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Incidence of Traumatic Brachial Plexus Injuries in Sweden 2016–2020, a Nationwide Retrospective Cohort Study

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Research Article

Keywords: Traumatic brachial plexus injury, TBPI, shoulder dislocation, epidemiology, nerve reconstruction, retrospective cohort study, peripheral nerve injury

Posted Date: September 16th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9865864/v1

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Additional Declarations: No competing interests reported.

Abstract

Background

Traumatic brachial plexus injury (TBPI) is uncommon but potentially devastating. Injury mechanism influences anatomical pattern and the need for nerve reconstruction. National data with clinically verified TBPI are limited. This study aimed to determine the nationwide incidence of TBPI in Sweden and to describe injury mechanisms, anatomical patterns and surgical management.

Methods

We conducted a retrospective nationwide cohort study of all individuals registered as residents in Sweden evaluated for suspected TBPI at the country's two National Specialised Medical Care brachial plexus centres between 2016 and 2020. Cases were identified using ICD-10 code S14.3 and included after specialist confirmation. Isolated terminal nerve injuries and non-traumatic aetiologies were excluded. Injuries were categorised by trauma mechanism and anatomical level as supraclavicular or infraclavicular. High- and low-energy TBPI were compared.

Results

A total of 288 clinically confirmed TBPI cases were identified, corresponding to an annual incidence of 0.57 per 100,000 inhabitants. High-energy trauma accounted for 119 cases with an incidence of 0.24 per 100,000 inhabitants, and predominantly affected early middle-aged men. The mean age was 40.3 years and male-to-female ratio was 3:1. Nerve reconstruction was performed in 45% of supraclavicular and 21% of infraclavicular high-energy injuries. Low-energy trauma accounted for 135 cases, with an incidence of 0.27 per 100,000 inhabitants. These injuries affected older individuals, with a mean age of 62.1 years, and were frequently associated with shoulder dislocation, which occurred in 71% of infraclavicular cases. Only one case with low-energy TBPI required nerve reconstruction.

Conclusion

TBPI in Sweden demonstrates two distinct clinical profiles: high-energy injuries in early middle-aged men frequently requiring nerve reconstruction, and low-energy injuries in older adults—commonly associated with shoulder dislocation—rarely requiring operative plexus intervention. These findings support differentiated referral pathways and management strategies.

Level of Evidence

II, Prognostic study (retrospective cohort)

BACKGROUND

Traumatic brachial plexus injury (TBPI) can result in profound impairment of upper limb function and is frequently accompanied by severe, treatment-resistant pain, leading to profound and lasting consequences for patients' lives [1-4]. TBPI represents a heterogeneous group of injuries, with outcomes influenced by factors such as the anatomical level of injury (supraclavicular vs. infraclavicular), the specific components of the plexus affected (e.g. roots, trunks, divisions, or cords), and the severity of nerve damage, ranging from transient conduction block to complete injury affecting multiple elements of the plexus [5, 6].

Understanding and effectively categorising this variability is crucial for healthcare planning and timely referrals, especially as these complex injuries are often managed in specialised centres. Even less severe TBPI cases that resolve without reconstructive surgery frequently require prolonged rehabilitation and long-term follow-up to detect potential indications for secondary surgical interventions. Early identification of predictive factors—such as injury mechanism and epidemiological variables including age and sex—may help optimise referral pathways and resource allocation, supporting individualised patient management and more efficient use of healthcare resources. Variations in incidence, injury mechanisms, and treatment options across time and regions likely reflect a complex interplay of factors. These include differences in population demographics, environmental conditions, socioeconomic status, and healthcare system structure.

Incidence of TBPI

The true incidence of TBPI remains uncertain owing to limited comprehensive epidemiological data, with most published estimates based on diagnostic or treatment codes that may not accurately capture injury severity or prevalence. Reported incidence rates vary widely across countries (see, for example, [7]), probably reflecting a combination of heterogeneous case definitions, reliance on registry-reported data, and true differences in trauma patterns and population demographics. This underscores the value of clinically verified, specialist-centre–based case identification when estimating national TBPI burden.
A Swedish study of traumatic peripheral nerve injuries reported to a national database showed TBPI as the most resource-demanding, with an average of 68 cases per year and a total of 960 hospital days annually [8]. To improve care for these patients, the Swedish National Board of Health and Welfare centralised surgical treatment of TBPI to two national centres, Stockholm and Umeå, in 2016. This centralisation provides a unique opportunity to assess the nationwide Swedish incidence of TBPI, as these centres serve as the sole providers of surgical intervention for the condition. Previous studies investigating the national incidence of TBPI have typically relied on registry or database data from individual hospitals or regions, or pooled data from many such studies, limiting their ability to provide a comprehensive national overview [8-13]. Even studies conducted at the national level—such as the Scottish National Database Study [9] have included a broader spectrum of injuries, such as proximal humeral-level and isolated peripheral nerve injuries, without clinical confirmation by brachial plexus specialists. To our knowledge, this is the first nationwide study in which all patients have been evaluated

by dedicated brachial plexus teams, allowing for a confirmed diagnosis of TBPI and the exclusion of isolated terminal nerve injuries.

Objective of the Study

The primary objective of this study was to determine the nationwide incidence of clinically verified TBPI in Sweden after centralisation of surgical care to two national referral centres. Secondary objectives were to describe injury mechanisms, anatomical injury patterns, demographic characteristics, seasonal variation and surgical management, with particular emphasis on differences between high- and low-energy trauma.

METHODS

Study Design and Setting

We conducted a retrospective cohort including all patients evaluated for suspected TBPI and diagnosed with TBPI between January 1, 2016 and December 31, 2020 at Sweden's two National Specialised Medical Care (NSMC) brachial plexus centres, located in Stockholm and Umeå. These centres constitute the national referral centres for surgical management of TBPI in Sweden.

Participants and Case Identification

Patients were identified through hospital records using the ICD-10 diagnostic code for TBPI (S14.3), with inclusion restricted to cases with a diagnosis confirmed by these two referral centres.

Cases with injuries to isolated nerves in the upper arm (S44.0–S44.2) and isolated axillary nerve injuries (S44.3) were not classified as TBPI. Patients who had fully recovered by the time of assessment by the brachial plexus team—so that a TBPI diagnosis could not be confirmed—as well as those diagnosed with neuritis or with tumours affecting brachial plexus function, were excluded. Consequently, the resulting dataset included only cases explicitly assessed as traumatic brachial plexus injuries. Individuals not registered as residents in Sweden at the time of injury (i.e., not recorded in the Swedish Population Register) were excluded because follow-up data were not consistently available. All clinical records were independently reviewed by two senior hand surgeons experienced in TBPI (authors FR, PN, Level 4 expertise, [14], and data were collected on the following variables:

- Patient sex
- Age
- Dominant hand
- Affected side
- Time and mechanism of injury
- Type of TBPI
- Concomitant injuries, specifically: shoulder dislocation, clavicular fracture, blood vessel injury

- Surgical procedures
- Time from injury to nerve reconstructive surgery

Injuries were categorised as supraclavicular or infraclavicular based on clinical records, imaging, and operative findings when available. Ambiguous or mixed injury patterns were resolved by consensus between the two reviewers.

Definitions of Classifications Used

Mechanisms of injury were divided into five groups according to clearly distinct trauma energies and mechanisms, with assumed potentially different treatment strategies:

*High-energy trauma:*Defined as injuries sustained through mechanisms such as motor vehicle accidents (MVA), skiing accidents, falls from horseback or bicycles, falls from a height greater than one meter, or impact from falling objects during sports or occupational activities. These mechanisms typically carry a high risk of traction or avulsion-type injuries to the brachial plexus, often resulting in severe damage such as neurotmesis or root avulsions.

Low-energy trauma: Defined as falls from standing height or from less than one meter, including prolonged immobilisation after a fall (“long lie”). These mechanisms are more likely to cause stretch or compressive injuries to the brachial plexus, with neurapraxia or axonotmesis being the more common types of nerve injury. Therefore, cases involving a long lie following a fall were categorised within this trauma mechanism [15-17]. For low-energy TBPI, referral to the national brachial plexus centres is typically reserved for patients with objective neurological deficits persisting for more than 2 months after injury.

*Sharp injury:*Defined as lacerations or penetrating injuries (e.g., knife wounds or glass cuts) directly involving the brachial plexus. These injuries typically result in sharp transection of nerves, with a high likelihood of neurotmesis.

*Gunshot injury:*Injuries caused by firearms, which may involve a combination of shockwave, thermal, and fragment effects on the nerves. These can result in mixed injury patterns, including both neurapraxia and neurotmesis.

Iatrogenic injury: Defined as nerve injuries sustained during medical or surgical procedures. This includes injuries due to sharp dissection or compression in the supraclavicular or infraclavicular brachial plexus during surgeries directly involving the region. Cases of indirect compression (e.g., from prolonged positioning, retraction, or ICU care) without direct surgical manipulation are categorised under low-energy trauma.

Concomitant Injuries

Concomitant injuries were defined and categorised as follows:

- Fractures: such as clavicular or scapular fractures.
- Major blood vessel injuries: In the supra- and infraclavicular areas.
- Shoulder dislocation: Presence or absence of shoulder dislocation.

Surgical procedure details

Surgical procedure details included whether nerve reconstructive surgery was performed, as well as whether any concomitant surgical procedures were carried out, such as vascular reconstruction or fracture management.

Statistical analysis

Statistical analyses were performed using two-tailed t-tests for comparisons of continuous variables and Chi-square tests for categorical variables. Logistic regression analysis was used to evaluate predictors of nerve reconstructive surgery. Analyses were conducted using Statistica version 12 (TIBCO Software Inc., Palo Alto, CA, USA). A p-value of less than 0.05 was considered statistically significant.

Ethical approval

Ethical approval for the study was granted by the Swedish Ethical Review Authority on November 10, 2021 (Dnr 2021-03649).

RESULTS

General overview

During the study period from January 1, 2016, to December 31, 2020, 288 patients in Sweden were diagnosed with TBPI, corresponding to an annual incidence of 0.57 per 100,000 inhabitants. The cohort included 187 men and 101 women (male-to-female ratio 1.9:1), with ages ranging from 11 to 92 years (median 51.5 years).

High- and low-energy TBPI were the most common and clinically distinct subtypes. In contrast, gunshot, sharp, and iatrogenic injuries were rare, with too few cases for statistical analysis (see Table 1). As such, statistical comparisons are limited to the high- and low-energy groups, with descriptive summaries provided for the remaining cases.

The following sections describe demographic patterns by injury mechanism—including laterality, trauma type, age distribution, and seasonal variation—and compare surgical interventions across trauma groups.
Table 1

Table 1. Injuries per type of injury and year. Numbers within parentheses denote supra- and infraclavicular injuries respectively. *One case had an unknown mechanism (assault) and was classified

as supraclavicular. **Annual incidence per 100,000 inhabitants, based on population data for each respective year[18](18).

Year	High-energy	Low-energy	Sharp	Gunshot	Iatrogenic	Total	Incidence**
2016	23 (8/15)	19 (2/17)	1 (0/1)	2 (2/0)	1 (1/0)	46 (13/33)	0.46
2017	21 (8/13)	30 (3/27)	1 (1/0)	1 (0/1)	2 (1/1)	55 (13/42)	0.55
2018	22 (12/10)	23 (4/19)	1 (0/1)	1 (1/0)	4 (3/1)	51 (20/31)	0.50
2019	29 (8/21)	28 (4/24)	4 (4/0)	1 (0/1)	8 (4/4)	70 (20/50)	0.68
2020	24 (7/17)	35 (5/30)	1 (1/0)	2 (0/2)	3 (1/2)	66* (15/51)	0.63
Total	**119 (43/76)**	**135 (18/117)**	**8 (6/2)**	**7 (3/4)**	**18 (10/8)**	**288**	**0.57**

High- and low-energy TBPI

Analysis of high- and low-energy trauma revealed trauma-specific incidences of 0.24 and 0.27 injuries per 100,000 inhabitants, respectively. Significant differences were observed between the two trauma mechanisms with regard to mean age, sex distribution, and the supraclavicular-to-infraclavicular injury ratio (Table 2).

Table 2. Demographic and Anatomical Differences Between high- and low-energy TBPI. M= male sex, F=female sex. ^= t-test, 2-tailed. ^^ Chi^2-test

	High-energy	Low-energy	Statistics
Mean Age (years)	40.3 (18.3)	62.1 (13.7)	p<0.0001^
M-F-ratio	3.0:1	1.3:1	p<0.001^^
Supra-/Infraclavicular injuries	1:1.8	1:6.5	p<0.001^^

Patients with high-energy injuries were younger, with a mean age of 40.3 years, compared with 62.1 years in the low-energy group. High-energy injuries showed a marked male predominance, with a male-to-female ratio of 3.0:1, whereas low-energy injuries were more evenly distributed between sexes (1.3:1).

Infraclavicular injuries were more common than supraclavicular injuries in both groups, particularly following low-energy trauma. The supraclavicular-to-infraclavicular ratio was 1:1.8 for high-energy injuries and 1:6.5 for low-energy injuries. These ratios were similar across sexes: for high-energy injuries, 1:1.8 in males and 1:2.0 in females; for low-energy injuries, 1:5.9 in males and 1:7.4 in females.

To further explore these distinct injury patterns, we conducted a detailed subgroup analysis. Given their differing demographics and clinical implications, high- and low-energy trauma mechanisms were examined separately.

Age distribution within high- and low-energy injuries by sex

Although mean age differed between high- and low injuries, there was no significant difference in mean age between sexes in the high-energy group. Mean age was 37.0 years in women and 41.4 years men (t-test: $p = 0.25$, see figure 1A for age distribution separated on sex). Similarly, no significant sex difference was observed in the low-energy group, where mean age was 63.9 years for women and 60.8 years for men (t-test: $p = 0.30$, see figure 1B for age distribution separated on sex).

Injured side, high- and low-energy injuries

Among the 119 high-energy injuries, 52% occurred on the right side, 45% on the left, and 3% were bilateral. There was no statistically significant difference between right- and left-sided injuries ($Chi^2 = 0.55$, $p = 0.46$). In 98 cases where handedness could be determined from the medical records, 91 individuals were right-handed. Of these, 52% sustained injuries on the right side, 46% on the left, and 2% were bilateral, with no significant side predominance ($Chi^2 = 0.28$, $p = 0.60$).

For the 135 TBPI caused by low-energy trauma, 58% occurred on the right side and 42% on the left, with no bilateral injuries reported. The side difference did not reach statistical significance ($Chi^2 = 3.27$, $p = 0.071$). Hand dominance was documented in 102 cases, of which 61 involved the dominant side (57 of 95 right-dominant and 4 of 7 left-dominant individuals). Statistical analysis showed a significantly higher likelihood of injuring the dominant side compared to the non-dominant side ($Chi^2 = 3.92$, $p = 0.048$).

Trauma mechanisms

The most common trauma mechanisms in high-energy injuries were motor vehicle accidents (MVA) followed by ‘Fall from >1 m’ and ski-injuries (downhill or cross-country, for details see Figure 2A). Among low-energy injuries, the most common mechanism of trauma was ‘Fall from <1 m’. The second most common mechanism was compression injury, most often associated with falls followed by prolonged immobilisation or intoxication, resulting in sustained pressure on the affected arm. Of these cases 11 were classified as iatrogenic. (seven related to intensive care unit stays, four to prolonged surgical procedures). For details see Figure 2B.

High-energy, mechanism of injury, age

MVAs were the most frequent cause in both the under-18 years (10 cases) and 19–65 (44 cases) age groups. In the group aged 66 years and older, ‘Fall from >1 m’ were the most common cause, accounting for 7 of 13 cases.

High-energy, mechanism of injury - sex

When stratified by sex, the mechanism of injury showed similar patterns, with MVAs accounting for 47% of cases in both men (42/89) and women (14/30). ‘Fall from >1 m’ and ski-related injuries accounted for 17% of cases among men and 10% among women. Bicycle accidents were observed in 8% of men and 17% of women. Kite or skydiving accidents occurred exclusively in men (3%), while equestrian injuries were more frequent in women (13%), compared to men 2%. Other causes accounted for 6% of cases in men and 3% in women.

Low-energy, mechanism of injury, age

For low-energy injuries in persons above 50 years of age ‘Fall from <1 m’ was the most common mechanism in all decades (50–59 years: 22 cases, 60–69 years: 31 cases, 70–79 years: 24 cases: 80 years and older: six cases), whereas below 50 years (n = 17) compression injuries were most common (seven cases), followed by ‘Fall from <1 m’ (6 cases).

Low-energy, mechanism of injury - sex

When analysing the mechanism of injury by sex, the patterns were largely similar between men and women. Fall from <1 m was the most common mechanism, accounting for 63% of cases in men (48/76) and 71% women (42/59). Compression injuries represented the second most frequent mechanism, occurring in 22% in men and 15% women.

Pull-force injuries were observed in 4% men and 3% women, while direct trauma accounted for 5% both in men and women. Other mechanisms were seen in 5% of both men and women.

High-energy injuries

Among the 119 high-energy injuries, 61 cases had undergone surgical intervention by the time of data compilation. Of these, 35 cases involved nerve reconstructive procedures, including primary reconstructions or nerve transfers. The average time from injury to nerve reconstruction was 90 days, ranging from 0 to 296 days. This interval was shorter for supraclavicular injuries, with a mean of 52 days (range: 0–169 days), compared to infraclavicular injuries, which had a mean of 142 days (range: 28–296 days).

Nerve reconstructions included 18 nerve graft reconstructions and 17 nerve transfers.

In infraclavicular injuries, four nerve graft reconstructions cases and 12 nerve transfers cases were performed. In supraclavicular injuries, reconstructions consisted of seven only grafts, five combined

grafts and nerve transfers for suprascapular nerve reconstruction, and seven cases reconstructed solely with nerve transfers.

Shoulder dislocations were rare in the supraclavicular high-energy TBPI group, with only four confirmed cases, none of which required surgical intervention. In contrast, shoulder dislocations were observed in 41 out of 77 high-energy infraclavicular injuries (53%). Among these, eight cases (20%) underwent nerve reconstruction. For infraclavicular injuries without shoulder dislocation, eight out of 36 cases (22%) underwent nerve reconstruction.

Table 3. Demographics and injury characteristics stratified by trauma energy level and injury location. *Supra* = supraclavicular; *Infra* = infraclavicular. Values are presented as absolute numbers with percentages in parentheses unless otherwise specified. Mean ages are given in years. 'Trauma related surgery performed' denotes fracture plating, vascular reconstruction etc.

	High-Energy		**Low-Energy**	
	Supra	Infra	Supra	Infra
Number of cases	42	77	18	117
Shoulder dislocation	4 (10%)	41 (53%)	3 (17%)	83 (71%)
Vascular injury	3	6	0	3
Open injury	1	0	0	0
Nerve reconstructive surgery	19 (45%)	16 (21%)	0	1 (0.9%)
Mean age at nerve reconstruction	33.4	29.2	-	24
Mean age at injury	36.0	42.7	55.3	63.3
Trauma related surgery performed	21 (50%)	40 (42%)	0 (0%)	28 (24%)

Only one of the high-energy injuries was an open injury, occurring in a car accident involving a seat-belted individual. Nine patients with high-energy injuries had major blood vessel involvement, with surgical intervention performed in eight cases: two subclavian artery injuries, five axillary artery injuries, and one subclavian vein injury. One arterial occlusion was managed without surgical intervention.

The mean age of patients undergoing nerve reconstruction was significantly lower, 31.5 years, compared to 44.0 years for those who did not undergo reconstruction, with a statistically significant difference ($p = 0.00018$). Gender analysis revealed some differences in surgical intervention rates. In the supraclavicular injury group, four out of 10 women (40%) and 15 out of 32 men (47%) underwent nerve reconstruction. In the infraclavicular group, two out of 20 women (10%) and 14 out of 57 men (25%) underwent nerve reconstruction. Logistic regression analysis including injury level (supraclavicular vs infraclavicular) and sex showed that supraclavicular injuries were independently associated with higher odds of nerve reconstruction (OR 3.16, 95% CI 1.38–7.23; $p = 0.006$), whereas sex was not significantly associated with

surgery (OR 0.51, 95% CI 0.18–1.43; p = 0.202). Among the high-energy injuries, 6 cases had undergone nerve exploration, four in supraclavicular injuries and 2 in infraclavicular injuries.

Low-energy injuries

Of the 135 patients with low-energy TBPI, 28 (21%) underwent surgical procedures related to their injuries, all of which were infraclavicular. These surgeries primarily addressed concomitant injuries associated with the brachial plexus trauma. The most common procedures included eight rotator cuff repairs, six platings of proximal humerus fractures using PHILOS plates, and five shoulder arthroplasties. Additionally, three closed reductions of proximal humerus fractures, one clavicle fracture plating, and three vascular reconstructions (involving the subclavian, axillary, and brachial arteries) were performed.

The group with low-energy injuries with shoulder dislocation (n = 86) had a mean age of 65.1 years while the group without shoulder dislocation (n = 49) had a mean age of 57.0 years. A two-tailed t-test demonstrated a significant age difference between the groups (**p < 0.001).**

In the shoulder dislocation group, the most common mechanism of injury was ‘Fall from <1 m’, which accounted for 74 out of 86 cases (86 %). In contrast, among those without shoulder dislocations, the most frequent mechanism was ‘Compression’, observed in 26 cases, followed by ´Fall from <1 m´ in 16 cases. Of these 16 cases involving ´Fall from <1 m´ without shoulder dislocation, seven had suffered proximal humerus fractures, four clavicular fractures, and one case involved a fall followed by a prolonged period of lying down unconscious for 15 minutes. Only one neurolysis procedure after TBPI was documented in the studied period.

Overall, surgical intervention for low-energy TBPI in our studied cohort was relatively uncommon and was predominantly directed at managing associated injuries rather than the brachial plexus itself. These findings underscore the different clinical and surgical profiles between low-energy and high-energy TBPI.

Among the 18 supraclavicular injuries caused by low-energy trauma, three resulted from falls from heights <1 meter, 13 from compression injuries (including five iatrogenic cases), one from direct blunt shoulder trauma, and one from other unspecified causes.

In cases involving shoulder dislocation, 83 of 86 presented with infraclavicular brachial plexus involvement, typically representing a combined traction and compression injury [5]. Among all compression injuries, external iatrogenic causes were identified in three of nine cases in women (33%) and in eight of 17 cases in men (47%), with five diagnosed as supraclavicular and six as infraclavicular injuries.

Seasonal variation in incidence of high- and low-energy injuries

High-energy injuries demonstrated a bimodal seasonal distribution. The first peak occurred during summer and early autumn (June–October), with a mean of 13.0 injuries per month over the five-year

study period. A second peak was observed in late winter (February–April), with a mean of 11.3 injuries per month. These peaks coincided with periods of increased outdoor and snow-related activities.

Low-energy injuries also showed seasonal variation. The highest incidence was observed between October and February, with a mean of 11.6 injuries per month. In contrast, from April to September, the mean number of injuries decreased to 8.3 per month.

Other injury mechanisms (sharp, gunshot, iatrogenic)

We categorised sharp assault, sharp iatrogenic, and gunshot injuries as distinct mechanisms separate from high- or low-energy injuries due to their unique characteristics (see Table 4). Sharp injuries, such as knife assaults or surgical trauma, typically result in clean, well-defined nerve transections, whereas gunshot injuries may cause nerve dysfunction indirectly through mechanisms such as oedema or shockwave effects. Due to their specific nature, these injury types were excluded from the high- and low-energy classifications.

The small number of cases in this group precludes meaningful statistical analysis; however, we provide a descriptive overview. Sharp assaults were reported in eight individuals (four men and four women), while all seven gunshot injury cases involved men. Iatrogenic injuries were observed in 18 individuals (10 men and eight women). The surgical interventions underlying iatrogenic brachial plexus injury included thoracic surgery, vascular surgical procedures, C5–C6 laminectomy, shoulder arthroplasty, shoulder stabilisation surgery, clavicular surgery, and brachial plexus blockade performed for hand surgery.

Table 4. Demographics and injury characteristics stratified by trauma energy level and injury location for 'Other' trauma mechanisms; *Supra* = supraclavicular; *Infra* = infraclavicular. Values are presented as absolute numbers with percentages in parentheses unless otherwise specified. Mean ages are given in years. ***Three cases involved shoulder dislocation not associated with brachial plexus injury at the time of trauma; the plexus injury occurred later following shoulder arthroplasty. Two of 13 supraclavicular injuries required nerve reconstruction. Four of 21 infraclavicular injuries required nerve reconstruction.

	Sharp assault		Gunshot		Iatrogenic	
	Supra	Infra	Supra	Infra	Supra	Infra
Number of patients	6	2	3	4	10	8
Shoulder dislocation	0 (0%)	0 (0%)	0 (0%)	0	0	0***
Vascular injury	2	2	1	2	0	0
Open injury	6	2	3	4	10	8
Nerve reconstructive surgery	2 (33%)	2 (100%)	0	2 (50%)	0	0
Mean age at nerve reconstruction	33.0	35.5	-	25.5	-	-
Mean age at injury	48.2	35.5	30.7	25.8	54.3	61.8
Trauma related surgery performed	2 (33%)	2 (100%)	0 (0%)	3 (75%)	10	8

DISCUSSION

This nationwide study represents the first comprehensive assessment of clinically verified traumatic brachial plexus injuries (TBPI) referred to national brachial plexus centres within a single country. Based on clinically confirmed cases from Sweden's two specialised TBPI centres, the referral-based incidence was 0.57 per 100,000 inhabitants per year. This should be interpreted as a minimum estimate, as mild or spontaneously resolving deficits may not result in referral, and cases with complete recovery at specialist assessment were excluded by design, potentially underrepresenting less severe injuries.

Cross-study comparisons are complicated by heterogeneous TBPI definitions. The Scottish national study by Warwick and Hems[8] reported a higher incidence, likely influenced by broader inclusion criteria including isolated axillary and distal terminal nerve injuries—entities not classified as TBPI in the present study. Differences in case definitions limit direct comparisons of both incidence and reconstruction rates and underscore the need for standardised, clinically meaningful classification protocols. Our more stringent inclusion criteria also likely contribute to the lower surgical reconstruction rate observed in this cohort (0.07 per 100,000/year vs. 0.1 in the Scottish study), with 35 nerve reconstructions performed over five years.

We advocate for future registry-based studies to distinguish between supraclavicular, infraclavicular, and distal terminal branch injuries, and to rely on clinical verification rather than diagnostic codes alone. An additional challenge is posed by injuries that do not conform to the supraclavicular–infraclavicular dichotomy, such as retroclavicular plexus involvement or mixed injury patterns, which limits the precision of registry-based classifications. Nonetheless, standardised criteria would improve cross-national comparisons and provide a clearer picture of TBPI epidemiology.

Our findings indicate a demographic shift in TBPI patterns. The classic “7×70 rule,” described by Narakas in 1985 [19], proposed that TBPI predominantly affects young men involved in high-energy motorcycle accidents—a profile that remains valid for many high-energy cases. In our cohort, high-energy injuries primarily affected early middle-aged men and were most often related to motor vehicle trauma. In contrast, low-energy TBPI showed a markedly different profile, with higher mean age, a more balanced sex distribution, and falls from standing height as the most frequent mechanism. These trends may reflect improved road safety measures, population aging, and shifts in injury mechanisms.
Beyond demographic differences, high- and low-energy TBPI also differed substantially in anatomical injury distribution. Although the trauma-specific incidences were similar (**0.24** and **0.27 per 100,000 inhabitants per year,** respectively), infraclavicular injuries predominated in both groups and were particularly common following low-energy trauma. The similarity in supraclavicular-to-infraclavicular ratios between sexes within each trauma category indicates that injury distribution is primarily driven by trauma mechanism rather than sex-specific factors.

These differences have important clinical implications. While nerve reconstruction was common after high-energy injuries, only one patient with low-energy TBPI required nerve surgery. These findings support a predominantly non-operative management strategy for low-energy TBPI, with surgical exploration considered selectively (e.g., suspected neurotmesis or lack of recovery on follow-up). This approach aligns with prior studies indicating that surgical intervention is rarely required after most plexus injuries associated with shoulder dislocation [20], although residual functional impairment may persist.

Importantly, even patients not requiring surgery often need prolonged rehabilitation [21] and follow-up, including structured pain management and monitoring for delayed deficits or secondary complications [3]. Our findings support a cautious, function-based approach to clinical decision-making, particularly in low-energy trauma.

Evidence for seasonal variation in TBPI remains limited. Lemus et al. reported increased case numbers during late winter in a single-centre study from Guatemala [22], without further analysis of underlying mechanisms. In our cohort, high-energy TBPI demonstrated peaks during summer and winter, potentially reflecting seasonal variations in traffic exposure and outdoor activities, whereas low-energy TBPI increased during winter, plausibly related to falls on icy surfaces. Seasonal patterns are likely influenced by geographical location and local environmental conditions and should therefore be interpreted in that context. Nonetheless, these observations may help inform targeted preventive strategies, including fall-prevention efforts during high-risk periods [23, 24].

The proportion of patients with concomitant injuries in our cohort appears lower than in the surgical series reported elsewhere [25]. This likely reflects differences in study design and case-mix, as prior reports focused exclusively on operated patients, enriching for high-energy trauma and complex injury patterns. Furthermore, our definition of concomitant injuries was restricted to prespecified variables in

the same arm (e.g., shoulder dislocation, clavicle fracture, and major vascular injury) rather than “any associated injury,” which may further contribute to lower reported rates.

Despite the study's comprehensive national coverage, several limitations should be acknowledged. First, this analysis focused on incidence, injury characteristics, and surgical management; functional outcomes and patient-reported outcome measures were therefore beyond its scope and are being addressed in a not yet published companion study. Secondly, the exclusion of non-residents may underestimate the true national TBPI burden. Thirdly, external factors—such as the COVID-19 pandemic—may have influenced trauma incidence and referral patterns in 2020.

Finally, TBPI classification remains challenging. Estimating injury extent without surgical exploration is imprecise, and mixed supra- and infraclavicular injuries further complicate categorisation. Development of a clinically oriented classification framework, supported by electrophysiology and imaging, may improve diagnostic accuracy and strengthen future epidemiological studies.
These findings have implications for referral pathways and resource allocation, supporting differentiated management strategies for high- and low-energy TBPI.

CONCLUSION

This nationwide retrospective cohort study found a referral-based annual incidence of clinically verified TBPI in Sweden of 0.57 per 100,000 inhabitants. High- and low-energy TBPI showed distinct clinical profiles. High-energy injuries predominantly affected early middle-aged men and frequently required nerve reconstruction, whereas low-energy injuries more often affected older adults, were commonly associated with shoulder dislocation and were rarely treated with operative plexus intervention. These findings support differentiated referral pathways and management strategies based on trauma mechanism and anatomical injury pattern. Standardised TBPI definitions and future studies addressing functional outcomes are needed to improve epidemiological comparisons and guide care.

Abbreviations

TBPI: Traumatic brachial plexus injury

MVA: Motor vehicle accident

NSMC: National Specialised Medical Care

ICD-10: International Classification of Diseases, 10th revision

ICU: Intensive care unit

OR: Odds ratio

CI: Confidence interval

PHILOS: Proximal Humerus Internal Locking System

SCB: Statistics Sweden (Statistiska centralbyrån)

Declarations

Ethics approval and consent to participate Ethical approval for this study was granted by the Swedish Ethical Review Authority on November 10, 2021 (Dnr 2021-03649). Informed consent was waived by the Swedish Ethical Review Authority due to the retrospective nature of the study.

Consent for publication Not applicable.

Availability of data and materials The datasets generated and/or analysed during the current study are not publicly available due to Swedish data protection regulations governing patient registry data, but are available from the corresponding author on reasonable request.

Competing interests The authors declare that they have no competing interests.

Clinical trial number: not applicable.

Funding Financial support was provided through a regional agreement between Umeå University and Västerbotten County Council, Sweden (ALF, Clinical Research Grant No. 1013248).

Authors' contributions FR and PN researched the literature, conceived the study, and performed data curation, formal analysis and interpretation of data with support from the other co-authors. MA was involved in gaining ethical approval. FR and PN wrote the first draft of the manuscript. MA, MW and PN supervised the study. All authors reviewed and edited the manuscript and approved the final version.

Acknowledgements Not applicable.

Authors' information Not applicable.

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Figures

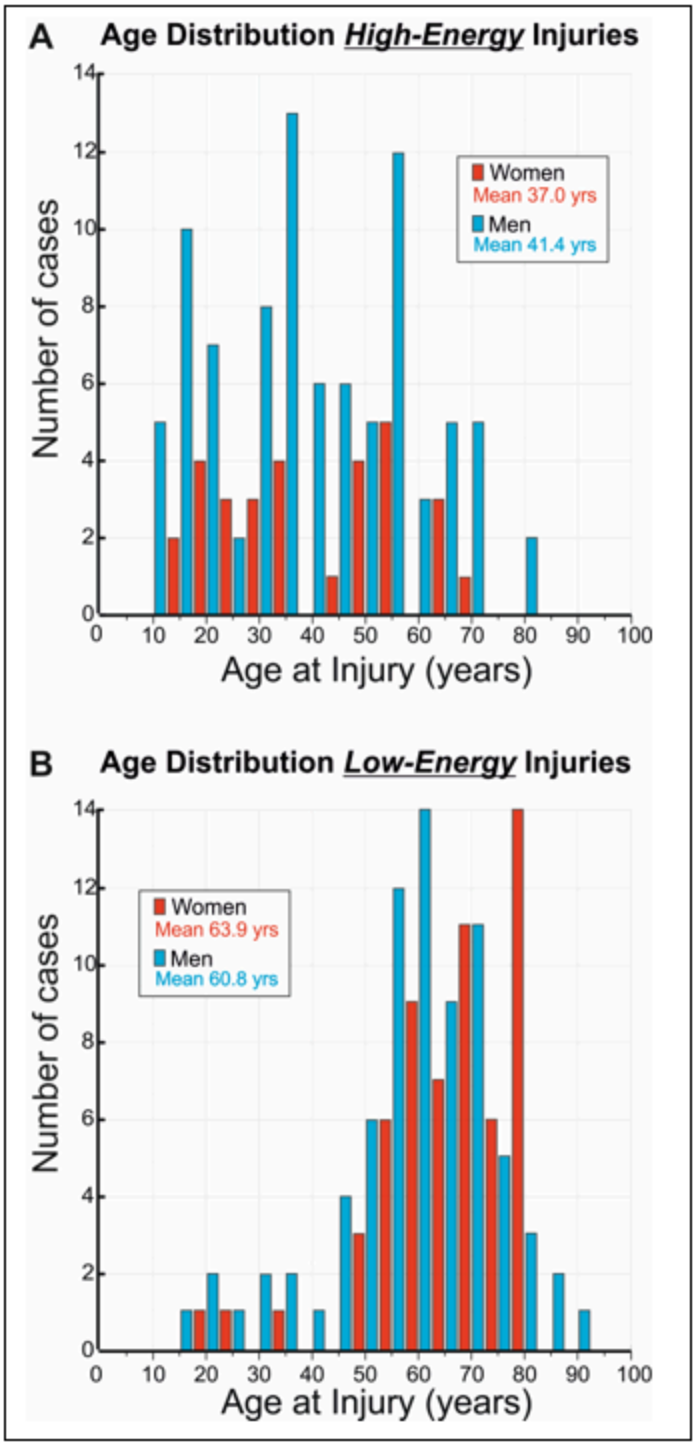


Figure 1

(A) Age distribution for high-energy trauma. The mean age was 40.3 years, median 39 years, range 11–82 years. The third decade of life was the most common age group for sustaining a high-energy injury (n = 25). Red bars represent women and blue bars represent men. **(B)**Age distribution for low-energy trauma. The mean age was 62.1 years, median 64 years, range 15–92 years. The most common age group for low-energy injuries was individuals in their 60s (n = 41).

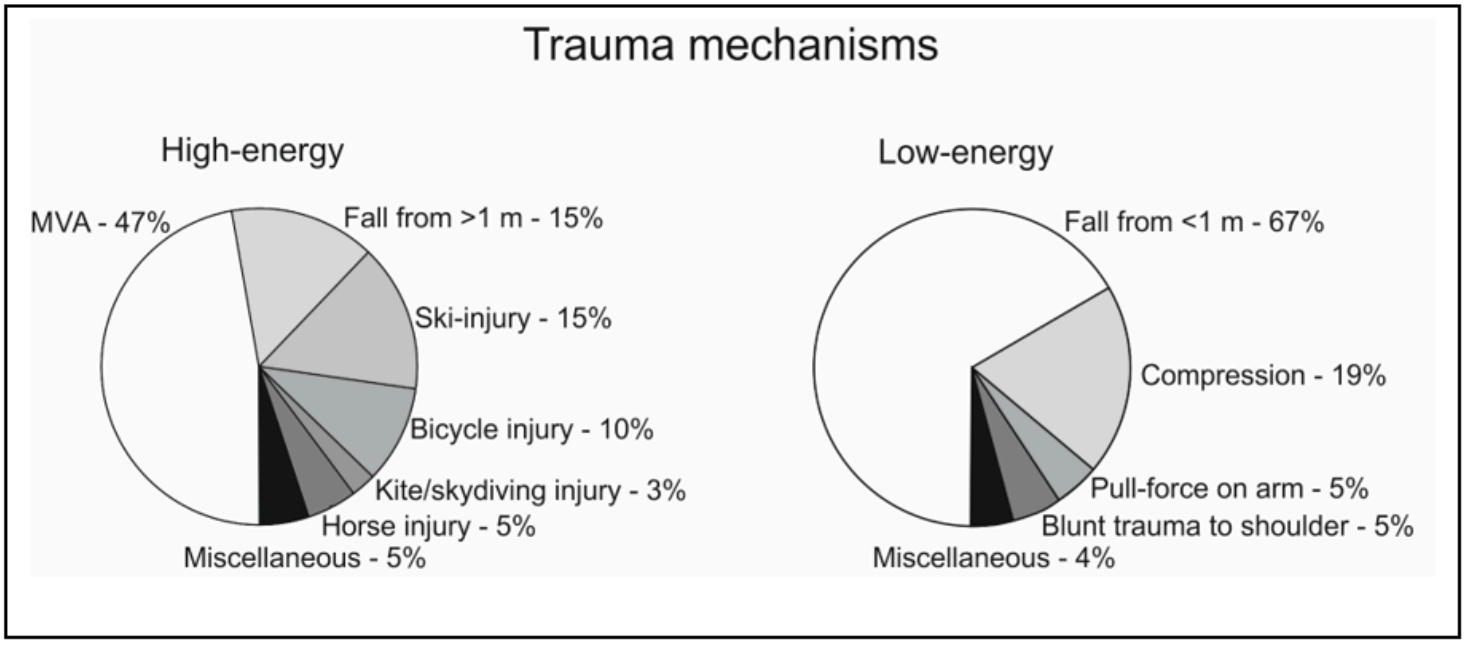


Figure 2

(A) Pie chart illustrating the distribution of trauma mechanisms among the 119 high-energy injury cases. The category miscellaneous includes cases that were difficult to classify under a specific mechanism (e.g., direct shoulder trauma caused by attacking livestock or falling objects). MVA = motor vehicle accident. **(B)** Pie chart illustrating the distribution of trauma mechanisms among the 135 low-energy injury cases.

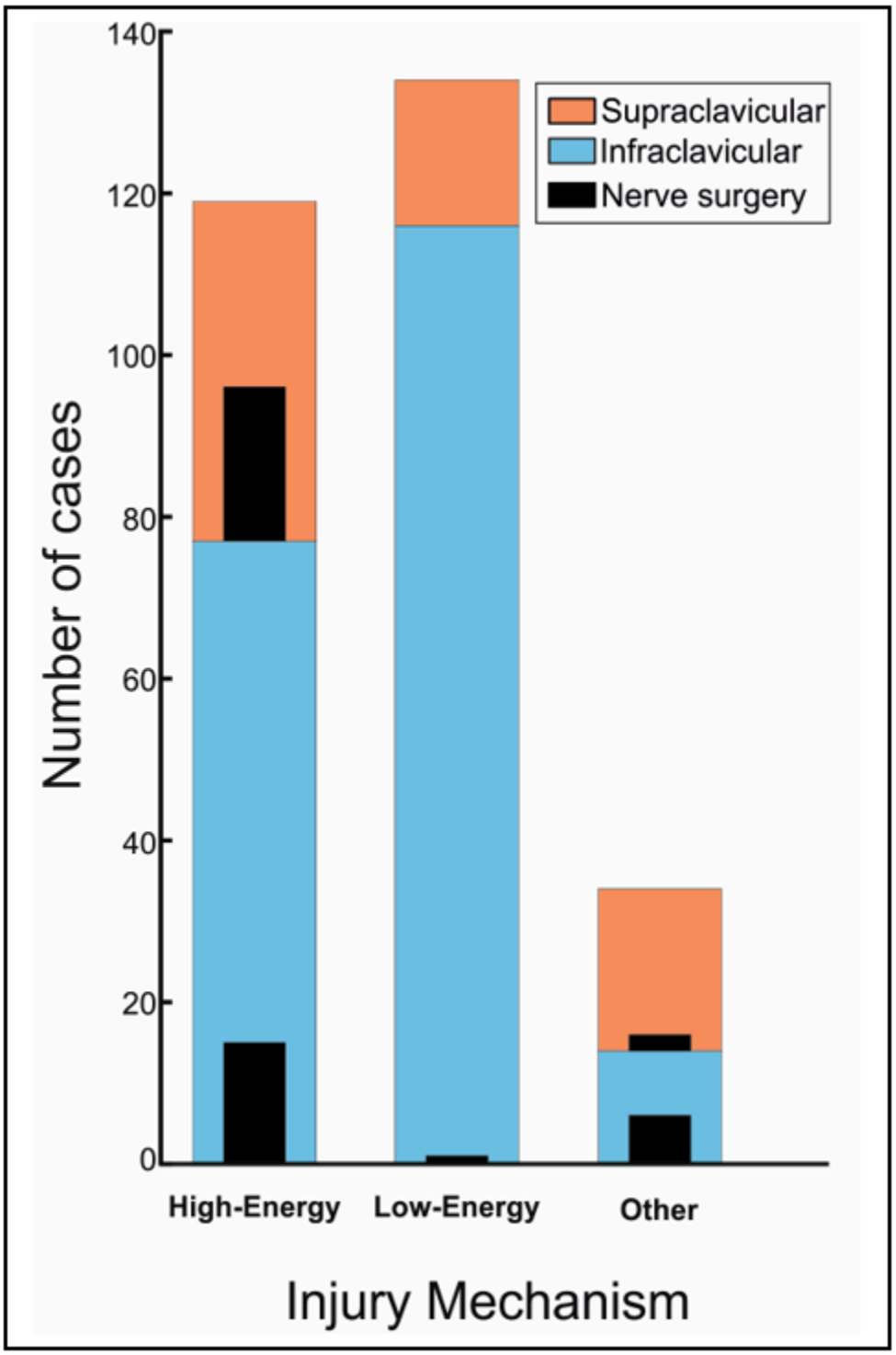


Figure 3

Histogram showing the number of cases by trauma type. Each bar is divided into supraclavicular (orange) and infraclavicular (light blue) cases, with a black inset bar indicating patients who underwent nerve reconstructive surgery.