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ORIGINAL ARTICLE

Neonatal birth fractures: a retrospective tertiary maternity hospital review

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ABSTRACT

We aimed to identify the incidence and types of neonatal birth fractures in a single tertiary maternity hospital in the United Kingdom and to find possible associated factors, including all live births born between 2000 and 2016. We reviewed hospital records and imaging of all neonates who had any imaging done to identify birth fractures. We identified 87,461 consecutive live births. Sixty-six sustained a fracture during delivery: 46 clavicle-, 13 humerus-, four skull-, one femoral-, one rib- and one tibial fracture. Five neonates with a clavicle or humeral fracture had an Erb's palsy. Sixty-five fractures were in singletons. Twenty-five fractures were diagnosed after discharge. Binary logistic regression analysis with R-Studio showed a significant association between 'Fracture' and 'Birthweight' ($p < .0005$), 'Delivery Mode' (Forceps: $p < .001$, Ventouse: $p < .0004$) and 'Gestation' ($p < .0005$) but not with 'Sex', 'Day' and 'Time' of delivery, 'Number of deliveries per day', 'Singleton/Multiple Births' and 'Breech'. The incidence of birth fractures (0.075%) was low with 24 hours obstetrician support on site in comparison to published data. We recommend to include data on neonatal birth injuries in addition to the existing clinical safety markers for delivery units.

KEYWORDS
Birth fractures; birth injuries; neonatal fractures; neonatal trauma

IMPACT STATEMENT

- **What is already known on this subject?** Most birth fractures affect the clavicle with a large variation in published incidences from 0.035% to 3.2%. High birthweight is the most frequently identified risk factor. An increased risk for out of hours deliveries (16.00–8.00) and inverse association between fracture rate and level of experience and academic qualification have also been reported. Between 14% and 39% of fractures are diagnosed after discharge but many studies are based on birth certificate and discharge diagnoses coding only.
- **What the results of this study add?** This is the first study on neonatal birth fractures from the United Kingdom and the only study for which radiological investigations of all neonates were reviewed. Our fracture rate of 0.075% for all fractures is therefore most likely the most accurate, showing no significant difference in the fracture risk between our six defined time intervals and days of the week, with experienced midwifes managing many high risk pregnancies and an obstetrician being present on site all the time.
- **What the implications are of these findings for clinical practice and/or further research?** Our findings support to use data on neonatal birth injuries as one indicator to assess the quality and safety of maternity units.

Introduction

The health service in England consists of 152 acute NHS trusts with 167 birth centres. There were 679,106 live births in England in 2017 with one in 50 pregnant women giving birth at home. Outcomes of maternity services in the UK currently do not include data on neonatal fractures and other neonatal injuries. In the 2013–2015 inspection period, the CQC classed 7% of maternity services as inadequate and 41% as 'requiring improvements' with the majority of issues being related to midwife access and continuity of care (Inspection Framework: NHS Acute Hospitals 2017; National Review of Maternity Services 2017). The complexity of pregnancies is increasing (e.g. maternal diabetes, obesity) but perinatal mortality reduced from 8.6 per 1000 deliveries in 2003 to 6 per 1000 deliveries in 2013 (4722 perinatal deaths: 3286 stillbirths, 1436 neonatal deaths). Maternal mortality reduced from 14 deaths to 9 deaths per 100,000 maternities during the same period. The Hospital Episode Statistics (HES) database recorded an increase in delivery complications in England of 7.38% (95,252) between 2010 and 2014 (National Review of Maternity Services 2017) and in its 2018 report, The Royal College of Midwifes (RCM) raised concern that the NHS England has an estimated shortage of 3500 full-time midwifes which has remained unchanged since 2016 (State of Maternity Services Report England 2018).

Our 120 bed maternity hospital provides a local and regional service for all women with high risk pregnancies. We have also been affected by the national shortage of midwifes

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which was reflected by three CQC inspections between April 2015 and September 2016 citing substantial midwife shortages and poor compliance in medical staffing with ‘staffing shortages within the delivery suite were seen each day…’ (Care Quality Commission 2017). The effect of staffing shortages on neonatal and/or maternal trauma is not known.

Neonatal fractures cause anxiety for parents and staff. The literature indicates that fractures most frequently involve the clavicle, followed by femur and then humerus, without resulting in long-term disability and/or deformity (Morris et al. 2002; Givon et al. 2007; Kancherla et al. 2012; Ahn et al. 2015). The most frequently identified risk factor is increased birth weight (>4000 g); others are increased head circumference, vacuum delivery, maternal gestational diabetes, advanced maternal age, academic degree of the attendant physician, nurse attendant, delivery during ‘risk hours’ which has been defined in the literature as the time between 16.00 and 8.00 and shoulder dystocia (Lam et al. 2002; Linder et al. 2013; Ozdener et al. 2013; Iskender et al. 2014).

We could not find any data in the current literature on neonatal birth fractures or other neonatal injuries from the United Kingdom (UK). Our aim was therefore to provide the first data on incidence and types of neonatal birth fractures from a single UK maternity unit which could be used as a guidance for other units and to find possible associated risk factors with an emphasis on timing of delivery.

Methods

Following approval by our institutional review board (ref: PRN 6319), we conducted a retrospective cohort study. We reviewed our hospital record databases to identify all live births born in our maternity unit over a 17 years period from January 1 2000 until December 31 2016. From the hospital radiology database, we identified all those patients out of this cohort who had any radiological imaging done within the first 12 months of life to account for children who sustained a fracture at birth where the diagnosis was delayed or missed. All radiological investigations and radiology reports were reviewed by the senior author. We collected data on birth weight, *in utero* baby position (breech or no breech), mode of delivery (spontaneous delivery, emergency Caesarean section, elective Caesarean section, forceps and Ventouse delivery), day (Monday to Sunday) and time of delivery (six time groups: 8.00–11.59; 12.00–15.59; 16.00–19.59; 20.00–23.59; 24.00–3.59; 4.00–7.59), number of deliveries per day (three groups: up to eight live births per day; 9–16; ≥17 live births per day), sex, single or multiple births and gestational age for all babies. RStudio was used for statistical analysis. We performed a binary logistic regression analysis (glm function) to test if any of our independent variables had a significant effect on the binary dependent variable ‘Fracture’ and calculated odds ratios and confidence intervals. We defined our Null-hypothesis as there being no significant correlation between the dependent variable ‘Fracture’ and the individual independent variables. We accepted the Null-hypothesis if p was ≥5% and rejected it if p was <5% (significant correlation). As part of the logistic regression calculation RStudio calculates parameter (variable) coefficients (estimates) which in case of a significant correlation indicate the direction of the correlation. The coefficient is positive if the independent variable increases the risk of the outcome variable happening. For a numeric variable, a positive sign means that the risk increases with the increase of its value and a negative sign indicates that an increase of its value decreases the risk. For two variables which are positively correlated (e.g. birthweight and gestation), the parameter coefficients can be reversed, giving a negative sign on one of the coefficients indicating that one of the variables has a larger effect on the outcome variable than the other (Simpson’s paradox). Data on head circumference, ethnicity and shoulder dystocia could not be included in the statistical analysis because the information was missing for a large number of the population of neonates. We had no information on the seniority of the staff attending the deliveries.

Results

We identified 87,461 live births, 42,552 girls and 44,909 boys with 84,141 being singletons. The modes of delivery were: 51,056 spontaneous, 11,797 emergency Caesarean section, 12,888 elective Caesarean section, 6159 forceps and 5561 Ventouse (Table 1). Breech position was documented for 3929 neonates with two fractures in this group (one humerus, one clavicle). The mean distribution of deliveries between Monday and Sunday was 12,494: 12,580, 12,808, 13,042, 13,912, 12,975, 11,178, 10,966. The number of deliveries was higher between 8.00 and 16.00 compared to the other four time groups: 8.00–11.59 (16,786), 12.00–15.59 (15,894), 16.00–19.59 (13,312), 20.00–23.59 (13,447), 24.00–3.59 (14,543) and 4.00–7.59 (13,479) (Table 2). On most days, there were between 9 and 16 live births: ≤8 (2836), 9–16 (54,009) and ≥17 (30,616) babies. The mean birth weight for live births with a fracture was 3702 g (median birth weight: 3835 g; range: 535–4813 g) (mean birth weight for non-fracture live births: 3368 g; median: 3415 g; range: 410–5680 g). The mean gestational age for live births with a fracture was 39.3 weeks (median gestational age: 40 weeks; range: 24–42 weeks) (gestational age for non-fracture live births: 39 weeks; median: 39 weeks; range: 17–46 weeks).

We identified 66 neonates who sustained a fracture during delivery: 46 clavicle-, 13 humerus-, four skull-, one femoral-, one rib- and one tibial fracture. Five babies with fractures also had an Erb’s palsy; three with a humeral fracture (in 2 Erb’s palsy was on the side of the fracture, in 1, on the opposite side) and two patients with a clavicle fracture (both on the fracture side). All five made a full spontaneous recovery without the need for a referral to a specialist peripheral nerve injury unit. One neonate with a humeral fracture and one with a clavicle fracture also had shoulder dystocia. The patient who sustained a tibial fracture also presented with healed intrauterine fractures of other bones as a result of osteogenesis imperfecta type 3. The other neonates with a fracture had no known underlying metabolic disorders. The patient with the femoral fracture was delivered by emergency Caesarean section and the one with the tibial fracture

Table 1. Live births, breech positions, multiple deliveries, delivery modes (1 = spontaneous; 2 = emergency Caesarean section; 3 = elective Caesarean section; 4 = forceps; 5 = Ventouse), fractures and delivery modes for fracture patients per year.

Year	Live births	Fractures	Breech	Multiple deliveries	Delivery modes: 1–5	Delivery modes (M) for fractures
2000	4472	2 (0.045%)	110	169	1=2568; 2=719; 3=441; 4=311; 5=433	1× M1 1× M2
2001	4434	2 (0.045%)	128	143	1=2631; 2=708; 3=469; 4=295; 5=330	1× M1 1× M4
2002	4465	8 (0.18%)	150	116	1=2606; 2=724; 3=503; 4=237; 5=395	2× M1, 1× M3, 1× M4, 4× M5
2003	4676	2 (0.042%)	197	168	1=2693; 2=657; 3=640; 4=233; 5=453	1× M1 1× M5
2004	4761	3 (0.063%)	217	188	1=2727; 2=557; 3=782; 4=248; 5=447	2× M1 1× M3
2005	4830	3 (0.062%)	235	166	1=2758; 2=554; 3=817; 4=271; 5=430	1× M2 2× M4
2006	4896	3 (0.061%)	272	203	1=2776; 2=669; 3=878; 4=250; 5=323	1× M1, 1× M2, 1× M4
2007	5057	3 (0.059%)	228	215	1=2965; 2=642; 3=789; 4=277; 5=384	1× M1 2× M4
2008	5427	3 (0.055%)	259	202	1=3190; 2=690; 3=853; 4=357; 5=336	2× M1 1× M5
2009	5344	3 (0.056%)	215	205	1=3070; 2=706; 3=854; 4=327; 5=388	2× M1 1× M4
2010	5587	3 (0.054%)	242	212	1=3235; 2=698; 3=900; 4=449; 5=305	2× M1 1× M3
2011	5592	4 (0.072%)	292	284	1=3138; 2=795; 3=891; 4=527; 5=241	1× M1 3× M5
2012	5656	3 (0.053%)	267	207	1=3291; 2=696; 3=927; 4=516; 5=226	2× M1 1× M4
2013	5715	5 (0.087%)	275	233	1=3446; 2=705; 3=922; 4=453; 5=189	4× M1 1× M4
2014	5683	7 (0.123%)	245	230	1=3415; 2=717; 3=866; 4=504; 5=181	1× M1, 1× M2, 1× M3, 4× M4
2015	5448	6 (0.110%)	303	173	1=3337; 2=755; 3=670; 4=466; 5=220	4× M1 2× M4
2016	5418	6 (0.111%)	295	206	1=3211; 2=805; 3=687; 4=437; 5=279	1× M1, 2× M2, 2× M4, 1× M5
Total	87,461	66 (0.075%)	3930	3320	1=51,056; 2=11,797; 3=12,888; 4=6159; 5=5561	28× M1, 6× M2, 4× M3, 18× M4, 10× M5

Table 2. Total number of fractures (1st number) and live births (2nd number) for each day of the week and time blocks for the period 2000–2016.

	08.00–11.59	12.00–15.59	16.00–19.59	20.00–23.59	24.00–03.59	04.00–7.59
Monday	2/2803	4/2124	2/1732	1/1916	3/2056	1/1949
Tuesday	1/1851	2/2941	3/2195	2/1896	1/2004	1/1921
Wednesday	1/2985	3/2234	2/1844	2/1985	0/2055	0/1939
Thursday	1/2758	1/2915	1/2226	2/1958	1/2130	0/1925
Friday	5/2925	1/2239	1/1786	2/1956	1/2150	1/1919
Saturday	l/1693	5/1734	0/1773	2/1880	2/2137	3/1961
Sunday	2/1771	0/1707	1/1756	0/1856	2/2011	0/1865

by elective Caesarean section. Seven clavicle fractures were identified by the senior author which had not been reported by the reporting radiologists at the time of the imaging. The radiology department confirmed the senior author's findings.

Out of the four skull fracture patients one had an elevation of a depressed fracture (delivered by emergency Caesarean section), one required two burr holes (delivered by emergency Caesarean section following failed forceps delivery) and two did not require surgery (one spontaneous delivery without instrumentation, one Ventouse delivery). None was in a breech position. The language skills of the patient who required burr holes were delayed by a 'few months' at a follow-up of 30 months, the others had made a full recovery. One humerus fracture (spontaneous delivery) was a completely displaced transphyseal fracture of the distal humerus which was reported at first as dislocation by the reporting radiologist. An ultrasound showed the fracture without dislocation. The child underwent an open reduction and fixation with 3K-wires (two lateral, one through olecranon). At 54 months follow up, the child was symptom free, had a symmetric carrying angle, full range of elbow/forearm movements apart from lacking the last about 10° to full extension and normal radiological alignment. The other long bone fractures were splinted for 2 weeks.

Twenty-eight babies were delivered spontaneously (no breech), six by emergency (one breech) and four by elective Caesarean section (three breech), 18 by forceps and 10 by Ventouse delivery. Sixty-five fractures were in singletons and one in a twin baby. Nine fracture patients had shoulder dystocia (two humerus-, seven clavicle fractures). Eighteen fractures (13 clavicle, four humerus and one rib fracture) were diagnosed after discharge, giving a total of 25 fractures (37.9%) which had not been diagnosed during the initial hospital stay.

Logistic regression analysis using the glm function in RStudio shows a significant association between the binary dependent variable 'Fracture' (yes/no) and Ventouse delivery ($p = .00037$), forceps delivery ($p = .00096$), birthweight ($p = .0005$) and gestation ($p = .00044$). The parameter coefficients are +1.6695 for 'Forceps Delivery', +1.3274 for 'Ventouse Delivery', +0.0015 for 'Birthweight' and –0.3028 for 'Gestation'. The positive coefficients for 'Forceps Delivery', 'Ventouse Delivery' and 'Birthweight' indicate that forceps and Ventouse delivery are correlated with an increased risk to sustain a fracture and that higher birthweight is correlated with an increase in fracture risk. As birthweight and gestation are positively linked with birthweight increasing with the increase in gestational age, the two coefficients have to be interpreted in association. Therefore, the positive birthweight coefficient and the significant result for the gestation effect indicate that the fracture risk increases also with an increase in gestational age. However, the negative coefficient estimate for gestation indicates that once birthweight has been taken into account, if two live births have the same weight, the risk to sustain a fracture was lower for the one with the higher gestational age (Table 3). The 95% confidence intervals of the odds ratios for the four independent variables above do not span 1, which also indicates that the association is statistically significant. The odds ratios for all other independent variables do not reach statistical significance with their confidence intervals spanning 1. Fifty-eight neonates without a fracture were excluded from the analysis because of missing data for birthweight and/or gestation.

Discussion

Our fracture rate of 0.075% is likely to be the most accurate rate for neonatal fractures seen in a consecutive population of all live births from a single maternity unit because fracture identification included review of all imaging of every child who had any imaging done during the first 12 months of life rather than searching for hospital codes only. As a result, we identified an additional seven (18%) clavicle fractures which had not been reported and not been coded. Even our series might not be complete since some children might have sustained a fracture without radiographs having been taken. A nerve injury was recorded in 7.6% of our fracture patients. In some of these children reduced arm function as a result of a fracture might have been mistaken for a nerve injury.

Previously reported numbers of fractures in the literature are likely to be too low since identification of fractures has been based solely on coding.

Wen et al. (2018) reported that neonatal fractures and other severe birth trauma had declined for spontaneous live births between 2004 and 2013 in Washington State/USA with the main effect for neonates being the reduction in birth fractures (2.35 fractures per 1000 live births in 2004 and 1.97 per 1000 in 2013, 2.82% of live births had more than one injury). This was based on birth certificate and hospital discharge data coding only, excluding mothers non-resident in the State, breech, multiple births and mothers who delivered <20 and >44 weeks of gestation without any given reason and 57,777 for record issues (exclusion of a total of 15.5%/134,531 of all mothers). Ahn et al. (2015) reported that 13.8%

Table 3. p Values (significance level .05), odds ratios and confidence intervals for association between the dependent variable 'Fracture' and the independent variables 'Mode of delivery' (spontaneous, emergency Caesarean, elective Caesarean, forceps, Ventouse), 'Birthweight', 'Gestation', 'Breech', 'Sex', 'Time of delivery' (Six 4-h blocks), 'Day of delivery', 'Singleton/Multiple births' and 'Life births delivered on the day' (three groups).

Independent variable	p Value	Odds ratio	Confidence interval: 2.5–95%
Ventouse delivery	p: .00037 PC: +1.33	3.74	1.81–7.75
Forceps delivery	p: .00096 PC: +1.67	5.06	2.78–9.19
Emergency Caesarean	.65	0.47	0.33–2.00
Elective Caesarean	.061	0.34	0.11–1.05
Birthweight	p: .0005 PC: +0.0016	1.0015	1.0009–1.0020
Gestation	p: .00044 PC: –0.303	0.75	0.64–0.88
Breech	.44	1.84	0.39–8.68
Sex	.45	1.21	0.73–2.01
Time 12.00–15.59	.54	1.26	0.60–2.62
Time 16.00–19.59	.84	0.91	0.41–2.05
Time 20.00–23.59	.78	0.89	0.39–1.99
Time 24.00–03.59	.42	0.7	0.29–1.65
Time 04.00–07.59	.12	0.46	0.17–1.23
Tuesday	.49	0.75	0.33–1.70
Wednesday	.24	0.6	0.24–1.43
Thursday	.09	0.43	0.16–1.13
Friday	.62	0.83	0.37–1.83
Saturday	.85	1.05	0.49–2.35
Sunday	.1	0.41	0.15–1.18
Singleton/multiple deliveries	.87	1.89	0.73–12.49
9–16 live births/day	.98	1.074	0.64–1.8
≥17 live births/day	.98	1.09	0.65–1.84

PC: parameter coefficient (estimate).
No values are listed for time: '08.00–11.59', 'Monday' and '1–8 Live Births/day' because the null hypothesis was that there was no difference between these levels and their corresponding group levels.

and Joseph and Rosenfeld (1990) that 38.9% of clavicle fractures in their medical record study had not been diagnosed until after discharge. In our study, 37.9% of neonatal fractures were undiagnosed at the time of discharge. The possibility of missing all fractures diagnosed after discharge and excluding >15.5% of live births reduces the validity of Wen et al.'s data and conclusion that neonatal birth fractures have declined over time.

Our fracture rate is within the lower end of published neonatal fracture rates with most publications reporting on smaller cohorts and on one type of fracture only (clavicle or long bone fractures), excluding subgroups of life births at times and usually not commenting on skull fractures. Published rates for clavicle fractures are 0.035–3.2% (Walle and Hartikainen-Sorri 1993; Beall and Ross 2001; Lam et al. 2002; Lurie et al. 2011; Ahn et al. 2015), femoral and humeral fractures 0.023% (Basha et al. 2013), clavicle and long bone fractures 0.064% (Al-Habdan 2003), femoral fractures 0.0077% (Toker et al. 2009) and 0.013% (Morris et al. 2002), all skull fractures 0.016% (Camus et al. 1985) and depressed skull fractures 0.0038% (Dupuis et al. 2005) to 0.01% (Mastrapa et al. 2007). The vast majority of femoral fractures were diagnosed several days after delivery (Morris et al. 2002; Toker et al. 2009). Most previous studies looking into neonatal birth fractures did not investigate if there is a difference between out of hours (16.00 and 8.00) and/or weekend deliveries and deliveries during regular working hours (8.00–16.00) and/or weekday deliveries. Linder et al. (2013) reported an increased risk of birth trauma for deliveries during at risk hours (before 8 am and after 4 pm) and weekends. We did not find a statistically significant difference between deliveries during any of our four hours blocks or day of the week and fracture rate which could be related to having staff with experience in a large number of high risk pregnancies and a consultant obstetrician being on site at any time. The relatively even distribution of the number of deliveries over the different time blocks and days of the week, apart from increased delivery numbers during most weekday morning and early afternoon blocks, might also be a factor. Several authors have shown an inverse association between the rate of birth trauma and level of experience and training of the attending staff. Murphy et al. (2003) reported on 393 operative deliveries with 59 cases of head trauma and brachial plexus palsy (fractures were not included) in two teaching hospitals in Bristol UK of which only 2% were completed by a consultant obstetrician and 79% were left to less experienced trainees. Five of the six most severe cases of neonatal morbidity were initiated by an inexperienced operator. Inglis et al. (2011) found a significant decrease in obstetric brachial plexus palsy following shoulder dystocia training for maternity staff. Ariyawatkul et al. (2017) reported a significantly increased neonatal fracture risk if the delivery was assisted by a nurse attendant.

Dupuis et al. (2005) reported that 4% of children with obstetric depressed skull fractures had severe long-term sequelae. One of our patients with a skull fracture had delayed language skills by a 'few months' at a follow-up of 30 months. We are not aware that any of our other fracture patients had any long-term sequelae as a result of the fracture which is reflected by findings reported in the literature.

Ahn et al. (2015) stated that it is most probably impossible to predict and prevent clavicle fractures and that the prognosis is benign without any sequelae. Givon et al. (2007) did not find any complications in 10 children who had sustained a neonatal femoral birth fractures at a mean follow-up of 5 years 2 months. Kancherla et al. (2012) did not find a length discrepancy and no residual angulation in 10 patients who had sustained a femoral birth fracture at a mean follow-up of 60 months (range: 24–84 months). Sherr-Lurie et al. (2011) examined nine children at 6 months who had sustained a humeral birth fracture and found that all had a good range of movements and no deformity on radiographs.

Our neonatal birth fracture rate of 0.075% was low despite managing the regional high risk pregnancies. We did not identify 'at risk hours' with experienced midwives and available consultant obstetrician support always available if required. The published evidence indicates that neonatal birth fractures, apart from some skull fractures, do not result in long-term sequelae. Despite the positive outcomes, we recommend the collection of data on neonatal birth injuries as part of the criteria used to assess maternity units.

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Disclosure statement

No potential conflict of interest was reported by the authors.

References

Ahn ES, Jung MS, Lee YK, Ko SY, Shin SM, Hahn MH. 2015. Neonatal clavicular fracture: recent 10 year study. Pediatrics International 57: 60–63.

Al-Habdan I. 2003. Birth-related fractures of long bones. Indian Journal of Pediatrics 70:959–960.

Ariyawatkul T, Worawuthangkul K, Chotigavanichaya C, Kaewpornsawan K, Chalayon O, Eamsobhana P. 2017. Potential risk factors for birth fractures: a case-control study. International Orthopaedics 41: 2361–2364.

Basha A, Amarin Z, Abu-Hassan F. 2013. Birth-associated long-bone fractures. International Journal of Gynaecology and Obstetrics 123: 127–130.

Beall MH, Ross MG. 2001. Clavicle fracture in labor: risk factors and associated morbidities. Journal of Perinatology 21:513–515.

Camus M, Lefebre G, Veron P, Darbois Y. 1985. Traumatismes obstétricaux du nouveau-né: enquête rétrospective à propos de 20409 naissances. Journal de Gynécologie Obstétrique et Biologie de la Reproduction 14:1033–1044.

Care Quality Commission. 2017. Addenbrooke's and the Rosie Hospitals. Reports. [cited 2019 Jun 17]. Available from: https://www.cqc.org.uk/location/RGT01

Dupuis O, Silveira R, Dupont C, Mottolese C, Kahn P, Dittmar A, Rudigoz RC. 2005. Comparison of "instrument-associated" and "spontaneous" obstetric depressed skull fractures in a cohort of 68 neonates. American Journal of Obstetrics and Gynecology 192:165–170.

Givon U, Sherr-Lurie N, Schindler A, Blankstein A, Ganel A. 2007. Treatment of femoral fractures in neonates. The Israel Medical Association Journal 9:28–29.

Inglis SR, Feier N, Chetiyaar JB, Naylor MH, Sumersille M, Cervellione KL, Predanic M. 2011. Effects of shoulder dystocia training on the incidence of brachial plexus injury. American Journal of Obstetrics and Gynecology 204:322.e1–322.e6.

Inspection Framework: NHS Acute Hospitals. 2017. NHS acute core service inspection framework for maternity and gynaecology. [cited 2019 Jun 17]. Available from: https://www.cqc.org.uk/search/site/maternity?-sort=default&distance=15&mode=html&f%5B0%5D=bundle%3Adocument

Iskender C, Kaymak O, Erkenekli K, Ustunyurt E, Uygur D, Yakut HI, Danisman N. 2014. Neonatal injury at cephalic vaginal delivery: a retrospective analysis of extent of association with shoulder dystocia. PLoS One 9:e104765.

Joseph PR, Rosenfeld W. 1990. Clavicular fractures in neonates. American Journal of Diseases of Children (1960) 144:165–167.

Kancherla R, Sankineani SR, Naranje S, Rijal L, Kumar R, Ansari T, Trikha V. 2012. Birth-related femoral fracture in newborns: risk factors and management. Journal of Children's Orthopaedics 6: 177–180.

Lam MH, Wong GY, Lao TT. 2002. Reappraisal of neonatal clavicular fracture. Relationship between infant size and risk factors. The Journal of Reproductive Medicine 47:903–908.

Linder N, Linder I, Fridman E, Kouadio F, Lubin D, Merlob P, et al. 2013. Birth trauma – risk factors and short-term neonatal outcome. Journal of Maternal-Fetal and Neonatal Medicine 26:1491–1495.

Lurie S, Wand S, Golan A, Sadan O. 2011. Risk factors for fractured clavicle in the newborn. The Journal of Obstetrics and Gynaecology Research 37:1572–1574.

Mastrapa TL, Fernandez LA, Alvarez MD, Storrs BB, Flores-Urueta A. 2007. Depressed skull fracture in Ping Pong: elevation with Medeva extractor. Child's Nervous System 23:787–790.

Morris S, Cassidy N, Stephens M, McCormack D, McManus F. 2002. Birth-associated femoral fractures: incidence and outcome. Journal of Pediatric Orthopedics 22:27–30.

Murphy DJ, Liebling RE, Patel R, Verity L, Swingler R. 2003. Cohort study of operative delivery in the second stage of labour and standard of obstetric care. BJOG 110:610–615.

National Review of Maternity Services. 2017. Assessment of quality in maternity services. [cited 2017 Aug 22]. Available from: https://www.england.nhs.uk/publication/national-review-of-maternity-services-assessment-of-quality-in-maternity-services/

Ozdener T, Engin-Ustun Y, Aktulay A, Turkcapar F, Oguz S, Yapar EG, Mollamahmutoğlu L. 2013. Clavicular fracture: its prevalence and predisposing factors in term uncomplicated pregnancy. European Review for Medical and Pharmacological Sciences 17:1269–1272.

Sherr-Lurie N, Bialik GM, Ganel A, Schindler A, Givon U. 2011. Fractures of the humerus in the neonatal period. The Israel Medical Association Journal 13:363–365.

State of Maternity Services Report England. 2018. Available from: https://www.rcm.org.uk/briefings-and-Reports

Toker A, Perry ZH, Cohen E, Krymko H. 2009. Cesarean section and the risk of fractured femur. The Israel Medical Association Journal 11: 416–418.

Walle T, Hartikainen-Sorri AL. 1993. Obstetric shoulder injury. Associated risk factors, prediction and prognosis. Acta Obstetricia et Gynecologica Scandinavica 72:450–454.

Wen Q, Muraca GM, Ting J, Coad S, Lim KI, Lisonkova S. 2018. Temporal trends in severe maternal and neonatal trauma during childbirth: a population-based observational study. BMJ Open 8:e020578.