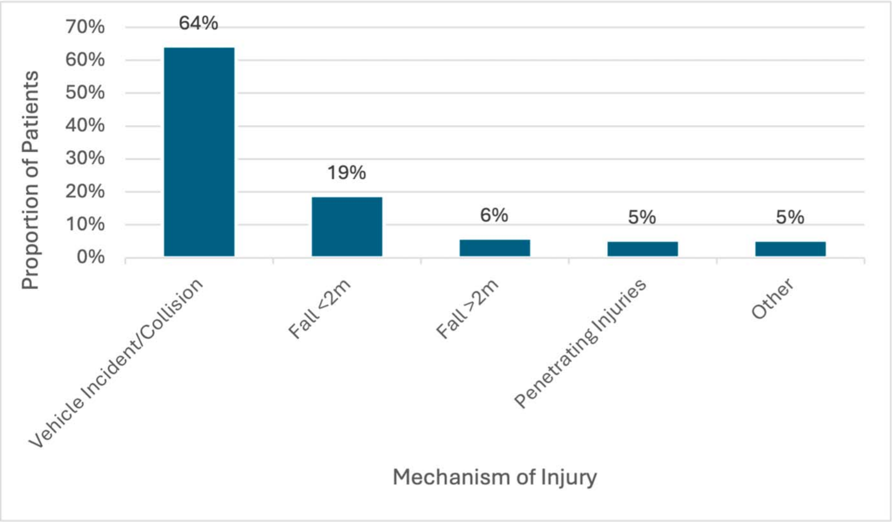

Fig. 2
Injury mechanisms implicated as etiology in traumatic brachial plexus injuries in England and Wales.

Mechanism of Injury

Etiologies of TBPI are summarized in Figure 2. The predominant cause was road traffic accidents (RTA) representing 65% of injuries (n = 836) and position within the vehicle appeared related to injury acquisition (Fig. 3). Within this category, motorcycle accidents were the commonest cause accounting for 62% of cases (n = 519). Of RTAs, there was evidence of alcohol consumption in 7% (n = 61), drug or substance intoxication in 0.6% (n = 5), and of both alcohol and drug/ substance misuse in a further 12 patients (1%). Another prevalent etiology was falls less than 2 m (e.g., from standing), accounting for 19% of TBPIs (n = 245). As for penetrating injuries, stabbings were the commonest modality (88%; accounting for 5% of all TBPIs, n = 61).

Distinct, common injury patterns emerged based on patient demographics. Male patients younger than 65 years were significantly more likely to sustain TBPI secondary to RTA (OR 6.3 [CI 4.9-8.1]). By contrast, female patients aged 65 years and older faced higher risk from falls less than 2 m (OR 38 [CI 23-63]).

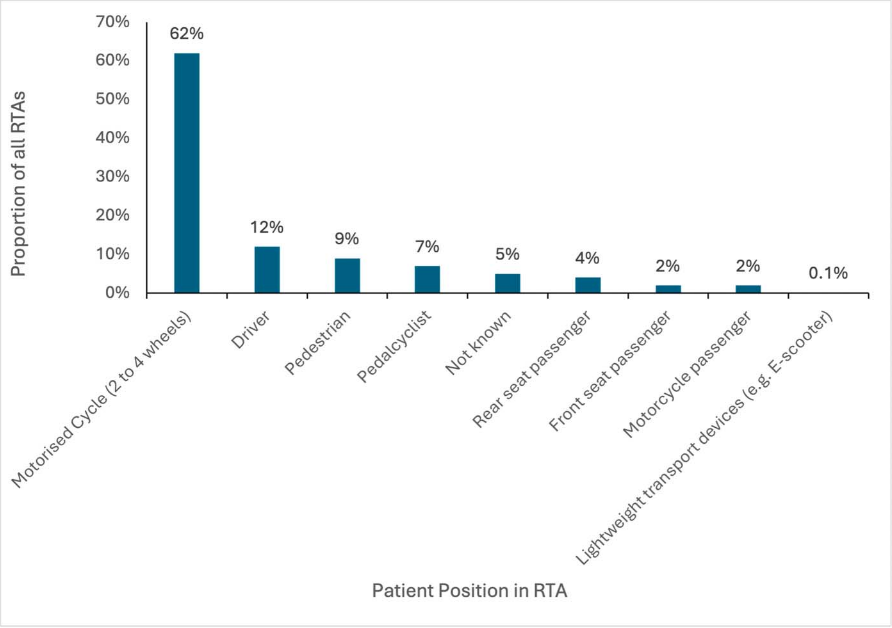

Fig. 3
Breakdown of the position within vehicle in RTAs leading to traumatic brachial plexus injuries in England and Wales. RTA = road traffic accidents.

Associated Injuries

Musculoskeletal Injuries

Fractures and dislocations were recorded in 80% (n = 1,034) of patients, most commonly rib fractures (37%, n = 477) (Fig. 4). Upper limb injuries included the scapula (23%, n = 302), clavicle (18% n = 231), and humerus (17%, n = 332). Injuries below the elbow were present in 40% (n = 512). Lower limb fractures and dislocations were recorded in 25% (n = 328).

Spinal Injuries

Vertebral fractures were present in 35% of patients (n = 453): thoracic (n = 302), cervical (n = 271), and lumbar (n = 107). Concurrent fractures in multiple vertebral regions occurred in 200 patients.

In addition to vertebral fractures, spinal cord injuries were seen in 18% (n = 221) of patients (Table II). Other injuries involving the spine were seen in 130 patients (10%), which primarily comprised spinal ligament injuries and damage to other nerve roots (Table III). Overall, 42% (n = 551) had at least one injury involving the spine or spinal cord.

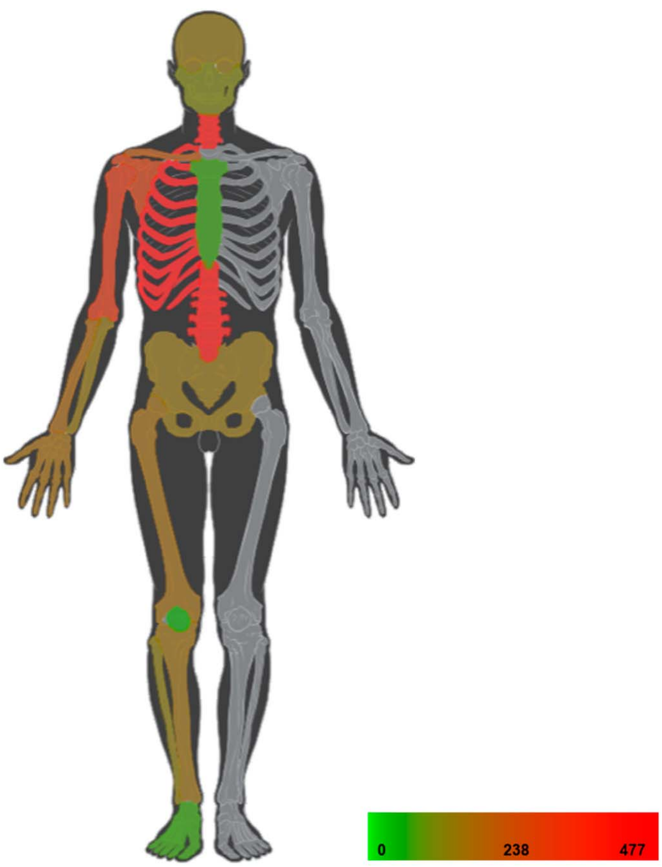

Fig. 4

Heat map representing the frequency of associated skeletal injuries in patients with TBPI in England and Wales. TBPI = traumatic brachial plexus injuries.

TABLE II Recorded Injuries to the Spinal Cord and Associated Proportion of Patients

Breakdown Spinal Cord Injury	No. of Patients (%)
Cervical cord contusion	90 (7)
Other cervical root injury	88 (7)
Thoracic cord contusion	39 (3)
Thoracic cord laceration	5 (0.4)
Thoracic root injury	24 (2)
Lumbar cord contusion	9 (0.7)
Lumbar root injury	1 (0.1)
Cord contusion–region not specified	3 (0.2)
Cauda equina	3 (0.2)

Visceral Injuries

Thoracic viscera injuries, encompassing hemothorax, pneumothorax, or lung contusion, were present in 40%. Meanwhile, abdominal visceral injuries were seen in 13%.

Head Injuries

Head injuries, including skull fractures, were reported in 29% (n = 375) of cases. This included cerebral injuries (14%), subarachnoid hemorrhage (10%), scalp injury (8%), and subdural hematoma (7%). Over half (55%) had multiple head injuries.

Vascular Injuries

Overall, 21% of patients had a major vascular injury, with trauma to axillary and subclavian vessels accounting for 14% of these (Fig. 5). Patients with upper limb fractures or dislocations had 1.4 times the odds of sustaining coexistent upper limb vascular injuries (OR 1.4 [CI 1.01-1.85]). Similarly, patients with fractures to the thoracic region and shoulder girdle were more likely to sustain vascular injuries (OR 1.4 [CI 1.04-1.79]).

Patients With Isolated TBPI vs. Polytrauma

Overall, 94% of patients (n = 1,219) had associated injuries. Patients with isolated TBPIs were on average 20 years older than polytraumatized patients (CI 12-28). Over 60% (n = 47) of isolated TBPIs resulted from falls less than 2 m. In comparison, 68% of patients involved in RTAs were polytraumatized and only 17% sustained isolated TBPIs. As compared with low-level falls, falling greater than 2 m or being involved in an RTA carried significantly higher risk of sustaining other injuries alongside TBPI (OR 15.5 [CI 2.1-115] and 9.5 [CI 4.3-21.3], respectively).

Complications and Deaths

Complications were documented in 22% of cases (n = 286). The 3 commonest were infection (n = 125, 10%), cardiac or respiratory arrest (n = 39, 3%), and acute kidney injury (AKI) or renal failure (n = 35, 3%) (Fig. 6). Overall, 33 patients died from their injuries or as a result of complications within 30 days, yielding a 30-day mortality rate of 2.5%.

TABLE III Other Injuries Reported to the Spine

Other Spinal Injury	No. of Patients (%)
Cervical interspinous ligament injury	55 (4)
Thoracic interspinous ligament injury	37 (3)
Lumbar interspinous ligament injury	8 (0.6)
Atlanto-occipital dislocation	7 (0.5)
Other vertebral dislocation	16 (1)
Cervical disk herniation/rupture	32 (2)
Thoracic disk herniation	4 (0.3)

Discussion

There has been a significant increase in the proportion of patients surviving major trauma with Moran et al., showing an increase in odds of survival by 19% between 2008 and 2017[20]. As TBPIs are estimated to occur in 1.2% of patients involved in major trauma[6], this increased survival has indirectly escalated incidence of such injuries, as seen in our cohort.

TBPI carries significant physical and psychological burden[2,21,22], often imparting lifelong sequelae on a largely economically active population[12,23,24]. The chronicity of the injury and complexity of management result in estimated costs of £35 million to the National Health Service and economy per annum[25,26]. The current demographic blueprint and epidemiology of TBPIs in England and Wales is unknown, complicating service provision and potential improvements. This study, based on the TARN data set spanning a 32-year period with a sample of 1,297 patients, is significant for 2 reasons: it is one of the largest cohorts studied, and one of few collated from a national database[1,6,23,27,28].

Our analysis discerned a 77% male preponderance in TBPI cases, which aligns with multiple studies[1,7,11,23,27-29]. Conversely, studies from Kaiser et al., Jain et al., and Cho et al. showed male predominance of 93% to 98%[23]. We often see male patients injured because of a higher likelihood to engage in high-risk activity including motorcycle use, speeding, and substance misuse[30-34] or be exposed to occupational hazards[35] than their female counterparts. This likely predisposes male patients to higher velocity and more severe injuries, thus necessitating surgical repair. In this study, we demonstrated that female patients are older at the time of injury and that older patients are more likely to sustain TBPI from low-velocity injury. As the aforementioned studies took place in surgical centers[7,23,28], it is possible the higher proportion of female patients in our population is due to recognition of patients not undergoing operative repair.

In our cohort, the mean age of patients was 40.5 years, which is older than other studies where the mean age was 24 to 34 years[1,6,7,23,27,36-38]. This may again be explained by the majority of studies originating from surgically managed populations. Our population comprised all patients with recorded TBPI regardless of management undertaken. Therefore, we may have a substantial contribution from low-velocity infraclavicular plexus injuries, which are significantly more likely to improve with nonoperative management[6,39,40]. Infraclavicular plexus injuries often occur in older patients with glenohumeral dislocation or humeral fracture following minor trauma[41]. Our analysis demonstrated the proportion of TBPIs occurring in patients aged older than 65 years increased over the 32-year period, perhaps as a result of an aging population. Increased inclusion of such patients in this study may explain the older mean age; however, database recording of plexus injury location was overwhelmingly incomplete and unable to be further analyzed.

RTA were the mechanism of injury in 65% (n = 836) of cases, with motorcycle and quad bike accidents accounting for 62% (n = 519) of these and car accidents for 18% (n = 154). These proportions are consistent with those reported within other European studies[7,29,37,42,43]. However, the proportion of TBPI attributed to motorcycle accidents has been reported as considerably higher in studies from countries within Asia and South America[23,27,28,36,44]. This may be explained by differing transport preferences and societal diversities. The lower figures in Europe may also be somewhat explained by road safety campaigns, including the "Think!" campaign in the UK[45] and European Transport Safety Council Road Safety Performance Index[46], which aim to reduce RTAs and improve road safety for all users, including specific motorcycle campaigns[47]. While these campaigns have likely contributed to improved safety, our findings highlight that motorcycle injuries remain a significant

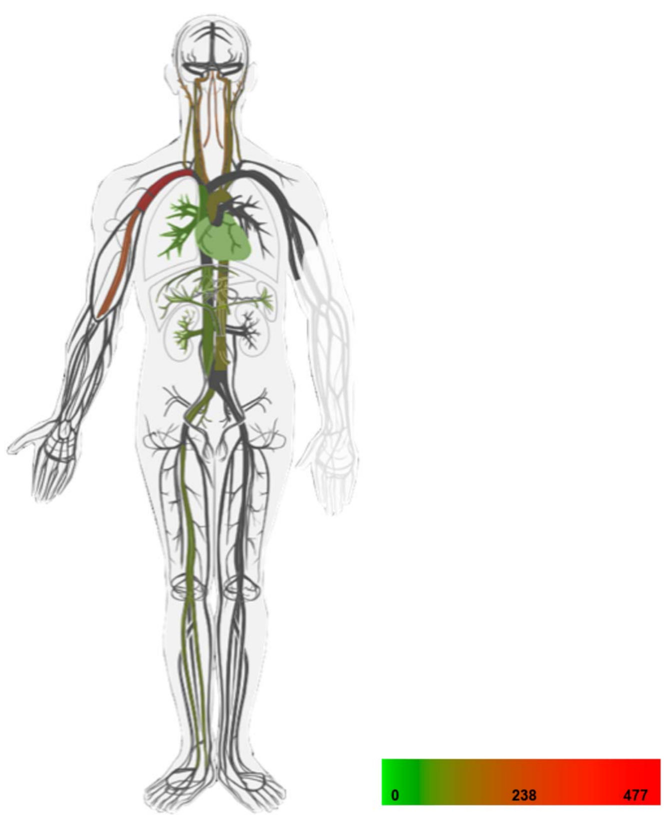

Fig. 5

Heat map representing the frequency of associated vascular injuries in patients with TBPI. TBPI = traumatic brachial plexus injuries.

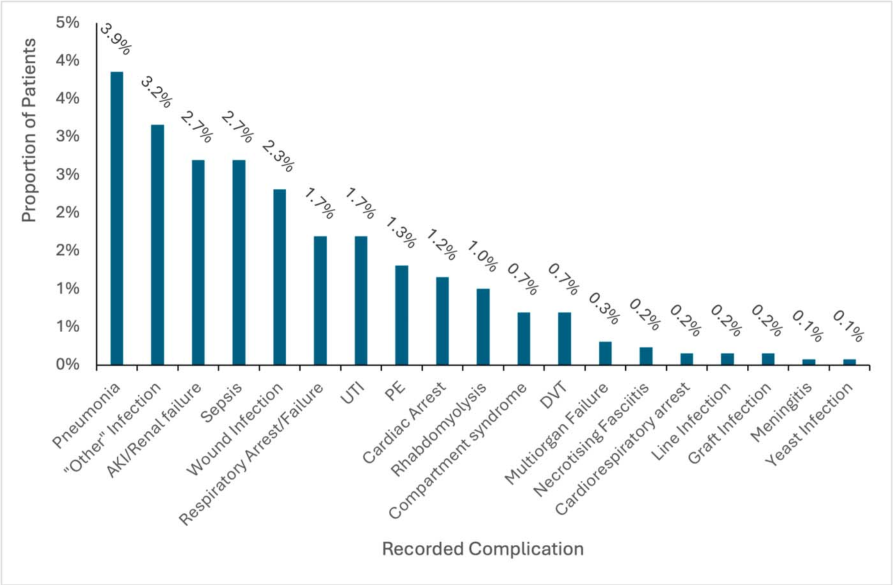

Fig. 6
Percentage prevalence of complications in patients with TBPI. TBPI = traumatic brachial plexus injuries.

etiology for TBPI and suggest that further work to improve motorcycle safety is vital, such as targeted road markings at sites identified as high risk for motorcycle accidents[48].

In our cohort, falls, particularly those less than 2 m, accounted for nearly 20% of TBPIs. This is a noteworthy variation from earlier literature which seldom associates falls to TBPI[16,18-22,25]. Such findings resonate with Li et al., who noted a 16% contribution of falls to TBPI, albeit without quantifying categories of fall height[1], and recently published findings from Scotland where fall from standing was the most common injury mechanism in their cohort[11]. Crucially, low-level falls were predominant in the over-65 age group, who represented almost 20% of all TBPIs in our data set. This increase in trauma in older demographics is consistent with advancements in trauma management, increasing life-expectancy, and extended active lifestyles[26,27]. Their inherent frailty renders them susceptible to severe injuries even from low-impact events[28]. Notably, patients from this age bracket presented with isolated TBPIs and were on average 20 years older than their counterparts with polytrauma. A significant 60% of these injuries arose from low-level falls, highlighting that elderly patients are more inclined toward sustaining isolated TBPIs from lower-velocity traumas. The absence of commonly associated injuries could undermine clinical suspicion, jeopardizing early detection and intervention. This highlights a pressing need for early identification of those at risk of falls, using tools such as the World Guidelines for Falls Prevention and Management's risk stratification[49], and effective prevention strategies, including supervised exercise programmes[50]. Given that a substantial portion of existing studies focus on surgically repaired TBPIs, our older demographic might be underrepresented in contemporary literature. This gap suggests that there is much to unearth about their clinical presentation, outcomes, and best management practices.

Patient factors and injury mechanism have also shown importance in occurrence of associated injuries. 94% of this population were polytraumatized, consistent with other studies[1,6,23,27-29,37]. Fractures and dislocations were the commonest associated injury occurring in almost 80%, consistent with other literature[1,23,27,36,37,42]. The frequency and site of bony injuries vary between studies; however, fractures affecting the shoulder and upper limb are reported with particularly high incidence[27,36,42,51]. Humeral, scapular, and clavicle fractures were each found in over 300 patients. We found the commonest coincident fractures affected the ribs and vertebrae. This high incidence of associated rib fractures may be highly important if risking damage to intercostal nerves which can be important donor sites for nerve reconstruction. We found 20% of patients to have an associated vascular injury, similar to other studies[37,52,53]. However, some have reported lower incidence (5%), suggesting wide variation in either diagnosis or occurrence[23,36]. This difference may be explained by the recommendation for routine whole-body computed tomography (CT) in the United Kingdom for adult patients following blunt trauma where multiple injuries are suspected[54]. While this approach is well represented in the literature and adopted throughout many countries in North America and Europe[55-60], it is not standardized worldwide, which may mean occult vascular injuries are missed. Nevertheless, this is an important injury to identify given that coincidental vascular injuries alter management and outcomes in TBPI[53,61,62].

The TARN data set allows identification of patients with TBPI, regardless of management undertaken, and while overall incidence may be underestimated, the epidemiology and injury patterns are likely representative of other countries within the United Kingdom and Western Europe with similar population characteristics.

Limitations

There were discrepancies in completeness of information submitted between centers. Compliance has improved since the inception of major trauma centers in the United Kingdom in 2012; however, data accuracy is contingent on the quality of individual hospital submission. As patients must meet specific inclusion criteria, it is likely that actual incidence of TBPI is underestimated, potentially leading to a higher true case mix and clinical burden than currently captured. It will be vital for future studies to capture a more comprehensive range of TBPI cases by including outpatient and hospital records and suggests there is need for a national TBPI-specific database to facilitate collection and analysis of this data.

Outcome metrics in TARN primarily focused on 30-day mortality and hospital stay length which are not typically relevant to patients with TBPI. The risk of death after hospital admission is small in this cohort, and the TBPI is not typically the reason the patient remains admitted. While these outcomes are important, future studies (national registry-based or otherwise) should capture objective functional and patient-reported outcomes, which are important to patients[26,63], and have not been captured in this study.

Furthermore, while TARN collects information relating to injury mechanism, specific details relating to the injury, such as nature of falls or speed of travel, were not available. Future studies should capture this information to enable greater analysis of the etiology of TBPI and implementation of specific prevention strategies.

Conclusion

This is the first epidemiological study of TBPI within England and Wales. These life-changing injuries typically afflict working-age male patients, often as a result of motorcycle collisions. However, there is a substantial cohort of elderly patients suffering TBPIs as a result of falls. Nonetheless, it is probable that our study underestimates the true burden of this catastrophic injury to patients and health service alike. This underscores a pressing need for national research into the true prevalence of TBPIs, particularly within the elderly population sustaining injury from low-velocity falls, and further analysis of the management and outcomes of these injuries to better understand their cost to the individual and health service. ■

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