



Cornthwaite, K., Draycott, T., Bahl, R., Hotton, E., Winter, C., & Lenguerrand, E. (2021). Impacted fetal head: A retrospective cohort study of emergency caesarean section. *European Journal of Obstetrics and Gynecology and Reproductive Biology*, 261, 85-91. <https://doi.org/10.1016/j.ejogrb.2021.04.021>

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[10.1016/j.ejogrb.2021.04.021](https://doi.org/10.1016/j.ejogrb.2021.04.021)

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Impacted fetal head: a retrospective cohort study of emergency caesarean section

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Abstract

Objective

To investigate risk factors, management and outcomes of impacted fetal head (IFH) at caesarean section (CS).

Study design

This is a retrospective cohort study of all women with singleton, cephalic pregnancies who had an emergency CS during one-year (2016) at North Bristol NHS Trust, UK (n=838).

The incidence of caesarean section at full dilatation (CSFD) and IFH were calculated using the annual birth rate. To identify risk factors for IFH, maternal, perinatal and intrapartum characteristics were compared according to the presence or absence of IFH, and separately for first- and second-stage CS. Techniques employed to disimpact the fetal head were described. Univariable and multivariable comparisons of maternal and perinatal outcomes were made between cases with and without an IFH. Characteristics and outcomes were compared using modified Poisson regression.

Results

CSFD accounted for 2.1% of all births. IFH complicated 1.5% of all births (11.3% of emergency CS), with 55.8% occurring prior to full cervical dilatation.

Increased rates of IFH at CS were associated with: oxytocin augmentation (RR=2.47 [1.61-3.80]), full cervical dilatation (RR=4.24 [2.96-6.07]), mid/low station (RR=4.14 [2.72-6.32]), moulding (RR=4.39 [2.55-7.54]) and caput (RR=6.60 [3.09-14.10]).

Junior operators documented IFH more than consultants (RR=9.61 [1.35-68.2]).

The strategies recorded for managing IFH included: tocolysis, reverse breech extraction and vaginal push up (33.7%, 14.7% and 11.6% cases respectively) with two or more techniques used in 21.1% cases.

IFH at CS was independently associated with an increased risk of uterine extensions (RR=3.09 [1.96-4.87]) and a composite adverse perinatal outcome (RR=1.66 [1.21-2.28]).

Conclusions

IFH is a common and heterogeneous complication associated with increased complications for both mother and baby, independent of those of CSFD.

Obstetricians must remain vigilant to the possibility of IFH at *all* emergency CS, particularly those at full cervical dilatation or with evidence of obstructed labour.

There is an urgent need for a standardised management algorithm and training in evidence-based disimpaction techniques.

Keywords

Impacted fetal head, caesarean section, cohort

1. Introduction

Impacted fetal head (IFH) at caesarean section (CS) is a complex, technically challenging obstetric emergency associated with significant risks to mother and baby. A recent single-centre, Scottish, audit reported that one in five emergency CS involved difficulty delivering a fetal head[1]. Furthermore, there has been a sharp increase in reports of perinatal brain injury associated with IFH, with escalating litigation[2] as well as Coronial enquiries in the UK[3,4] and internationally[5].

IFH is commonly considered to be a problem of CS at full cervical dilatation (CSFD)[6,7]. The apparent rise in IFH complications may be explained by a decline in assisted vaginal birth expertise[8] and rising incidence of CSFD[9–12]. In Ireland, there has been a reported 35% increase in CSFD[11]. However, the current UK incidence of CSFD is unclear and IFH can also occur in CS performed in the first-stage of labour[1,13] [14]. Moreover, to date, most studies investigating IFH have been restricted to CSFD[7,14–16]. It is therefore difficult to separate the risks related to IFH from the general risks of CSFD[15–18]. IFH remains a nebulous and poorly understood condition.

A range of strategies have been reported to manage an IFH, including tocolysis[19], vaginal push up[20] and reverse breech extraction[13,21]. However, there is no consensus on the safest and/or most effective strategy. Furthermore, most research into IFH has been conducted in low- and middle-income settings that may not reflect current practice or training in more developed settings, such as the UK.

We investigated the incidence, risk factors, management and outcomes of IFH in a cohort of all emergency CS, in a tertiary-level NHS maternity unit.

2. Materials and Methods

2.1. Study design

Retrospective cohort study of all women who had an emergency CS during one-year (01/01/16 - 31/12/16) at North Bristol NHS Trust. It is an observational, descriptive study of anonymised data.

2.2. Study population

Emergency CS was defined as category 1, 2 or 3 caesarean birth[22]. Cases were restricted to women with live, singleton pregnancies with cephalic presentation.

2.3. Data collection

Data variables were information routinely collected as part of clinical care.

Emergency CS cases were identified using maternity databases. Midwives and obstetricians reviewed electronic and hand-held notes, documenting information on customised, anonymous, data collection forms.

Individual operation records were reviewed to identify cases of IFH at CS. There is no formal definition for IFH in clinical use. For this study, IFH was defined where “impacted fetal head”, “deeply engaged fetal head” or “difficult delivery of head” was documented in the CS operation record and/or recognised additional techniques were used to deliver the baby[14]. Additional techniques included all methods listed in the literature for IFH: lowering of operating table / use of step, change of hand,

change of operator, tocolysis (GTN / Terbutaline / Salbutamol), vaginal push up, reverse breech extraction, Patwardhan method, or T/J incision to facilitate delivery. Fetal pillow was not used in the index unit.

2.4. Outcomes of interest

Maternal characteristics included age, ethnicity, BMI, smoking, parity, previous CS and diabetes. Perinatal factors included scan evidence of macrosomia (defined as estimated fetal weight >95th centile at final growth scan[23]), gestational age at birth (completed weeks), gender and birthweight (kg). Intrapartum characteristics included epidural, induction of labour (IOL), oxytocin use (indication, duration, maximum cumulative dose), duration of first-stage and second stage (if CSFD), cervical dilatation, fetal position, station, presence of moulding / caput, CS category, CS indication, attempted assisted vaginal birth (AVB), seniority of primary operator and consultant presence.

The number and type of techniques recorded to assist delivery of the IFH were collected. Maternal and perinatal outcomes were: post-partum haemorrhage >1 litre, blood transfusion, uterine extension, visceral injury (including injury to ureter, bladder or cervix), hysterectomy, operative time >1 hour, infection (including wound infection, endometritis, urinary tract infection and need for postnatal intravenous antibiotics), length of stay, readmission to hospital (within 14 days), intensive care unit (ICU) admission and death. Perinatal outcomes were low Apgar score (<7 at 5 minutes), low cord pH (<7.1), birth trauma (including intracranial haemorrhage, skull fracture, other bony fracture, peripheral nerve injury, facial injury, spinal cord injury and unspecified birth trauma), neonatal intensive care unit (NICU) admission, hypoxic

ischaemic encephalopathy (HIE grade 1, 2 and 3), perinatal death and a composite adverse perinatal outcome consisting of low Apgar score, low pH, birth trauma, HIE or perinatal death.

2.5. Statistical analysis

Incidence rates for IFH and second-stage CS were derived using the annual birth rate and total number of emergency CS at North Bristol NHS Trust in 2016 as the denominators. Descriptive data are presented as frequencies and proportions, or mean and median with respective standard deviation or interquartile range, according to data distribution.

2.5.1. Risk factors

Comparisons were made between maternal, perinatal and intrapartum characteristics of cases with and without an IFH during all emergency CS, and separately for first- and second-stage CS. Results, derived from modified Poisson regression, are reported as relative risks (RRs) and 95% Confidence Intervals (CIs)[24].

2.5.2. Management

Strategies used to manage an IFH are reported as frequencies and proportions. Pearson's Chi-squared or Fisher's exact tests (where expected frequencies were <5) were performed to compare strategies according to stage of labour.

2.5.3. Outcomes

Univariable and multivariable comparisons of maternal and perinatal outcomes were made using modified Poisson regression, according to the presence or absence of IFH. Confounding factors were included in the multivariable model if biologically plausible. Covariates included maternal age, BMI, smoking, parity, diabetes, gestational age and full dilatation. Results are reported as RRs and 95% CIs.

2.5.4. Subgroup analysis within IFH group

Further analyses compared characteristics and outcomes according to whether additional techniques were employed at CS to deliver the IFH. Comparisons were made using Pearson's Chi-squared or Fisher's exact tests.

Analyses were performed using Stata version 14.2.

2.6. Ethical approval

Data were collected with full regulatory approvals (REC reference 18/HRA/0004; 19/05/2017). The study is exempt from full ethical review since the research is limited to secondary use of information previously collected in the course of normal care, data were anonymised and clinical management was not affected by inclusion in the study.

3. Results

In 2016, 838 women underwent an emergency CS out of 6,332 births at North Bristol NHS Trust. Of those, 132 were CSFD (2.1% of all births and 15.8% of all emergency CS). There were 95 cases of IFH (1.5% of all births and 11.3% of all emergency CS), 55.8% (n=53) of which occurred prior to full cervical dilatation (Figure 1).

3.1. Population characteristics

Maternal, perinatal and intrapartum characteristics were similar to national averages for women undergoing emergency CS (supplementary Table S1).

3.2. Risk factors (Table 1)

3.2.1. Maternal and perinatal

Primiparity (RR=1.60 [1.03-2.51]) conferred an increased risk of IFH at CS, whilst previous CS (RR=0.52 [0.29-0.96]), and low birthweight (RR=0.22 [0.05-0.86]) were associated with reduced risk. In the separate groups of CS prior to and at full cervical dilatation, the only significant factor was the protective effect of preterm birth for first-stage CS (RR=0.13 [0.02-0.92]).

3.2.2. Labour and delivery

IFH was encountered in emergency CS performed at cervical dilatations ranging from <2cm to 10cm; the risk increased with advancing cervical dilatation (Figure 2). Augmentation with oxytocin was associated with an increased risk of IFH (RR=1.60 [1.03-2.51]), although the risk was not affected by the dose nor duration of oxytocin. Mean duration of labour was similar between groups (first-stage: IFH: 8.1hr (SD 4.5); No IFH: 7.0hr (SD 5.0); second-stage: IFH: 2.2hr (SD 1.3); No IFH: 2.1hr (SD 1.3)). IFH was more likely in those with failure to progress (RR=2.29 [1.41-3.73]). Epidural analgesia (RR=1.49 [1.02-2.17]), mid/low station (RR=4.14 [2.72-6.32]) and presence of caput (RR=6.60 [3.09-14.10]) and moulding (RR=4.39 [2.55 – 7.54]) all increased risk of IFH. Full cervical dilatation significantly increased the risk of IFH

(RR=4.24 [2.96-6.07]), with 31.8% of second-stage CS reporting an IFH (42/132) compared with 7.5% of first-stage CS (53/706).

Trends remained similar in the separate group of first-stage CS: augmentation with oxytocin (RR=2.67 [1.56-4.58]), mid/low station (RR=3.16 [1.79-5.60]) and features of obstructed labour (moulding (RR=5.10 [2.37-10.99]), caput (RR=7.27 [2.62-20.15]), and failure to progress (RR=2.45 [1.40-4.30])), were all associated with an increased risk of IFH. IFH was also more likely with occipito-posterior (OP) position, compared with occipito-anterior (OA) position (RR=4.01 [1.23-13.11]).

For second-stage CS, augmentation with oxytocin (RR=1.64 [1.00-2.69]), mid/low cavity station (RR=3.75 [1.24-11.36]) and failed AVB (RR=2.19 [1.05-4.57]) increased the risk of IFH. However, difficulties delivering the fetal head were less likely with OP position than OA (RR=0.04 [0.30-0.98]).

3.3. *Management* (Table 2)

In 44.2% of cases (42/95), IFH was clearly documented although no additional disimpaction techniques were recorded in the operation note. Additional techniques were less likely to be employed in first-stage CS (52.8% vs 59.5%, $p < 0.001$). Of the 53 cases that required additional techniques to deliver the IFH, 62.3% (33/53) were resolved with 1 technique, 17.0% (9/53) with 2 techniques and 11 cases (20.8%) required 3 or more techniques.

Compared with consultant obstetricians, the risk of IFH for senior house officers (ST1-2) and junior registrars (ST3-5) were RR=8.61 [1.17-63.4] and RR=8.16 [1.14-

58.5] respectively (Table 1). Tocolysis was the most commonly used strategy (33.7% of cases) with sublingual glyceryl trinitrate (GTN) most frequently used (82.1%). In >20% of cases, delivery was taken over by a more senior operator. Overall, reverse breech extraction was performed more than a vaginal push up (14.7% vs 11.6%). However, vaginal push up was performed more often in CSFD than in first-stage CS (21.4% vs 3.8%, $p=0.01$).

3.4. Outcomes (Table 3)

3.4.1. Maternal

There was strong evidence of an increased risk of uterine extensions (adjusted RR=3.52 [2.36-5.26]) and operative time >1 hour (adjusted RR 1.58 [1.19-2.09]).

3.4.2. Perinatal

Infants with IFH at CS were more likely to be admitted to NICU (adjusted RR=1.81 [1.22-2.69]) and have a cord pH <7.1 (adjusted RR=1.91 [1.21-3.02]). The risk of birth trauma, HIE and perinatal death was low in both groups, but the risk of a composite adverse perinatal outcome was higher amongst infants with an IFH (adjusted RR=1.66 [1.21-2.28]).

3.5. Subgroup analysis (supplementary table S2)

Cases of IFH where additional techniques were used had an increased risk of admission to NICU (34.0%) compared with those where IFH was only documented (14.3%; $p=0.03$). There was no significant difference in all other characteristics and outcomes.

4. Discussion

This study highlights that IFH is a frequently encountered, heterogeneous condition, as common in CS prior to, as at full cervical dilatation. Low fetal station and signs of obstructed labour were associated with an increased risk of IFH during first- and second-stage CS. Junior obstetricians were more likely to record an IFH. Finally, this study confirms that complications such as uterine extensions, fetal hypoxia and NICU admission are independently increased by IFH.

4.1. Strengths and limitations

This is the largest study, to date, investigating the incidence of IFH at CS and the first to undertake detailed analysis of associated risk factors, management and outcomes. The study was undertaken in a nationally-representative maternity unit with good success rates (80-90%) in rotational AVB[25] and consultant supervision. Findings are likely to be generalisable to other UK maternity units. Rigorous data collection, reviewing individual records for every case, minimised missing data and ensured accuracy of data obtained. Missing variables were mostly from CS performed at less than 4cm dilatation, where IFH was less common, minimising the impact. Data collection was comprehensive allowing investigation of a wide-range of potential predictors and multivariable adjustment for outcomes. Separate analyses were performed for IFH prior to, and at full cervical dilatation, to differentiate risk factors according to stage of labour.

We defined IFH a priori, as those where IFH was documented and/or additional disimpaction strategies were recorded. We performed a sub-group analysis that demonstrated, with the exception of NICU admission, that characteristics and

outcomes did not differ between cases where IFH was documented only versus those requiring additional techniques. Therefore, we consider our definition robust.

We acknowledge that, whilst techniques such as vaginal push up and reverse breech extraction are likely to be documented, other strategies such as change of hand may be less reliably recorded. This may have led to underestimation of IFH incidence, particularly amongst more senior operators who might have more success disimpacting the fetal head with simple manoeuvres. Finally, our sample size did not allow accurate comparison of rare outcomes particularly hysterectomy, visceral injury, severe birth trauma and perinatal death.

4.2. Incidence

Injuries relating to IFH have noticeably increased nationally[3,4] and internationally[5]; IFH was identified as a contributory factor in 9% of cases in the recently published NHS Resolution Early Notification Scheme cohort[2]. Our results are equivalent to a recent single-centre audit that estimated the rate of CSFD as 1.9%[1]. However, over half the cases of IFH in our study occurred in CS prior to full dilatation.

4.3. Risk factors

Although full cervical dilatation was a significant risk factor for IFH, only a third of cases of second-stage CS were complicated by IFH. Therefore, studies using full dilatation as a surrogate for IFH may overestimate the benefits of any intervention[26,27]. Failed AVB, malposition in first-stage and signs of obstructed labour, increased the risk of IFH, independently from full cervical dilatation.

We identified a significant association between IFH and oxytocin augmentation (independent of dose and duration), but not induction of labour. Oxytocin augmentation is used for slow progress of labour, which itself could be an early sign of obstructed labour[28].

4.4. Management

This study suggests that junior operators are more likely to record IFH than consultants. Existing research indicates low rates of evidence-based training for IFH and widespread use of the push method amongst UK practitioners[1,14]. A variety of strategies were employed to manage IFH in this cohort particularly reverse breech extraction; this variation may result from the lack of national direction and management guidance.

Most studies investigating techniques for IFH restrict cases to women with cervical dilatations $\geq 7\text{cm}$ [21,29,30]. However, a fifth of IFH cases in this cohort occurred with cervical dilatations $< 7\text{cm}$. Therefore, future research should include data from all emergency CS.

4.5. Outcomes

This is the first study to separate the risks of IFH from those of second-stage CS. Manoeuvres employed to disimpact the fetal head may increase the risk of uterine extensions, leading to longer operative times. IFH was associated with an increased risk of fetal hypoxia and NICU admission. However, rates of birth trauma, HIE and perinatal death were low. Accordingly, large sample sizes may be required for any

randomised trials to assess the safety of management strategies if powered primarily for perinatal outcomes.

5. Conclusion

Obstetricians must be vigilant as to the possibility of IFH in *all* emergency CS and prepared to use more than one strategy to disimpact the fetal head, if required.

Large population studies are warranted to collect data and develop predictive models for IFH at CS. Although IFH appears to be almost as common as shoulder dystocia, there is no standardised management algorithm nor evidence-based training.

Improving IFH management through practical training is likely to be the most effective method of reducing the associated morbidity.

Funding

North Bristol NHS Trust Springboard grant and David Telling Charitable Fellowship.

Researchers worked independently from the funder. There was no involvement of the funder nor the sponsor in the study design, data collection, analysis, writing of report or decision to publish.

Conflict of interest

None.

Acknowledgements

The authors would like to thank all those involved in data collection, with particular thanks to Sophie Renwick, Hadi Waheed, Stephanie Brammeld, Alessia Bulfone, and Sally Hall.

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Figures and Tables

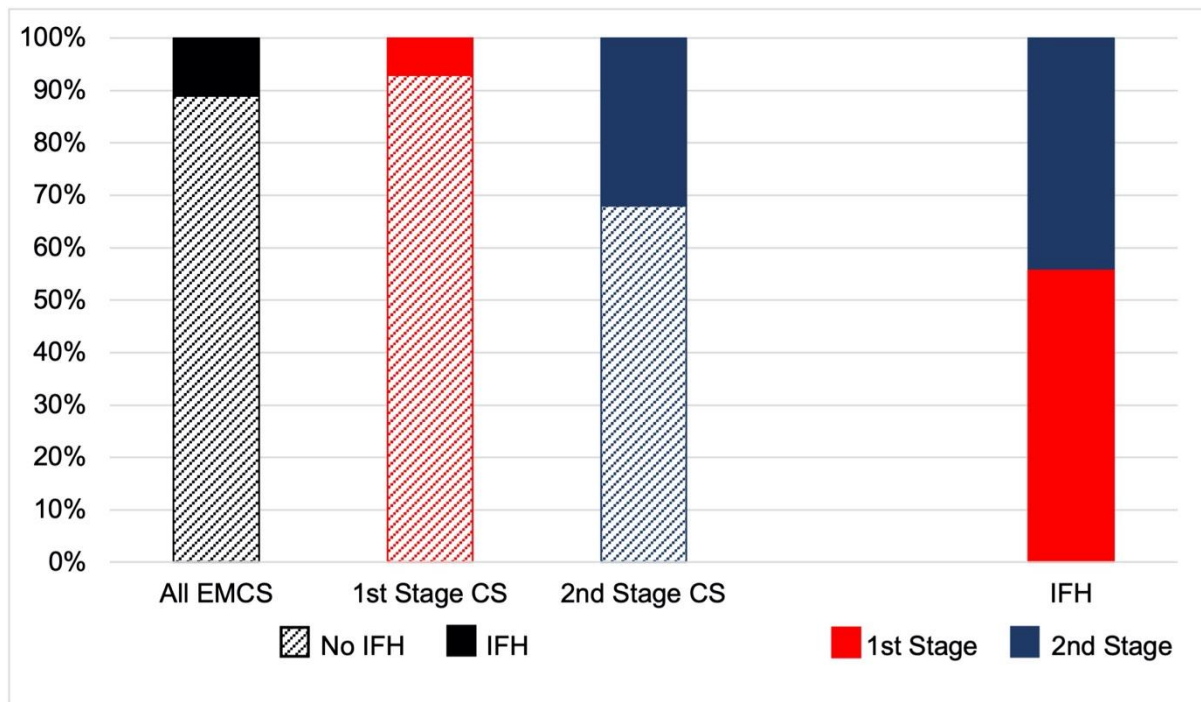


Figure 1 Risk of impacted fetal head at caesarean section

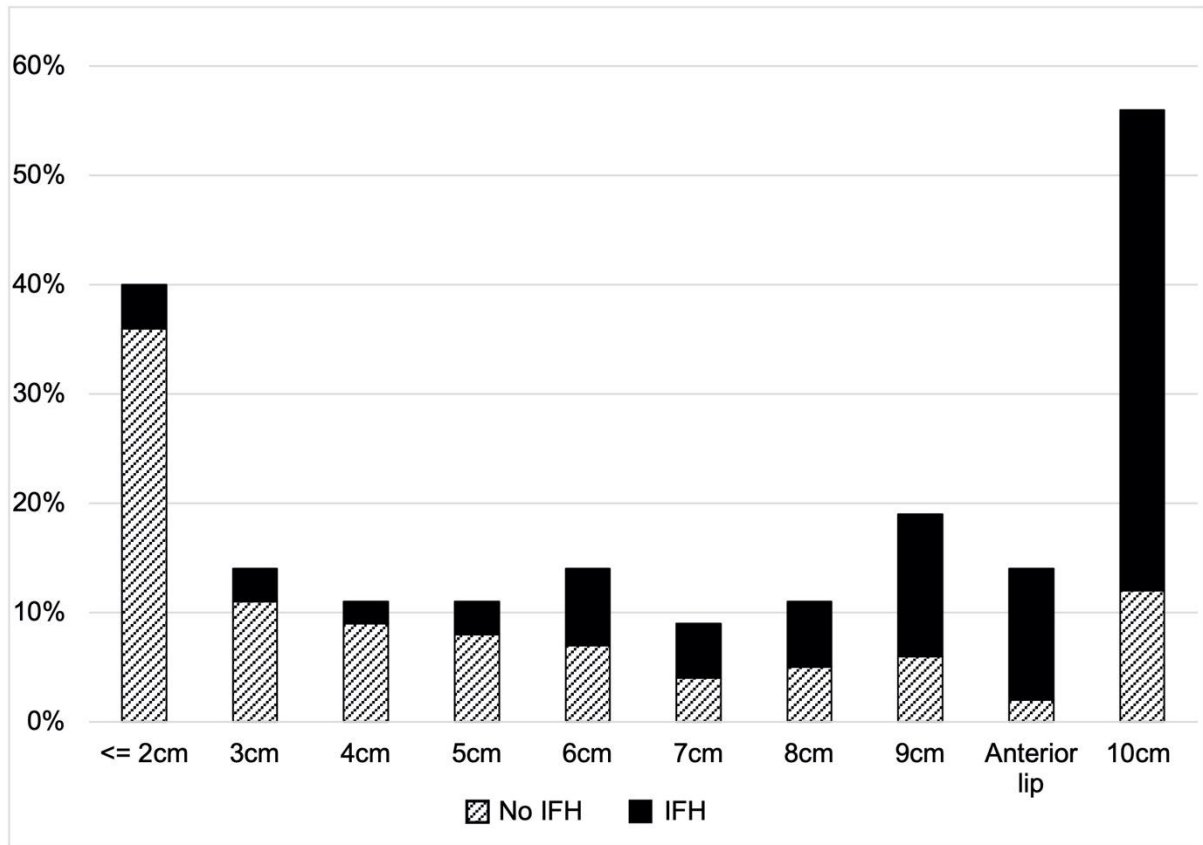


Figure 2 Risk of impacted fetal head according to cervical dilatation

Table 1 Maternal, perinatal, labour and delivery characteristics in relation to the presence or absence of impacted fetal head at caesarean section, and according to stage of labour

	All CS			CS prior to full dilatation			CS at full dilatation		
	IFH (n=95)	No IFH (n=743)	RR (95% CI)	IFH (n=53)	No IFH (n=653)	RR (95% CI)	IFH (n=42)	No IFH (n=90)	RR (95% CI)
Maternal & perinatal									
Primiparous	72 (75.8)	482 (64.9)	1.60 (1.03 – 2.51)*	37 (69.8)	418 (64.0)	1.28 (0.73 – 2.25)	35 (83.3)	64 (71.1)	1.7 (0.82 – 3.40)
Previous CS	11 (11.6)	156 (21.0)	0.52 (0.29 – 0.96)*	7 (13.2)	143 (21.9)	0.56 (0.26 – 1.22)	4 (9.5)	13 (14.4)	0.71 (0.29 – 1.75)
Maternal diabetes	2 (2.1)	55 (7.4)	0.30 (0.07 – 1.17)	1 (1.9)	50 (7.7)	0.25 (0.04 – 1.78)	1 (2.4)	5 (5.6)	0.51 (0.08 – 3.12)
Gestational age <37 weeks	1 (1.1)	92 (12.4)	0.08 (0.01 – 0.60)*	1 (1.9)	91 (13.9)	0.13 (0.02 – 0.92)*	0 (0.0)	1 (1.1)	-
Birthweight <2.5kg	2 (2.1)	74 (10.0)	0.22 (0.05 – 0.86)*	2 (3.8)	74 (11.3)	0.33 (0.08 – 1.31)	0 (0.0)	0 (0.0)	-
Birthweight >4kg	24 (25.3)	131 (17.6)	1.49 (0.97 – 2.29)	13 (24.5)	115 (17.6)	1.47 (0.81 – 2.66)	11 (26.2)	16 (17.8)	1.38 (0.80 – 2.38)
Labour									
Duration									
First-stage (hr), mean (SD)	8.1 (4.5)	7.0 (5.0)	-	-	-	-	-	-	-
Second-stage (hr), mean (SD)	2.2 (1.3)	2.1 (1.3)							
Epidural analgesia	45 (47.4)	271 (36.5)	1.49 (1.02 – 2.17)*	24 (45.3)	224 (34.3)	1.53 (0.91 – 2.57)	21 (50.0)	47 (52.2)	0.94 (0.57 – 1.55)
Induced labour	39 (41.1)	376 (50.6)	0.70 (0.48 – 1.03)	21 (39.6)	338 (51.8)	0.63 (0.37 – 1.07)	18 (42.9)	38 (42.2)	1.00 (0.61 – 1.67)
Augmentation with oxytocin ^a	33 (34.7)	109 (14.7)	2.47 (1.61 – 3.80)**	17 (32.1)	89 (13.6)	2.67 (1.56 – 4.58)**	16 (38.1)	20 (22.2)	1.64 (1.00 – 2.69)*
Second stage CS	42 (44.2)	90 (12.1)	4.24 (2.96 – 6.07)**	-	-	-	-	-	-
Position									
OA	17 (17.9)	96 (12.9)	Ref	3 (5.7)	80 (12.3)	Ref	14 (33.3)	16 (17.8)	-
OT	26 (27.4)	139 (18.7)	1.05 (0.60 – 1.84)	14 (26.4)	115 (17.6)	3.00 (0.89 – 10.15)	12 (28.6)	24 (26.7)	0.71 (0.39 – 1.30)
OP	35 (36.8)	162 (21.8)	1.18 (0.69 – 2.01)	20 (37.7)	118 (18.1)	4.01 (1.23 – 13.11)*	15 (35.7)	44 (48.9)	0.04 (0.30 – 0.98)*
Face	0 (0.0)	5 (0.7)	-	0 (0.0)	4 (0.6)	-	0 (0.0)	1 (1.1)	-
Mid / low cavity station	52 (54.7)	112 (15.1)	4.14 (2.72 – 6.32)**	16 (30.2)	52 (8.0)	3.16 (1.79 – 5.60)**	36 (85.7)	60 (66.6)	3.75 (1.24 – 11.36)**
Moulding	58 (61.1)	187 (25.2)	4.39 (2.55 – 7.54)**	26 (49.1)	132 (20.2)	5.10 (2.37 – 10.99)**	32 (76.2)	55 (61.1)	1.58 (0.78 – 3.20)
Caput	69 (72.6)	255 (34.3)	6.60 (3.09 – 14.10)**	34 (64.2)	194 (29.7)	7.27 (2.62 – 20.15)**	35 (83.3)	61 (67.8)	2.67 (0.90 – 7.94)
Delivery									
CS indication									
Presumed fetal compromise	26 (27.4)	331 (44.6)	Ref	19 (35.9)	298 (45.6)	Ref	7 (16.7)	33 (36.7)	Ref
Failure to progress	32 (33.7)	160 (21.5)	2.29 (1.41 – 3.73)**	26 (49.0)	151 (23.1)	2.45 (1.40 – 4.30)*	6 (14.3)	9 (10.0)	2.29 (0.91 – 5.73)
Failed assisted vaginal birth	28 (29.5)	46 (6.2)	5.20 (3.24 – 8.33)**	-	-	-	28 (66.7)	45 (50.0)	2.19 (1.05 – 4.57)*
Other	9 (9.5)	203 (27.3)	0.58 (0.28 – 1.22)	8 (15.1)	200 (30.6)	0.64 (0.29 – 1.44)	1 (2.4)	3 (3.3)	1.43 (0.23 – 8.93)
Primary operator									
Consultant	1 (1.1)	72 (9.7)	Ref	1 (1.9)	65 (10.0)	Ref	0 (0.0)	7 (7.8)	-
Senior registrar	5 (5.3)	64 (8.6)	5.29 (0.63 – 44.2)	2 (3.8)	52 (8.0)	2.44 (0.23 – 26.28)	3 (7.1)	12 (13.3)	-
Junior registrar	69 (72.6)	455 (61.2)	9.61 (1.35 – 68.2)*	38 (71.7)	397 (60.8)	5.77 (0.80 – 41.34)	31 (73.8)	58 (64.6)	-
SHO	20 (21.1)	138 (18.6)	9.24 (1.26 – 67.6)*	12 (22.6)	126 (19.3)	5.74 (0.76 – 43.27)	8 (19.1)	12 (13.3)	-

Data are number of cases (%). Only characteristics with p-value <0.1 shown. *p-value <0.05, **p-value <0.001. Relative Risk (RR) calculated using modified Poisson regression. Missing cases excluded from inferential tests (n<5 for all variables other than: position (n=358), station (n=308), moulding (n=315), caput (n=297), primary operator (n=14))

^aAugmentation: duration of oxytocin >6hr: IFH: 7 (21.2), No IFH: 30 (27.5), (RR=0.76 [0.36-1.61]); max cumulative dose of oxytocin >20ml: IFH: 7 (21.2), No IFH: 23 (21.2), (RR=1.01 [10.48-2.09])

Table 2 Strategies employed to deliver the impacted fetal head according to stage of caesarean section

	All IFH (n=95)	CS prior to full dilatation (n=53)	CS at full dilatation (n=42)	p-value
No additional technique documented	42 (44.2)	25 (47.2)	17 (40.5)	<0.001
Use of step / lowering of operating table	2 (2.1)	2 (3.8)	0 (0.0)	0.50
Change of hand	9 (9.5)	3 (5.7)	6 (14.3)	0.18
Change of operator	20 (21.1)	14 (26.4)	6 (14.3)	0.15
Tocolysis	28 (33.7)	16 (30.2)	12 (28.6)	0.86
Vaginal push up	11 (11.6)	2 (3.8)	9 (21.4)	0.01
Reverse breech extraction	14 (14.7)	7 (13.2)	7 (16.7)	0.64
T / J incision	8 (8.4)	3 (5.7)	5 (11.9)	0.46
Other	1 (1.1)	1 (1.9)	0 (0.0)	-

Data are number of cases (%). 'Other' = incision inferiorly into lower segment
p-values calculated using Pearson's Chi-squared test or Fisher's exact test where numbers were small.

Table 3 Maternal and perinatal outcomes according to presence or absence of impacted fetal head at caesarean section

	IFH (n=95)	No IFH (n=743)	Unadjusted RR (95% CI)	Adjusted RR (95%CI) ^a
Maternal				
Blood loss >1L	22 (23.2)	113 (15.2)	1.52 (1.02 – 2.28)*	1.35 (0.85 – 2.14)
Blood transfusion	1 (1.1)	11 (1.5)	-	-
Uterine extension	27 (28.4)	60 (8.1)	3.52 (2.36 – 5.26)**	3.09 (1.96 – 4.87)**
Visceral injury	2 (2.1)	2 (0.3)	-	-
Hysterectomy	1 (1.1)	2 (0.3)	-	-
Operative time >1 hour	37 (39.0)	202 (27.2)	1.44 (1.09 – 1.89)*	1.58 (1.19 – 2.09)**
Infection	8 (8.4)	48 (6.5)	1.30 (0.64 – 2.67)	1.94 (0.94 – 3.99)
Return to theatre	0 (0.0)	1 (0.1)	-	-
Length of stay >2 days	47 (49.5)	343 (46.2)	1.07 (0.86 – 1.33)	1.17 (0.92 – 1.48)
Readmission to hospital	9 (9.5)	45 (6.1)	1.59 (0.80 – 3.14)	1.99 (0.99 – 3.99)
ICU admission	0 (0.0)	0 (0.0)	-	-
Death	0 (0.0)	0 (0.0)	-	-
Perinatal				
Low Apgar score	3 (3.2)	28 (3.8)	0.84 (0.26 – 2.71)	1.03 (0.33 – 3.26)
Low cord pH	21 (22.1)	57 (7.7)	2.88 (1.83 – 4.53)**	1.91 (1.21 – 3.02)*
Birth trauma	1 (1.1)	1 (0.1)	-	-
NICU admission	24 (25.3)	147 (19.8)	1.28 (0.88 – 1.86)	1.81 (1.22 – 2.69)*
HIE	1 (1.1)	6 (0.8)	-	-
Perinatal death	0 (0.0)	2 (0.3)	-	-
Composite adverse perinatal outcome	36 (37.9)	186 (25.0)	1.69 (1.15 – 2.49)*	1.66 (1.21 – 2.28)*

Data are number of cases (%). *p-value <0.05, **p-value <0.001.

Unadjusted and adjusted analysis using modified Poisson regression models. ^aAdjusted for maternal age, BMI, smoking, parity, diabetes, gestational age and full dilatation (No IFH as reference). Missing cases excluded from inferential tests (n<5 for all variables other than: operative time > 1 hour (n=34), length of stay > 2 days (n=11), readmission to hospital (n=6))

Supplementary Figure and Tables Captions

Table S1 Demographics of cohort compared with national averages

Table S2 Subgroup analysis of characteristics and outcomes according to whether impacted fetal head was documented only or additional techniques were employed