Risk factors for peripheral nerve injuries following neuraxial labour analgesia: a nested case–control study

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Background: Post-partum lower extremity motor and sensory dysfunctions occur in 0.1–9.2‰ of deliveries. While macrosomia, lithotomy position and forceps use are well-identified causes of peripheral nerve injuries, additional contributors such as patient condition and anaesthesia care may also have to be considered.
Methods: We performed a case–control study nested in a cohort of 19,840 patients having neuraxial anaesthesia for childbirth. Cases were all patients who developed motor or sensory dysfunction of lower extremities in the post-partum period. These were compared, using Chi-square, Fisher's exact test, logistic regression and time series, to a random sample of controls without any neurological symptoms or injury.
Results: We identified 19 (0.96‰) patients with peripheral nerve injuries of which 15 (0.76‰) were likely associated with obstetrical care. In four additional cases (0.20‰), a nerve root injury due to the Tuohy needle was suspected. Univariate risk factors were: a gestational age ≥ 41 weeks, Odds Ratio (OR) 3.8; 95% CI: 1.1–13.1, late initiation of neuraxial anaesthesia OR 8.2; 95% CI: 1.8–37.9, a repeated anaesthetic procedure OR 2.8; 95% CI: 1.0–7.8, assisted delivery with forceps OR 9.8; 95% CI: 1.2–114.1 and newborn birth weight > 3.5 kg with an OR 6.8; 95% CI: 2.0–22.5.
Conclusion: Obstetrical related factors are the most prominent risk associated with peripheral nerve injuries. This study highlights however that patient and anaesthesia-related factors may also contribute to peripheral nerve injuries.

Editorial comment
This report demonstrates that both patient- and anaesthesia-related factors may contribute to peripheral nerve injury after labour and delivery, in addition to the more prominently associated obstetrical factors.

Neuraxial anaesthesia has become the most prevalent method for labour analgesia in patients. Recent figures show that 49.3% of patients in the United Kingdom, 58.7% in Canada, 61% in the United States and 79.3% in France give birth under neuraxial anaesthesia.[1–4] While widely used in obstetrics, neuraxial blocks (spinal, epidural or combined spinal-epidural) are not free of risks, including neurological complications. The most feared but

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fortunately rare complication is an injury to the central nervous system. This injury occurs in 1/145,000 to 1/240,000 of the procedures (obstetrics and general surgery) and results in long-lasting or permanent loss of motor and sensory function of the sphincters and lower extremities.[5–9] This can be due to a compressive haematoma or abscess, a direct puncture of the spinal cord (by needle or catheter), or a chemical irritation of the spinal cord by hypertonic or toxic drug injections.[10]

Peripheral nerve injuries are also a well know complication, particularly in obstetrics. Following labour and delivery, their incidence ranges between 0.1‰ and 9.2‰.[11–14] Most often, symptoms associated with these injuries are transitory and resolve spontaneously within one year. In a small number of cases, the damages last permanently.[12,15] While peripheral nerve injuries are well identified, causation is more controversial. Most published data[7,16] seem to indicate that these complications are mostly related to compression or distraction of the nerve roots, plexus and/or peripheral nerves (femoral nerve, lateral femoral cutaneous nerve, obturator nerve, pudendal nerve and common peroneal nerve) due to obstetrical factors.[17] These include cephalopelvic disproportion, instrumental vaginal delivery, prolonged pushing in the lithotomy position, positioning of the mother during delivery and prolonged second stage of labour.[13,14,18–20]

Disk herniation with associated nerve roots compression has also been cited as a possible cause for radicular pain and paraesthesia with variable signs of muscle weakness in pregnant patients.[21]

Other studies associate non-obstetric-related factors with peripheral nerve injuries,[22–28] mainly radiculopathies following needle or catheter injuries. Current evidence of this association is however weak. Case reports and clinical audits, sometimes outside the field of obstetrics, suggest involvement of needle or catheter-related nerve root injuries as a cause of lower extremity motor and sensory dysfunctions.[22–28] No study has yet clearly identified and measured the specific contribution of anaesthesia and patient-related factors to these dysfunctions or their magnitude compared with obstetrical factors. The purpose of this study was therefore to assess the incidence and risk of obstetrical and non-obstetrical risk factors of these injuries.

Methods

Setting and data collection process

The Maternity Department of the Geneva University Hospitals (Geneva, Switzerland) is a tertiary referral centre with an average number of 3500–4000 childbirths per year. Over 80% of the deliveries are performed under neuraxial analgesia. All patients are routinely seen by an anaesthetist several days or immediately before the delivery and followed up between 48 h to several weeks, depending on post-partum clinical course. Since 2001, the Department of Anaesthesia has developed an electronic patient data recording system (EPR) to record all information related to patients and procedures during the pre, intra and post-partum periods.

This includes demographic characteristics, comorbidities, obstetrical information, anaesthetic procedure, timing and duration of the procedure. Staff characteristics and all intrapartum incidents and complications associated with obstetrical or anaesthetic procedures are also included in the database. The database is used exclusively for clinical and quality improvement purposes. It includes no personal or sensitive data and it complies with local and institutional rules governing personal health information.

Within 48 h following delivery, all patients are followed up by an anaesthetist or a nurse anaesthetist. During the visit, patients are interviewed individually and potential complications following anaesthesia such as post-dural puncture headaches, neurological disorders, nausea/vomiting and overall patient satisfaction are assessed. When a neurological complication is suspected, a special form is completed for the detailed recording of patient symptoms, investigations and management. A formal evaluation by a neurologist is systematically requested when persisting motor and/or sensory dysfunction is observed within 24–48 h following procedure. The collected information is recorded on a specific section of the EPR.

Following Institutional Ethics Committee approval (Geneva University Hospital Ethics Committee-CER 09-206R), we retrieved from the EPR all patients having a neuraxial procedure (spinal, epidural or combined spinal-epidural) for labour analgesia between January 2004 and 2011. We identified patients with neurological complications by extracting all patients having a neurological complication form completed and a confirmed examination by a neurologist according to information extracted from the hospital neurology department administrative database.

Cases with peripheral nerve injuries were defined as patients who in the post-partum period, developed signs of lower extremity motor and/or sensory dysfunction.

The injury had to be confirmed by the neurologist and Electroneuromyography (ENMG), Magnetic Resonance Imaging (MRI) or a Computed tomography scan (CT scan). All data extracted from the anaesthesia EPR were systematically cross-checked and completed using handwritten medical charts and the hospital administrative database. The data checking and cleaning process was completed by the use of automatic algorithms to detect typing errors such as double data entries or illogical variables (i.e. male gender, age > 100 years). Furthermore, to confirm diagnosis and to determine the possible association with anaesthesia care, two senior staff anaesthetists (GH; GS) audited and classified individual cases using additional information included in handwritten medical charts and clinicians' annotations.

To avoid misclassification bias due to an imbalance in the number of patients likely to suffer from obstetrics vs. anaesthesia-related complications, we included only patients receiving neuraxial analgesia for labour (80% of our study population).

We excluded patients who had pre-existing neurological disorders (i.e. symptomatic disk hernia, multiple sclerosis) and those with a post-dural puncture headache. Patients transferred to other hospitals or discharged within 24 h with no follow up visit were also excluded.

We also excluded patients undergoing an elective caesarean section as labour analgesia was the main study focus.

To identify factors potentially associated to lower extremity motor and sensory dysfunctions following neuraxial anaesthesia, a nested case–control study was performed. For each case identified in the case series, four random controls without any signs of lower extremity motor and/or sensory dysfunction were chosen in the original dataset using computerised random sampling techniques with the Statistical Package for the Social Sciences version 20 (SPSS Inc®, Chicago, IL, USA). This number of four controls per case was chosen to limit data extraction and validation-related costs while maximising statistical power.[29]

Controls were matched with cases for the month of the procedure, but for no other factors. All data extracted for control patients were cross-checked with medical charts. As this was an observational study on a rare complication, we used all cases of confirmed peripheral nerve injuries that we could identify and did not perform a priori sample size calculations.

Statistical analysis

For descriptive analyses, we used frequencies, proportions, means with standard deviations (SD). Continuous variables such as age, body mass index (BMI) at the end of pregnancy, number of gestations, parity, gestational age, birthweight and the timing of anaesthetic procedures were recoded into separate and mutually exclusive categories and transformed into categorical variables according to distribution. We transformed variables such as day of the week and nationality into binary categorical variables. Anaesthetic procedures were divided into three different categories: combined anaesthesia (Tuohy needle 18G/Whitacre needle through needle technique 27G), epidural anaesthesia, and spinal anaesthesia (Whitacre needle 25/27G). Late initiation of neuraxial anaesthesia was defined as a procedure performed with cervical dilation of 5 cm or above (median value of the study sample) and the variable was categorised accordingly.[30] We created a binary variable for anaesthetic repeated procedure by aggregating the variable 'more than one level punctured' and 'change of operator' (more than one anaesthetist involved in the procedure). Level of anaesthetists' training was divided into three categories: registrar (in training), senior registrar (certified up to 3 years before), consultant (certified staff anaesthetist).

We first performed a univariate analysis comparing all cases and control patients for demographic, anaesthesia and obstetric-related factors. Chi-square, Fisher's exact test for contingency tables with an expected count of < 5 and binary logistic regression were used. We calculated P values and derived odds ratio (OR) with 95% confidence interval (CI) an OR > 1.0 indicates an increased risk of peripheral nerve injuries. Due to the small sample size and to limit the risk of finding spurious correlations we only performed univariate analyses.

To assess the potential impact of the timing of the year on the incidence of peripheral neurological complications, we used time series analysis with autoregressive integrated moving average (ARIMA) models according to the Box-Jenkins methodology. This model allows the stochastic dependence of consecutive data to be modelled.[31] Among the different models generated through the analyses, we chose the most parsimonious one. Significance tests for parameter estimates were set at a $P < 0.05$. The predictive value of the model was assessed with the R^2 statistics. We used the Eviews 8 software (QMS, Irvine, USA).

Results

After data retrieval of 19,840 patients who had had a neuraxial procedure for labour analgesia and complete follow-up, 19 (0.96‰) patients who suffered from lower extremities injuries were identified (Fig. 1).

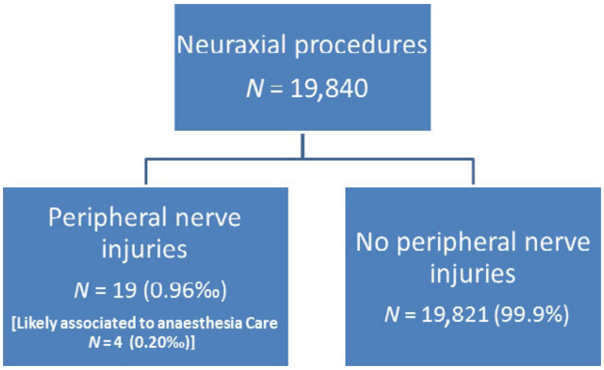

Fig. 1. Flow chart of data extraction process.

Injuries were on the lumbosacral plexus (8) or associated roots (5). Other injuries were on the femoral nerve (4), the obturator nerve (3) and the common peroneal nerve (2). Some patients had injuries on more than one nerve. Two patients had associated discal protrusion. But these were intercurrent findings and in none of the case could this explain the neurological symptoms. According to neurologists' conclusions, likely mechanisms of injuries were compression and tractions by baby's head or obstetrical manoeuvers and instruments in 15 of 19 cases. In four patients a direct injury caused by a needle to the nerve roots was hypothesised by the neurologist following clinical examination, MRI and/or ENMG results. In one case (No. 4), injury was hypothesised following clinical signs of a well-defined sensory loss in the L5 nerve root territory and major pain in the same territory during local anaesthesia injection in the catheter. In two other cases (No. 9, 18), ENMG analysis showed signs of neuropraxia at L5 nerve root level, close to the dorsal root ganglion, and attributed to the Tuohy needle.

In the last case (No. 10) where an injury of the right L2 and L3 nerve roots was suspected, MRI showed an oedema at the L2-L3 intervertebral space where neuraxial anaesthesia had been performed. These conclusions from the neurologist were critically assessed by two senior staff anaesthetists (GH; GS) and cross-checked with information extracted from medical charts and anaesthetists' and midwifes' handwritten records. These confirmed the presence of paresthesia or pain at Tuohy needle insertion, catheter placement or local anaesthesia injection in three cases (No. 4, 10, 18). This suggests an incidence of 0.20‰ for peripheral nerve injuries likely to be directly linked to anaesthesia care (Fig. 1).

Regarding long-term outcomes, nine patients had persisting symptoms beyond 6 days and one of them up to 3 years. Ten patients made a full recovery within 40 days. Injuries, symptoms and duration are detailed in Table 1.

After comparison with a random group of control patients without any neurological complications, univariate correlates were calculated and are presented in Table 2. These included a gestational age ≥ 41 weeks OR 3.8; 95% CI: 1.1–13.1), late initiation of neuraxial anaesthesia OR

Table 1 Signs, symptoms, neurological investigations findings of patients with lower extremity motor and sensory dysfunction.

Case	Procedure	Symptoms	Neurologist examination/ Additional tests findings (CT;MRI;Electromyography)	Duration of symptoms treatment neurological outcome
Patient 1	Assisted vaginal delivery (forceps)	Difficulties at standing up and walking with weakness of hip flexion and pain into the right inguinal fold and labia	Injury of the right femoral and pudendal nerves by compression	96 h Spontaneous resolution; no treatment
Patient 2	Spontaneous and oxytocin augmented contractions for vaginal delivery	Left foot drop and dorsal paraesthesia with pain at the posterior part of the left thigh	Extensive injury of the lumbosacral plexus (L4, L5, S1) by compression	3 years Regular follow-up by neurologist
Patient 3	Oxytocin induced contractions for vaginal delivery	Numbness of the right leg and dorsum of the foot and toe	Injury of the lumbosacral plexus (L4-L5 right) by stretching	96 h Spontaneous resolution
Patient 4	Oxytocin induced contractions for vaginal delivery	Numbness of the dorsum of the right leg	Injury of the right L5 nerve root possibly by the epidural needle	96 h Spontaneous resolution
Patient 5	Oxytocin induced contractions for vaginal delivery	Weakness of left hip flexion	Injury of the left femoral and obturator nerves following compression	Symptoms persisting at 14 days Lost to follow-up
Patient 6	Assisted delivery (Vacuum)	Left foot drop and paraesthesia of the foot dorsum	Injury of the left common peroneal nerve by compression during prolonged lithotomy position	Symptoms persisting at 10 days Foot splint prescribed Lost to follow-up
Patient 7	Assisted vaginal delivery (forceps)	Left foot drop and numbness of the posterior part of the leg	Extensive injury of the lumbosacral plexus (L4, L5, S1) by compression	19 days Spontaneous resolution
Patient 8	Spontaneous vaginal delivery	Numbness of the internal part of the right leg	Injury of the right L4 nerve root. Discal protrusion at L4- L5 and L5-S1 level with associated irritation of the sciatic nerve. Unclear causal factor.	Symptoms persisting at 6 days Lost to follow-up
Patient 9	Spontaneous initiation followed by Caesarean section	Right foot drop and numbness of the anterior part of the leg	Injury to the right L5 nerve root possibly by the epidural needle	26 days Spontaneous resolution
Patient 10	Spontaneous vaginal delivery	Weakness of right hip extension and numbness of the internal and anterior part of the right thigh	Injury of the right L2 and L3 nerve roots. Discal protrusion at L4-L5 and oedema at L2-L3 intervertebral space following epidural needle insertion. Unclear causal factor.	Persisting at 45 days Treatment Gabapentin + Clonazepam
Patient 11	Assisted vaginal delivery (Forceps)	Difficulties at standing up with weakness of hip flexion on both sides	Bilateral injuries of the femoral and obturator nerves following compression	40 days Spontaneous resolution
Patient 12	Assisted vaginal delivery (Forceps)	Weakness of left hip flexion and bilateral numbness of the thighs	Injury of the left femoral nerve following compression	Persisting at 18 days Lost to follow-up
Patient 13	Assisted vaginal delivery (Forceps)	Weakness at flexion and numbness (posterior part) of the left leg	Injury of the left sciatic nerve plexus following compression	Persisting at 21 days
Patient 14	Oxytocin induced contractions for vaginal delivery	Right foot drop and numbness of the external part of the right leg	Injury of the lumbosacral plexus (L5-S1 right side) by compression	Spontaneous resolution 96 h

Table 1 (Continued)

Case	Procedure	Symptoms	Neurologist examination/ Additional tests findings (CT;MRI;Electromyography)	Duration of symptoms treatment neurological outcome
Patient 15	Assisted vaginal delivery (Vacuum)	Tingling right foot	Injury of the lumbosacral plexus (L5-S1 right side) by compression	30 days Temporary treatment amitryptiline Full recovery
Patient 16	Spontaneous initiation followed by oxytocin augmented contractions for vaginal delivery	Tingling left foot	Injury of the lumbosacral plexus (L5-S1 right side) by compression with local oedema	Persisting at 21 days Lost to follow-up
Patient 17	Assisted vaginal delivery (Vacuum)	Right foot drop and paraesthesia of the lateral part of the right leg	Injury of the lumbosacral plexus (L4-L5 right side) by compression	Persisting at 30 days Lost to follow-up
Patient 18	Spontaneous initiation with prolonged lateral decubitus followed by Caesarean section	Weakness of right leg flexion and numbness of the anterior part of the leg	Injury to the right L5 nerve root with possible injury of the right common peroneal nerve Possibly mixed causal factors (epidural needle-compression)	Symptoms resolving progressively at 20 days Foot splint prescribed Lost to follow-up
Patient 19	Spontaneous delivery	Weakness of left thigh adduction	Injury of the left obturator nerve	Persisting at 60 days Follow-up by general practitionner

8.2; 95% CI: 1.8–37.9, a repeated anaesthetic procedure OR 2.8; 95% CI: 1.0–7.8, assisted delivery with forceps OR 9.8; 95% CI: 1.2–114.1 and newborn birth weight > 3.5 kg OR 6.8; 95% CI: 2.0–22.5.

Results of the ARIMA models developed to identify the association of timing of the year with peripheral nerve injuries are provided in Fig. 2. It assesses a time dependant pattern in the rate of injuries (‰) following neuraxial procedures. The unit of analysis is the quartile for all years of the study period. We did not find a seasonal pattern of injuries occurrence during the study period in the time series analysis. R^2 was 13% for quartiles of observation years.

Discussion

We found an incidence of 0.96‰ of post-partum spinal nerve roots, lumbosacral plexus and lower extremity nerve injuries. In one-fifth of the cases (incidence 0.20‰), the injury was more likely to be associated with anaesthesia care. Following statistical analysis, risk factors associated with injuries were found to be not only obstetric-related (use of forceps for assisted delivery, newborn birth weight > 3.5 kg) but also patient (gestational age ≥ 41 weeks) and anaesthesia (late initiation of neuraxial anaesthesia, repeated anaesthetic procedure) related.

A number of case series report the incidence of post-partum lumbosacral plexus and lower extremity dysfunction following regional ansaesthesia or analgesia for labour and delivery. Current figures range between 0.1‰ and 9.2‰ depending on studies and methodology.[11-14] The incidence of 0.96‰ found in our study is in the lower range of figures reported in the literature. This may be due to the fact that we selected only cases who had confirmed spinal nerve roots, plexus or peripheral nerve injury following examination by a neurologist and additional testing (ENMG, MRI, CT scan). Thus, we did not include transitory pressure point and surgical site numbness such as in the study by Dar et al. who report a higher incidence of complications of 5.8‰.[11]. Nor did we consider patients with a suspected diagnosis of peripheral nerve injuries based exclusively on clinical examination such as in the study by Wong

Table 2 Patient, surgical procedure and anaesthetist characteristics and univariate risk factors for peripheral nerve injuries.

Risk factors	Cases *N* = 19 (%)	Controls *N* = 76 (%)	OR (95% CI)	*P* value
Patient characteristics				
Age				
≤ 35 years	14 (73.7)	66 (86.8)	1 (reference)	0.16
> 35 years	5 (26.3)	10 (13.2)	2.3 (0.5–9.0)	
Marital status				
Married	16 (84.2%)	62 (81.6%)	1 (reference)	0.78
Single	3 (15.8%)	14 (18.4%)	0.83 (0.2–3.2)	
Profession				
Student/housewife	4 (21.0%)	22 (29%)	Ref (1.0)	0.77
Employee	11 (57.9%)	39 (51.3%)	1.5 (0.4–5.4)	
Manager	4 (21.0%)	15 (19.7%)	1.4 (0.3–6.8)	
Gestational age				
< 41 weeks	11 (57.9%)	64 (84.2%)	Ref (1.0)	0.01
≥ 41 weeks	8 (42.1%)	12 (15.8%)	3.8 (1.1–13.1)	
Gravidy				
G1	6 (31.6%)	31 (40.8%)	Ref (1.0)	0.73
G2	8 (42.1%)	26 (34.2%)	1.5 (0.4–5.1)	
G3 et +	5 (26.3%)	19 (25.0%)	1.3 (0.3–5.0)	
Parity				
P0	9 (47.4%)	53 (69.7%)	Ref (1.0)	0.06
P1 and more	10 (52.6%)	23 (30.3%)	0.3 (0.1–1.2)	
Body Mass Index (kg/m^2)				
Normal (≤ 25)	3 (15.8%)	22 (28.9%)	Ref (1.0)	0.38
Overweight (> 25 to < 30)	9 (47.4%)	29 (38.2%)	2.2 (0.5–9.4)	
Obesity (≥ 30)	7 (36.8%)	25 (32.9%)	2.0 (0.4–8.9)	
Past Caesarean section				
No	17 (89.5%)	74 (97.4%)	Ref (1.0)	0.12
Yes	2 (10.5%)	2 (2.6%)	4.3 (0.2–62.6)	
Past lumbar disease				
No	18 (94.7%)	71 (93.4%)	Ref (1.0)	0.83
yes	1 (5.3%)	5 (6.6%)	0.7 (0.1–7.7)	
Procedure related factors				
Type Neuraxial anaesthesia				
CSE	16 (84.2%)	64 (84%)	Ref (1.0)	0.96
Spinal	1 (5.3%)	5 (6.6%)	0.7 (0.1–7.2)	
Epidural	2 (10.5%)	7 (9.2%)	1.1 (0.2–5.9)	
Day of procedure				
Week days (Monday–Friday)	16 (84.2%)	57 (75.0%)	Ref (1.0)	0.39
Week end (Saturday–Sunday)	3 (15.8%)	19 (25.0%)	0.5 (0.1–2.3)	
Timing of procedure				
Day (7–19 h)	9 (47.4)	32 (42.1)	Ref (1.0)	0.43
Night (19–24 h)	6 (31.6)	17 (22.4)	1.2 (0.3–4.1)	
Late night (0–7 h)	4 (21.1)	27 (35.5)	0.5 (0.1–1.9)	
Level of regional procedure*				
L3L4	13 (68.4%)	53 (75.7%)	Ref (1.0)	0.55
L4L5	5 (26.3%)	11 (15.7%)	1.8 (0.5–6.2)	
L2L3	1 (5.2%)	6 (8.6%)	0.6 (0.1–6.1)	
Late anaesthetic procedure (dilation > 5 cm)				
No	12 (63.2%)	71 (93.4%)	Ref (1.0)	< 0.001
Yes	7 (36.8%)	5 (6.6%)	8.2 (1.8–37.9)	

Table 2 (Continued)

Risk factors	Cases N = 19 (%)	Controls N = 76 (%)	OR (95% CI)	P value
Paraesthesia during procedure				
No	15 (83.3%)	52 (88.1%)	Ref (1.0)	0.59
yes	3 (16.7%)	7 (11.9%)	1.4 (0.2–7.5)	
Repeated procedure				
No	11 (57.9%)	51 (67.1%)	Ref (1.0)	0.04
Yes	8 (42.1%)	25 (32.9%)	2.8 (1.0–7.8)	
Level of training				
Registrar	8 (44.4%)	45 (65.2%)	Ref (1.0)	0.25
Senior registrar	3 (16.7%)	9 (13.0%)	1.8 (0.4–8.4)	
Consultant	7 (38.9%)	15 (21.7%)	2.6 (0.8–8.4)	
Obstetrical related factors				
Stage 1 duration (min)	277 (34.7)†	261 (18.8)†		0.83
Stage 2 duration (min)	50 (7.5)†	39 (4.4)†		0.12
Type of labour				
Spontaneous	8 (42.1%)	37 (48.7%)	Ref (1.00)	0.77
Induced	5 (26.3%)	21 (27.6%)	1.1 (0.3–3.8)	
Mixed (initially spontaneous followed by augmented contractions)	6 (31.6%)	18 (23.7%)	1.5 (0.4–5.1)	
Forceps delivery				
No	15 (78.9%)	74 (97.3%)	Ref (1.0)	0.01
Yes	4 (21.1%)	2 (2.6%)	9.8 (1.2–114.1)	
Vacuum delivery				
No	16 (84.2%)	63 (82.9%)	Ref (1.0)	0.89
Yes	3 (15.8%)	13 (17.1%)	0.9 (0.1–3.9)	
Emergency caesarean section				
No	17 (89.3%)	65 (85.5%)	Ref (1.0)	0.65
Yes	2 (10.5%)	11 (14.5%)	0.6 (0.1–3.6)	
Episiotomy				
No	16 (84.2%)	65 (86.5%)		0.88
Yes	3 (15.8%)	11 (14.5%)	1.1 (0.1–4.9)	
Perineal tears (stage 1–4)				
No	8 (42.1%)	29 (38.2%)		0.75
Yes	11 (57.9%)	47 (61.84%)	0.8 (0.2–2.7)	
Newborn Birth weight (kg)				
≤ 3.5	4 (21.1%)	49 (64.5%)	Ref (1.0)	0.01
> 3.5	15 (78.9%)	27 (35.5%)	6.8 (2.0–22.5)	

*Clinically estimated intervertebral space. †Mean (SD).

et al.[13] who found an incidence of 9.2‰ of complications.

Our study confirmed, as already published in the obstetrical literature,[13,14,18–20] that the use of forceps can increase the risk of peripheral nerve damages in patient. However, as we combined results from formal examinations by a neurologist (incl. ENMG, MRI, CT scan) with statistical analysis of contributing factors associated with peripheral nerve injuries, we managed to also identify the possible contribution of anaesthesia to these injuries. More specifically, we found that four patients had a high likelihood of an injury caused by the catheter or Tuohy needle at nerve root level and that anaesthesia-related factors such as repeated Tuohy needle punctures and neuraxial procedures performed at cervical dilation of 5 cm and above were significantly associated with peripheral nerve injuries. In three of four of these patients with a high

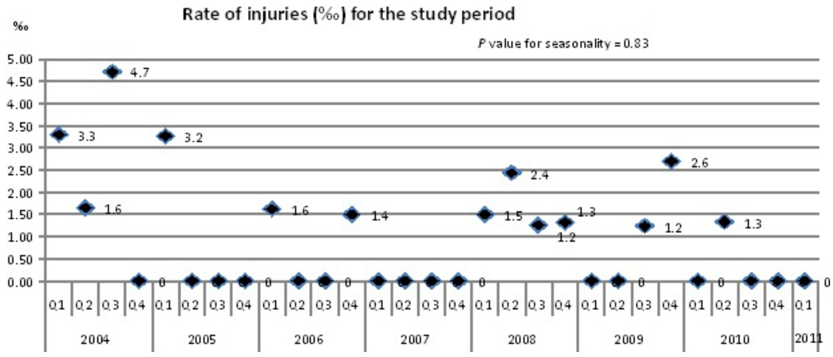

Fig. 2. Rate of injuries (‰) following neuraxial procedures by quartiles of years (whole study period).

suspicion of injury caused by the Tuohy needle, the procedure was performed with a cervical dilation ≥ 5 cm. All these patients had a difficult anaesthetic procedure with either severe pain at injection or paraesthesia or several attempts for catheter insertion.

Several hypotheses may explain this latter finding. First, a procedure performed at cervical dilation of 5 cm or above may be a surrogate marker of a high birth weight and/or dystocic presentation. In such cases, patients may start the delivery process without analgesia but later on, as labour progress stops, ocytocine infusion to augment contractions may be required. This results in increased pain. Epidural/spinal analgesia may therefore be needed and this, at a more advanced stage of labour (cervical dilatation 5 cm or above). Thus, a late procedure may actually be a confounding factor for a dystosic presentation or high birth weight, two typical obstetrics related factors. A more likely explanation is that neuraxial procedures performed late during the labour process are often more difficult. Patients often have painful contractions that have lasted for many hours before the anaesthetist is called. As a result, patients are often more agitated and may have difficulties in maintaining the position required for neuraxial analgesia. This increases the risk of repeated punctures and spinal nerve roots injuries by needle or catheter puncture.

While late compared with early initiation of epidural analgesia for labour has already been analysed in a large meta-analysis[30] and was not found to make a difference for both patients and neonates, authors did not specifically address the issue of neurological complications.

We also observed that most neurological injuries had a spontaneous resolution within 3 months following the initial trauma. This is in line with the study by Wong et al.[13] showing that most lower extremity motor and sensory dysfunction spontaneously resolve within 3–6 months.

However in some patients, symptoms may persist and be associated with neuropathic pain.

In such cases, to relieve symptoms, treatment by tricyclic antidepressants or gabapentin may be required. When patients develop lower extremities weaknesses, physiotherapy, foot splints or walking braces should be considered. In all cases, when an injury is suspected in the post-partum period, careful examination by a senior anaesthetist should be performed as quickly as possible. If a space occupying lesion is suspected (cauda equina syndrome, saddle numbness, bilateral lower limb motor dysfunction) an emergency CT scan or MRI should be performed. Patients should be rapidly referred to a neurosurgeon or an orthopaedic surgeon.

In other cases, referral to a neurologist and additional investigations such as electroneuromyography, evoked potentials and MRI should be considered. This will contribute to the identification of location and severity of the injury and help to provide adequate support to the patient.[10,32]

A number of limitations of this study should be considered. First, this was a single centre study and our findings may lack generalisability. Our results are however in line with existing literature on peripheral nerve injuries in obstetrics suggesting reproducibility of our findings.

Second, as we performed a retrospective case–control study using existing data, we could not analyse potentially relevant variables that had not been collected. These include foetal presentation, position during childbirth, staff fatigue, light, noise in labour rooms and some other working conditions-related factors. However, we still managed to analyse some human-related factors such as week end procedures, seasonal variations and seniority of the anaesthetist in charge. None of these factors appeared to be associated with an increased risk of injuries. Nevertheless due to the small number of cases identified in our study, a type 2 error cannot be excluded.

Third, as we based our case definition on patients who were formally referred to a neurologist and had additional testing (ENMG, MRI, CT scan) to confirm a nerve injury, we may have missed a number of cases where injuries were present but were not identified because no referral to a hospital-based neurologist was performed. This may be the case for benign conditions such as injuries to the lateral femoral cutaneous nerve. This is the most common peripartum neuropathy but it is often benign, self-limited and as a consequence, patients are rarely referred to a neurologist.[33] As a result, this has probably contributed to reduce the incidence of peripheral nerve injuries observed in our study. At the same time, the strict definition used in our study reinforces case definition and enhances internal validity of the case–control study design. Fourth, as we assessed association of peripheral injuries with anaesthesia care using a retrospective assessment of clinical charts, some level of uncertainty persists as to the real contribution of anaesthesia. However to limit this weakness, we used a wide range of data sources including neurologist and anaesthetists annotations as well as formal results of ENMG and MRI exams. We classified information and possible causes of injuries following a formal consensus process. Finally, we also extracted cases and controls from a large series of 19,840 patients and performed a formal analysis that confirmed the contribution of a number of non-obstetrical factors.

Finally, because spinal nerve roots, lumbosacral plexus and peripheral lower extremities nerve injuries during childbirth remain rare complications in obstetrics, we managed to identify only 19 patients with this injury over a 7-year observation period. This resulted in large confidence intervals and a strong risk of type 2 errors in the univariate analyses. This is why we used exact tests (Fisher's test) and time series in these univariate analyses. Nevertheless, due to the small size of the case–control study sample, the overall statistical analysis remains largely exploratory and aims more at generating hypotheses than providing definitive conclusions. Furthermore, as a number of patients were lost to follow-up and ~20% of the parturients did not receive any neuraxial analgesia, the frequency of neurological complication in this group is not known. The calculated incidence of peripheral nerve injuries has to be interpreted with caution.

Despite these limitations, our findings show that altogether patient, anaesthesia and obstetric-related factors are associated with lower limb motor and sensory dysfunction following neuraxial labour analgesia. These results remind us that obstetrics is not the only cause of peripheral nerve injuries during labour and delivery. While neuraxial anaesthesia for labour is a very safe technique, the risk of peripheral nerve deficiencies following injuries by Tuohy needle or catheter insertion at root nerve level should not be minimised, particularly as symptoms can persist for long periods of time (from 6 weeks up to 1 year).[34]

To our knowledge, this is the first study to provide incidence and risk of post-partum lower extremity motor and sensory dysfunction associated with anaesthesia care based on a systematic and formal assessment of cases by a neurologist and supported by conclusions of additional statistical analysis (case–control study design). Future research should look at designing studies that increase the amount of data collected and have the statistical power to identify a wider range of risk factors associated to these injuries. This would contribute to the development of predictive models of neurological injuries and preventive measures that limit their occurrence.

Conclusion

While post-partum lower extremity motor and sensory dysfunctions following labour and delivery occurs extremely rarely and is typically self-limited, their impact on patients' life and wellbeing is important. Our study findings suggest that altogether obstetrics, patients and anaesthesia-related factors are associated with these dysfunctions.

Authors' contributions

F. G., G. H., G. S., I. P.: Study protocol and design, data collection.

G. H., G. S.: Data cross checking, chart review.

G. H., I. P.: Statistical analysis and data interpretation.

F. G., G. H., G. S., I. P.: Manuscript preparation.

F. G., G. H., G. S., I. P.: Manuscript revision.

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