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Original Article

Incidence and risk factors of clavicle, humerus fractures, and brachial plexus injuries due to birth trauma in the neonatal period

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ABSTRACT

Objectives: This study aims to investigate the incidence and associated risk factors of clavicle and humerus fractures and brachial plexus injuries (BPIs) secondary to birth trauma.

Patients and methods: Between October 2019 and May 2023, a total of 556 newborns (300 males, 256 females; median age: 5 days; range, 0 to 5 days) with clavicle, humerus fractures, and BPIs secondary to birth trauma were retrospectively analyzed. The sex, Appearance, Pulse, Grimace, Activity, and Respiration (APGAR) scores at 1 and 5 min, need for resuscitation, gestational week, mode of delivery, birth weight, birth length, and head circumference of the neonates were recorded. Concomitant BPI, evaluation specialty, and maternal characteristics were also noted.

Results: A larger head circumference was associated with an increased risk of clavicle fractures ($p<0.001$, odds ratio [OR]=1.681). High birth weight ($p<0.01$, OR=1.001), larger head circumference ($p<0.001$, OR=1.523), and lower APGAR score at 1 min ($p=0.018$, OR=0.605) were associated with BPI risk. Fractures were mainly evaluated by orthopedists, while BPI was primarily assessed by physical medicine and rehabilitation and pediatric neurology specialists ($p<0.001$). Neonatal physicians most frequently requested consultations from orthopedics for fractures and rehabilitation or neurology for BPI ($p<0.001$).

Conclusion: Our study results show that larger head circumference increases the risk of clavicle fractures and BPI. Higher birth weight and lower APGAR scores at 1 min also raise BPI incidence. Newborns with these risk factors should undergo a thorough evaluation.

Keywords: Birth trauma, brachial plexus injuries, clavicle fractures, humerus fractures.

Birth trauma or perinatal trauma is a trauma experienced by the newborn during labor or at any stage of the delivery process. The incidence of birth trauma in the neonatal period is reported to be between 6.7 and 14 per 1,000 live births.[1] Clavicle fractures are the most common type of birth-related bone tissue injuries in newborns. The incidence ranges from 0.2 to 4.5%.[2] Clavicle fractures may be asymptomatic or present with symptoms such as upper extremity swelling, movement limitation, and absence of the Moro reflex in the following days after birth.[3,4] It usually heals without sequelae. However, it is crucial in terms of parental anxiety and neurologic traumas that may rarely accompany it.[5] The most commonly reported risk factors for clavicle fractures are macrosomia, post-term labor, induction of labor, use of assistive instruments during labor, shoulder dystocia, and prolonged labor.[6-8]

Neonatal brachial plexus injury (BPI) is a rare condition of unknown etiology. It is a flaccid paralysis condition in which active movement of the affected extremity is more limited than passive movement.[9] It is estimated to occur at a rate of 0.4 to 2.6 per 1,000 live births.[10] The risk factors for the development of BPI are shoulder dystocia, maternal diabetes mellitus (DM), macrosomia, breech presentation, and the use of an instrument at birth.[8,11]

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The clinical course is closely related to the type of initial injury (neuropraxia, rupture, avulsion, etc.) and the roots affected (upper, lower, middle, and total brachial plexus palsy).[12] The humerus is the second most commonly injured bone at birth, following the clavicle.[13] Fractures may occur in the epiphyseal region or the shaft region. It may develop due to rotation and hyperextension of the arm during passage through the birth canal.[14] In particular, in large babies, complicated deliveries, and breech presentation, the risk of proximal humerus fracture is higher, as is the risk of other possible fractures.[15]

In the present study, we aimed to comprehensively investigate the incidence, anatomical distribution, and concomitant injuries of clavicle and humerus fractures and BPIs secondary to birth trauma, along with associated neonatal and maternal risk factors and the multidisciplinary clinical approach, using the most extensive dataset from a tertiary care center in Türkiye.

PATIENTS AND METHODS

This retrospective study was conducted at Ankara Bilkent City Hospital, Department of Physical Medicine and Rehabilitation, Neonatal Clinic between October 2019 and May 2023. Patients diagnosed with clavicle, humerus fracture, and BPI due to birth trauma in the neonatal period (detected before discharge) were included in the study. Sex, Appearance, Pulse, Grimace, Activity, and Respiration (APGAR) scores at 1 and 5 min, history of a requirement for cardiopulmonary resuscitation at birth, birth week, mode of delivery (vaginal delivery or cesarean section), birth weight, birth length, and head circumference were recorded. Concomitant BPI, the side of the clavicle and humerus fracture, and the specialties by which the patient was evaluated were reported. Maternal age, number of pregnancies, whether spontaneous or assisted reproduction technique was used, and additional chronic diseases and medications, if any, were noted. Patients with a history of trauma, congenital anomaly, metabolic disease of the newborn, and maternal or neonatal bone disorders were excluded. Finally, of 63,553 deliveries, 556 newborns (300 males, 256 females; median age: 5 days; range, 0-5 days) with clavicle, humerus fractures, and BPIs were included in the study. Written informed consent was obtained from the parents and/or legal guardians of the patients. The study protocol was approved by the Ankara Bilkent City Hospital Ethics Committee (Date: 15/05/2024, No: TABED 2-24-102). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 25.0 software (IBM Corp., Armonk, NY, USA). The normality of numerical data distribution was examined using the Kolmogorov-Smirnov test. Continuous data were expressed in mean ± standard deviation (SD) or median and interquartile range (IQR; 25^{th}-75^{th} percentiles). Categorical data were expressed in number and frequency. Categorical variables were compared using the Pearson chi-square test and the likelihood ratio. Numeric variables were analyzed with the Kruskal-Wallis test, and post-hoc Dunn test and Bonferroni correction were applied. Binary logistic regression analyses were performed to determine variables associated with clavicula or humerus fracture and BPI. The confidence interval was 95%, and the margin of error accepted was set to 5%. A p value of <0.05 was considered statistically significant.

RESULTS

A total of 31,282 normal spontaneous vaginal deliveries (NSVD) and 32,271 cesarean section (C/S) deliveries occurred during this period. The birth injury ratio was 1.68% (526/31282) for NSVD and 0.92% (30/32271) for C/S deliveries (30/32271). There was no statistically significant difference between the groups with isolated clavicle fractures, humerus fractures, and BPI according to sex (p=0.717). There were eight patients (1.4%) with multiple injuries. Among the seven newborns with clavicle fracture plus BPI, three (42.9%) were female, and four (57.1%) were male. One male newborn had a humerus fracture plus a BPI. The APGAR score at 1 min was higher in the group with isolated clavicle fracture than in the group with isolated BPI (p=0.001); there was no significant difference in other pairwise comparisons (p>0.05). The APGAR score at 5 min was higher in the group with isolated clavicle fracture than in the group with isolated humerus fracture and isolated BPI (p=0.029, p<0.001, respectively). The gestational week of labor was higher in the clavicle fracture group than in the humerus fracture group (p=0.024). Birth weight was higher in the group with BPI than in the group with the clavicle and humerus fracture (p<0.001 and p=0.005, respectively). Head circumference was similarly higher in the BPI group

TABLE 1
The demographic and clinical features of the children (n=556)

	All (n=556) (including multiple injuries; n=8)				Isolated clavicula fracture (n=466)				Isolated humerus fracture (n=8)				Isolated brachial plexus injury (n=74)				
	n	%	Median	IQR	n	%	Median	IQR	n	%	Median	IQR	n	%	Median	IQR	*p*
Sex																	0.717[a]
Female	256	46.0			218	46.8			4	50.0			31	41.9			
Male	300	54.0			248	53.2			4	50.0			43	58.1			
APGAR score																	
1st min			7.0	1.0			7.0	1.0			7.0	0.0			7.0	1.0	**<0.001[b]**
5th min			9.0	0.0			9.0	1.0			8.5	1.0			9.0	1.0	**<0.001[b]**
CPR history	2	0.4			1	0.2			-				1	1.4			NA
Birth week			39.0	2.0			39.0	2.0			38.0	2.0			39.0	1.0	**0.025[b]**
Delivery method																	NA
NSVD	526	94.6			446	95.7			5	62.5			67	90.5			
C/S	30	5.4			20	4.3			3	37.5			7	9.5			
Weight (gr)			3522.5	589.0			3495.0	533.0			3300.0	188.0			3692.5	788.0	<0.001[b]
Height (cm)			51.0	2.0			51.0	2.0			50.5	2.0			50.5	2.0	0.803[b]
Head circumference (cm)			35.0	2.0			35.0	2.0			34.0	3.0			36.0	2.0	**<0.001[b]**
Maternal age			29.0	8.0			29.0	8.0			32.5	10.0			30.0	9.0	0.454[b]
Number of children (mean±SD)			2.3±1.3				2.0	2.0			1.5	2.0			2.0	2.0	0.650[b]
Systemic diseases of the mother																	NA
Preeclampsia	5	0.9			2	0.4			1	12.5			2	2.7			
Gestational DM	5	0.9			2	0.4			1	2.5			2	2.7			
DM	4	0.7			2	0.4			-	-			2	2.7			
HT	1	0.2			1	0.2			-	-			-	-			
Hypothyroidism	38	6.8			34	7.3			-	-			3	3.7			
Epilepsia	5	0.9			4	1.2			1	11.1			-	-			
Hyperthyroidism	1	0.2			1	0.2			-	-			-	-			
Asthma	2	0.4			2	0.4			-	-			-	-			
Other	2	0.4			1	0.2			-	-			1	1.2			

IQR: Interquartile range; APGAR: Appearance, pulse, grimace, activity, and respiration; CPR: Cardiopulmonary resuscitation; NSVD: Normal spontaneous vaginal delivery; C/S: Cesarian section; SD: Standard deviation; DM: Diabetes mellitus; HT: Hypertension; [a] Likelihood ratio; [b] Kruskal-Wallis test; NA: Not analyzed due to low number of cases which does not meet Chi-square criteria.

compared to the clavicle fracture (p<0.001) and humerus fracture groups (p=0.037). There was no significant difference between the injury groups in terms of birth length (p=0.803). Maternal age and number of children were similar between the groups (p>0.05).

The demographic and clinical features of the children, as well as comparisons of these features in terms of injuries, are presented in Table 1.

The frequencies of the clavicula and humerus fractures and BPI due to birth trauma and consultations are listed in Table 2. Physical medicine and rehabilitation (PMR) consultation was more frequent in patients with BPI than in those with clavicle fracture (p<0.001), orthopedic consultation was more frequent in patients with clavicle and humerus fracture than in the BPI group (p<0.001), and pediatric neurology consultation was more frequent in the BPI group than in those with clavicle or humerus fracture (p<0.001).

Binary logistic regression analysis revealed that head circumference (p<0.001, odds ratio [OR]=1.428) was positively associated with the risk of isolated clavicle fracture (p<0.05). No variables were associated with humerus fracture risk among the variables listed in Table 3 (p>0.05). Weight (p=0.013, OR=1.001) and head circumference (p<0.001, OR=1.563) were positively associated with isolated BPI risk, while APGAR score at 1 min (p=0.018, OR=.670) was negatively associated with BPI risk (Table 3).

TABLE 2
Birth injuries and consultations of the children (n=556)

	n	%	*p*
Clavicula fracture			
Right	285	51.3	
Left	183	32.9	
Bilateral	4	0.7	
Humerus fracture			
Right	7	1.3	
Left	2	0.4	
Brachial plexus injury			
Right	46	8.3	
Left	36	6.5	
Consultations			**<0.001**[a]
PMR	276	59.2	
Isolated clavicula fracture	7	88.5	
Isolated humerus fracture	73	98.6	
Isolated BPI			**<0.001**[a]
Orthopedics	430	92.3	
Isolated clavicula fracture	7	87.5	
Isolated humerus fracture	21	28.4	
Isolated BPI			**<0.001**[a]
Pediatric Neurology	24	5.2	
Isolated clavicula fracture	1	12.5	
Isolated humerus fracture	49	59.8	
Isolated BPI			

PMR: Physical medicine and rehabilitation; BPI: Brachial plexus injury; [a] Likelihood ratio.

DISCUSSION

In the present study, a total of 63,553 deliveries, including 31,282 NSVD and 32,271 C/S deliveries, were analyzed, and 556 newborns developed clavicle fracture, humerus fracture, and BPI due to birth trauma. The frequency of birth traumas, which we found to be 8.7 per 1,000 live births in the current study, was compatible with the literature.[1]

Clavicle fracture was the most common type of injury, followed by BPI. Humerus fractures were extremely rare. The incidence of clavicle fracture was found to be 0.41% in a retrospective study analyzing 77,543 live births in Korea.[16] In a study conducted in our country evaluating clavicle and humerus fractures due to birth trauma consulted to orthopedics, 20,090 deliveries were examined, and a total of 27 cases (0.13%), including humerus fractures in two newborns and clavicle fractures in 25 newborns were reported.[17] In our study, the rate of clavicle and humerus fractures was higher (0.75%) than in this study. We believe that this may be due to the inclusion of all newborns evaluated by neonatology, PMR, orthopedics, and pediatric neurology rather than just those consulted by orthopedics, as well as our screening of a larger number of newborns. In addition, BPI is observed in the neonatal period with a frequency of 0.4 to 2.6% per 1,000 live births.[10] The frequency of BPI injuries due to birth trauma in the neonatal period was found to be 1.6% per 1,000 live births in a study conducted in our country.[18] In this study, the frequency of BPI was 1.2% per 1,000 live births, consistent with the literature. Although the humerus is the second most common bone after the clavicle at birth, fractures are rare.[13] Only nine newborns (0.14/1,000 live births) had humerus fractures in this study. A study evaluating 11 years of neonatal data from a tertiary hospital was conducted to investigate long bone fractures. The study reported a rate of 0.05% per 1,000 live births for humeral fractures, similar to that observed in our study.[19] Humerus fractures may occur during vaginal delivery or cesarean section.[19,20] A study found evidence of an increased

TABLE 3
Binary logistic regression analysis for variables associated with isolated clavicula fracture and isolated brachial plexus injury

					95% CI for OR	
Isolated clavicula fracture	B	SE	*p*	OR	Lower	Upper
Sex	0.281	0.257	0.276	1.324	0.799	2.193
Delivery method	−0.833	0.486	0.087	0.435	0.168	1.127
Gestational week	0.167	0.102	0.101	1.181	0.968	1.442
Weight	−0.021	0.000	0.055	0.999	0.999	1.002
Height	0.023	0.022	0.306	1.023	0.979	1.068
Head circumference	0.356	0.099	**<0.001**	**1.428**	0.1236	1.851
APGAR 1st min	0.491	0.204	0.016	1.634	1.096	2.436
APGAR 5th min	−0.116	0.236	0.624	0.891	0.561	1.415
Maternal age	0.022	0.026	0.404	1.022	0.971	1.076
Number of children	−0.003	0.109	0.981	0.997	0.806	1.234
Presence of systemic diseases	−0.174	0.380	0.646	0.840	0.399	1.768
Isolated BPI						
Sex	−0.342	0.281	0.224	0.711	0.409	1.233
Delivery method	0.586	0.546	0.283	1.796	0.617	5.234
Gestational week	−0.169	0.110	0.123	0.844	0.681	1.047
Weight	0.001	0.000	0.013	**1.001**	1.000	1.002
Height	−0.024	0.023	0.286	0.976	0.933	1.021
Head circumference	0.446	0.110	**<0.001**	**1.563**	1.261	1.937
APGAR 1st min	−0.400	0.217	0.014	0.670	0.438	1.024
APGAR 5th min	0.127	0.247	0.607	1.136	0.699	1.845
Maternal age	−0.018	0.028	0.527	0.982	0.929	1.039
Number of children	−0.049	0.120	0.680	0.952	0.753	1.203
Presence of systemic diseases	0.245	0.406	0.547	1.278	0.576	2.834

CI: Confidence interval; OR: Odds ratio; SE: Standard error; APGAR: Appearance, pulse, grimace, activity, and respiration; BPI: Brachial plexus injury.

risk of fracture in the male sex; however, the cause of this was not fully understood.[19-21] No sex difference was found for isolated humeral fractures in our study.

No association was found between sex and clavicle fracture or BPI. In a previous study in which sex and birth trauma in term babies were assessed, and 118,280 newborns were evaluated during 24 years, it was concluded that there was no relationship between sex and birth trauma.[22] A study from our country also showed that nerve injuries at birth were more common in girls; however, the authors concluded that this was not a risk factor alone and should be evaluated together with other accompanying risk factors.[23] Another study examining 212 clavicle fractures showed that fractures were equally distributed in both sexes.[24]

In our study, the mean gestational age at birth was 38.9±1.6 weeks, indicating that they were mostly term babies. We found no significant relationship between birth week and clavicle fracture or BPI. In a study investigating bone and nerve tissue damage due to birth trauma, no relationship was found between birth week and BPI.[23] In another study investigating congenital clavicle fractures, 96% of the cases were term babies, and no relationship was found between birth week and clavicle fracture.[25] No statistically significant relationship was found between gestational week and birth traumas in a study which investigated birth traumas in a tertiary hospital.[26]

Considering maternal risk factors, most were multiparous (the mean number of children was 2.3±1.3) in our study. There was no risk between

parity and the clavicle fractures and BPI. In the literature, studies similar to this study did not find a relationship between parity and clavicle fractures and BPI.[23,25] In another study, parity was not found to be associated with BPI; however, it was concluded that clavicle fractures were related to the development of BPI.[1] The most common comorbidities in maternal factors were DM, hypothyroidism, and hypertension, respectively. Our study found no association between clavicle fracture, BPI, and maternal comorbidities. In a study investigating risk factors for clavicle fractures in newborns, the most common maternal comorbidities were reported as DM, vitamin D deficiency, and hypertension.[25] We did not evaluate vitamin D deficiency in maternal comorbidities. We screened for chronic diseases or gestational diseases. A similar study found that maternal obesity and DM were not associated with neonatal BPI.[27] 94.6% of our patients had been born with NSVD, but there was no association between clavicle fractures and BPI with the type of delivery. Many studies have found that clavicle fractures were associated with NSVD.[23,25,28] In a survey of 4,297 deliveries and 26 newborns with clavicle fractures, there was no association between NSVD and clavicle fractures.[29] A total of 0.03% of clavicle fractures occur after C/S.[30] In another study, the ratio of clavicle fractures after C/S was similar to that of NSVD, and it was reported that clavicle fractures could not be avoided with C/S delivery.[31] No association was found between clavicle fracture and BPI and type of delivery in a similar study from our country.[1] Although some studies comparing the low rate of clavicle fractures with the quality of delivery clinics may lead clinicians to C/S section delivery, another study on this subject did not find a relationship between operative vaginal delivery and shoulder dystocia-clavicle fractures. Although clavicle fractures may occur in a few cases due to improperly managed labor, they are usually seen at the end of an uncomplicated labor.[29]

In the current study, there was no statistically significant association between a low APGAR score and clavicle fracture; however, BPI was associated with a low APGAR score at 1 min. Some studies have reported an increased risk of clavicle fracture associated with a low APGAR score, while others did not find an association, as in our study.[16,32,33] In a study in which 168 newborns diagnosed with BPI were examined, a low APGAR score was found to be associated with BPI due to birth trauma, similar to our study.[33]

In our study, the mean birth weight of newborns was 3520.6±475.3 g, which fell within the normal limits of birth weight. We found that birth weight was associated with BPI; however, we found no relationship between clavicle fractures and birth weight. In a retrospective study investigating the risk factors for clavicle fractures in newborns, the researchers concluded that the risk of clavicle fracture was not associated with birth weight, which is consistent with our study.[6] A birth weight of ≥4,000 g is a known risk factor for birth trauma. The association between birth trauma and birth weight has been shown in some studies.[22] While BPI develops due to shoulder dystocia in macrosomic newborns, it occurs in low and middle-weight newborns due to other malpresentations.[34]

The mean head circumference of newborns with birth trauma was 34.8±1.6 cm. We found that increased head circumference was a risk factor for clavicle fracture and BPI. In another study, the mean head circumference of newborns with clavicle fractures was between the 50th and 95th percentile in 54% of patients, and the researchers reported that the risk of clavicle fracture increased with increasing head circumference.[25] A study comparing babies born over 4,000 g in shoulder dystocia revealed that head circumference was a risk factor for shoulder dystocia.[35] Shoulder dystocia is associated with BPI, with a rate of 4 to 40%.[36] We believe that an increase in head circumference increases the risk of shoulder dystocia and contributes to the development of BPI.

Previous studies have also reported a higher rate of right clavicle fractures, consistent with our findings. These studies showed that right clavicle fractures were more common than left clavicle fractures, with ratios of 69.6%,[15] 59%,[31] and 60%.[24] In our study, 51.3% of all birth traumas involved right clavicle fractures, and 60.3% of clavicle fractures occurred on the right side. Anterior occiput anterior approaches cause more pressure on the right shoulder, resulting in a higher incidence of fractures in the right clavicle.[30] We found bilateral clavicle fractures in four newborns. Bilateral clavicle fractures are rare and have been reported as case reports in the literature.[37]

According to the results of our study, neonates with BPI injuries were more frequently consulted to PMR and pediatric neurology than the clavicle fracture and humerus fracture groups. In contrast, humerus and clavicle fractures were more frequently

consulted to orthopedics than the BPI group. In general, these patients were consulted by the relevant departments after evaluation by the neonatologist. Clavicle fractures are usually diagnosed within the first three days of birth.[16,38] In a previous study, it was concluded that neonatal clavicle fractures were diagnosed in 38.9% of the patients at follow-up visits after discharge from the hospital.[39] Early diagnosis and treatment in the first two or three weeks of the postpartum period BPI increases the chance of conservative therapy in BPI.[40] We believe that establishing a standard algorithm for the assessment of fractures and nerve injuries that may coexist with birth traumas or may develop as a result of similar risk factors and performing an evaluation with a multidisciplinary approach may be effective in detecting these injuries in the early period and preventing severe complications that may develop, *albeit* rarely.

We found that a larger head circumference was associated with an increased risk of clavicle fractures. Higher birth weight and lower APGAR scores at 1 min were associated with BPI. Clavicle fractures, humerus fractures, and BPI were more common in the right upper extremity. While clavicle and humerus fractures were mostly consulted by the orthopedic department, BPI patients were evaluated by PMR and pediatric neurology.

The main strengths of our study were that it was the study with the largest number of patients in Türkiye on birth traumas performed in a tertiary care hospital where all data were digitally recorded, simultaneous evaluation and comparison in terms of clavicle and humerus fracture and BPI, and evaluation of the multidisciplinary approach of neonatologists in birth traumas, which had not been evaluated in previous studies. The main limitations to our study included its retrospective nature, the lack of statistical evaluation of risk factors due to the low number of newborns with humerus fractures, and the absence of a control healthy group.

In conclusion, we believe that it is essential to know the risk factors of the mother and the baby to detect clavicle, humerus fractures, and BPI injuries that may develop due to birth trauma in the early period and to prevent complications that may develop. Further multi-center, large-scale, prospective studies are warranted to identify possible risk factors.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Concept, design, critical review: F.S., F.E.C., E.A.; Control/supervision: F.E.C., E.A., E.Ş.B.; Resources, materials, data collection and/or processing: E.E.B., D.E., F.S.; Analysis and/or interpretation: E.Ş.B., E.E.B., D.E.; Literature search: D.E., E.E.B., F.S., E.Ş.B.; Writing manuscript: F.S.

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