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Maternal and neonatal outcomes after induction of labor: a population-based study

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Abstract
Purpose To evaluate maternal and neonatal outcomes at and beyond term associated with induction of labor compared to spontaneous onset of labor stratified by week of gestational age.
Methods In this retrospective cohort study, data form 402,960 singleton pregnancies from the Austria Perinatal Registry were used to estimate odds ratios of secondary cesarean delivery, operative vaginal delivery, epidural analgesia, fetal scalp blood testing, episiotomy, 3rd/4th-degree lacerations, retained placenta, 5-min APGAR <7, umbilical artery pH <7.1, and admission to neonatal intensive care unit. Multivariate logistic regression models based on deliveries with gestational age ≥37 + 0 were applied for adjustment for possible confounders.
Results Induction of labor was associated with increased odds for cesarean delivery (adjusted OR; 99% confidence interval: 1.53; 1.45–1.60), operative vaginal delivery (1.21; 1.15–1.27), epidural analgesia (2.12; 2.03–2.22), fetal scalp blood testing (1.40; 1.28–1.52), retained placenta (1.32; 1.22–1.41), 5-min APGAR <7 (1.55; 1.27–1.89), umbilical artery pH <7.1 (1.26; 1.15–1.38), and admission to neonatal intensive care unit (1.41; 1.31–1.51). In a subgroup of induction of labor with the indication, "post-term pregnancy" induction was similarly associated with adverse outcomes.
Conclusions In Austria, induction of labor is associated with increased odds of adverse maternal and neonatal outcomes. However, due to residual confounding, currently, no recommendations for treatment can be derived.

Keywords Cesarean section · Cohort study · Epidural analgesia · Induction of labor · Maternal outcomes · Neonatal outcomes

Introduction

Induction of labor is common in developed countries. In the United States, induction of labor is carried out in 23% of births [1]. In the European Union, rates of labor induction vary widely ranging from 6.8% in Lithuania to 33% in Wallonia, Belgium [2]. While induction rates declined slightly in the United States recently, in Austria, there is a constant increase in induction of labor rates from 17.1% of life births (primary cesareans excluded) in 2008 up to 21.6% in 2014 [3, 4].

Observational studies demonstrated that induction of labor at term is associated with an increased risk of adverse outcomes in particular cesarean sections when compared with spontaneous onset of labor [5–8]. In contrast, randomized controlled trials of induction of labor at full term in uncomplicated singleton gestations resulted in cesarean and operative vaginal delivery rates similar to controls with expectant management [9]. In addition, observational studies comparing "elective" induction with expectant management demonstrated decreased risks of cesarean delivery and

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other maternal and neonatal morbidities after induction of labor [10, 11]. These conflicting findings in observational studies might reflect various factors influencing the practice of induction and its outcomes. Potential factors include differences in study population characteristics and size, practice preferences, hospital culture, changes in guidelines or clinical practice, differences in national guidelines, and different study designs [12–16].

No current observational studies on obstetric outcomes of induction of labor from german-speaking countries have been performed. Here, we report maternal and neonatal outcomes after induction of labor at and beyond term based on data form the Austria Perinatal Registry 2008–2014.

Materials and methods

This is a retrospective cohort study involving all term and post-term (gestational age ≥37 + 0) singleton hospital deliveries, which occurred in Austria between January 1, 2008 and December 31, 2014. After exclusion of primary cesarean deliveries, the remaining data set comprised 402,960 deliveries. In Austria, no ethics committee approval is required for retrospective studies according to Sect 46 Federal Act Concerning the Protection of Personal Data (Datenschutzgesetz 2000). The data for this study were retrieved from the Austrian Perinatal Registry with permission from the board of the Austrian Perinatal Registry at the Department of Clinical Epidemiology of Tyrolean State Hospitals. In this database, obstetricians and midwives of all public and private hospitals in Austria provide data structured according to the German Quality Assurance Program (Datensatz Geburtshilfe 16/1; specification 14.0 SR. AQUA Institute for Applied Quality Improvement and Research in Health Care, Göttingen, Germany) [17]. Besides demographic information, the data essentially consist of basic data on the course of pregnancy and delivery, as well as the perinatal outcome. Plausibility checks and checks for completeness of data are an integral part of the software, and quality checks are conducted on a regular basis.

Data were stratified by weeks of gestation (37 + 0–37 + 6; 38 + 0–38 + 6; 39 + 0–39 + 6; 40 + 0–40 + 6; 41 + 0–41 + 6; ≥42 + 0). Statistical analysis was done using the STATA statistical software version 13.1 for Windows. Univariate odds ratios (OR) comparing induction of labor with spontaneous labor onset were calculated for the obstetric outcomes secondary cesarean delivery, operative vaginal delivery, epidural analgesia, fetal scalp blood testing, episiotomy, 3rd/4th-degree lacerations, retained placenta, 5-min APGAR <7, umbilical artery pH <7.1, and admission to neonatal intensive care unit. Data were stratified by parity and mode of delivery where appropriate as indicated in the "Results" section. For the final analysis and to account for confounding, logistic regression models based on all deliveries with gestational age ≥37 + 0 were applied. Gestational age, age of the mother, pre-pregnancy body mass index, parity, duration of labor, birth weight, mode of delivery, and year of birth were included as confounding factors. Different rates in sample characteristics and obstetric outcomes were tested with the Chi-square test and considered statistically significant when $p < 0.05$.

Results

The cohort included 402,960 singleton pregnancies with a gestational age ≥37 + 0. 323,717 (80.3%) woman had spontaneous onset of labor and 79,243 (19.7%) woman had induction of labor. Characteristics of the cohort are shown in Table 1. The two groups differed significantly in each characteristic examined (except age group 35–39). Women undergoing induction of labor were at a higher gestational age, more likely to be nulliparous and to have a higher body mass index. Young (<25 years of age) and older (≥40) mothers were represented excessively in the induction of labor group as were babies with low (<2500 g) and high (≥3500 g) birth weight. Induction rates constantly and significantly increased by birth year from 2008 to 2014.

When stratified by gestational age, induction of labor was associated with an increase in odds of secondary cesarean delivery from 38 + 0 completed weeks of gestation onwards (Table 2). Women undergoing induction of labor were also more likely to have operative vaginal delivery at all gestational weeks except ≥42 (Table 2). Moreover, induction of labor was associated with increased rates of epidural analgesia and fetal scalp blood testing at all gestational ages (Table 2). Rates of epidural analgesia were based on vaginal deliveries only, since cesarean deliveries principally require analgesia/anesthesia.

Likewise, the rates for the maternal outcomes episiotomy, lacerations, and retained placenta were calculated based on vaginal deliveries. In addition, given the higher risk of nulliparous women for episiotomy and lacerations, these outcomes were stratified by parity. Induction of labor was associated with increased rates of episiotomy after 39 + 0 completed weeks and increased rates of 3rd/4th-degree lacerations at week 39 + 0–39 + 6 in nulliparous women (Table 3). However, despite being statistically significant, the observed differences in rates of episiotomy and 3rd /4th-degree lacerations were very moderate and thus probably lack clinical relevance. Consistently, primi-/multiparous women had lower rates of both outcomes that were not associated with the type of labor onset (Table 3). Induction of labor was associated with higher rates of retained placenta at all gestational ages tested (Table 3).

Table 1 Sample characteristics according to induction of labor

Onset of labor Characteristic	Total sample	Spontaneous *n* (%)	Induced *n* (%)	*p* value
Gestational age				
37 + 0–37 + 6	24,257	19,628 (6.1)	4,629 (5.8)	0.019
38 + 0–38 + 6	58,803	50,308 (15.5)	8,495 (10.7)	<0.001
39 + 0–39 + 6	112,479	100,150 (30.9)	12,329 (15.6)	<0.001
40 + 0–40 + 6	133,933	111,679 (34.5)	22,254 (28.1)	<0.001
41 + 0–41 + 6	70,622	40,975 (12.7)	29,647 (37.4)	<0.001
≥42 + 0	2866	977 (0.3)	1,889 (2.4)	<0.001
Age group				
<20	9456	7,509 (2.3)	1,947 (2.5)	0.022
20–24	60,607	47,806 (14.8)	12,801 (16.2)	<0.001
25–29	123,580	99,750 (30.8)	23,830 (30.1)	<0.001
30–34	128,211	104,175 (32.2)	24,036 (30.3)	<0.001
35–39	65,175	52,265 (16.1)	12,910 (16.3)	0.316
≥40	15,890	12,180 (3.8)	3,710 (4.7)	<0.001
Parity				
0	201,981	155,563 (48.1)	46,418 (58.6)	<0.001
1	135,534	115,121 (35.6)	20,413 (25.8)	<0.001
≥2	65,445	53,033 (16.4)	12,412 (15.7)	<0.001
Body mass index				
<18.5	17,954	15,347 (4.7)	2,607 (3.3)	<0.001
18.5–24.9	183,534	151,064 (46.7)	32,470 (41.0)	<0.001
25.0–29.9	51,509	39,318 (12.1)	12,191 (15.4)	<0.001
30.0–34.9	17,272	12,060 (3.7)	5,212 (6.6)	<0.001
35.0–39.9	5293	3415 (1.1)	1,878 (2.4)	<0.001
≥40.0	1924	1,119 (0.3)	805 (1.0)	<0.001
Duration of labor				
<12 h	322,770	263,075 (90.1)	59,695 (91.5)	<0.001
12–24 h	31,521	26,690 (9.1)	4,831 (7.4)	<0.001
>24 h	2862	2,179 (0.7)	683 (1.0)	<0.001
Birth weight group (g)				
<2500	6230	4,273 (1.3)	1,957 (2.5)	<0.001
2500–2999	58,644	47,690 (14.7)	10,954 (13.8)	<0.001
3000–3499	166,778	138,026 (42.6)	28,752 (36.3)	<0.001
3500–3999	131,880	104,982 (32.4)	26,898 (33.9)	<0.001
4000–4499	34,942	25,663 (7.9)	9,279 (11.7)	<0.001
≥4500	4094	2,767 (0.9)	1,327 (1.7)	<0.001
Birth year				
2008	54,345	45,117 (13.9)	9,228 (11.6)	<0.001
2009	55,003	45,007 (13.9)	9,996 (12.6)	<0.001
2010	58,141	47,195 (14.6)	10,946 (13.8)	<0.001
2011	57,865	46,095 (14.2)	11,770 (14.9)	<0.001
2012	58,737	46,728 (14.4)	12,009 (15.2)	<0.001
2013	58,481	46,275 (14.3)	12,206 (15.4)	<0.001
2014	60,388	47,300 (14.6)	13,088 (16.5)	<0.001

Induction of labor was associated with an increase in odds of having a 5-min APGAR score <7 at all gestational ages except ≥42 + 0 and of having an umbilical artery pH <7.1 at 38 + 0–41 + 6 after vaginal delivery (Table 4). Moreover, admission to a neonatal intensive care unit after vaginal delivery was more frequent after induction of labor compared with spontaneous onset of labor at all gestational weeks (Table 4). After cesarean section, rates of 5-min APGAR score <7 and umbilical artery pH <7.1 did not differ significantly between spontaneous and induced onset of labor (data not shown).

To account for confounding, multivariate logistic regression models were applied to all obstetric outcomes that were significantly associated with the mode of onset of labor at least at two gestational ages tested. All singleton deliveries with gestational age ≥37 + 0 were included in these models that adjusted for all characteristics listed in Table 1 and additionally mode of delivery (except when secondary cesarean or operative vaginal delivery were the outcome). Rates for the obstetric outcomes as well as univariate OR and adjusted OR are given in Table 5. Even after accounting for confounding factors, induction of labor was associated with increased odds for cesarean delivery (adjusted OR; 99% confidence interval: 1.53; 1.45–1.60), operative vaginal delivery (1.21; 1.15–1.27), epidural analgesia (2.12; 2.03–2.22), and fetal scalp blood testing (1.40; 1.28–1.52). Episiotomy was not associated with mode of labor induction, while retained placenta was more common after induction of labor (1.32; 1.22–1.41). Moreover, adverse neonatal outcomes were more frequent after induction of labor (5-min APGAR <7: 1.55; 1.27–1.89; umbilical artery pH <7.1: 1.26; 1.15–1.38; admission to neonatal intensive care unit: 1.41; 1.31–1.51; Table 5).

Obstetric outcomes after induction of labor are likely associated with the indication, e.g., prior or existing maternal or fetal pathologies. In the Austrian Perinatal Registry, indication should be selected by obstetricians and midwives from a given list of obstetric risk factors. However, in approximately half of the available data sets, indication is not specified or specified as "other reasons". Thus, it is not possible to unambiguously identify inductions of labor for non-medical reasons. At gestational age ≥40 + 0, induction of labor is frequently performed due to post-term pregnancy. In Austria, post-term pregnancy should be managed according to the AWMF Guideline established by the German, Austrian, and Swiss Societies for Gynecology and Obstetrics [18]. Ultrasound examination with assessment of fetal weight and determination of amniotic fluid volume at 40 + 0 is recommended, followed by CTG controls and determination of amniotic fluid volume every 3 days and from 41 + 0 onwards every other day. Moreover, the guideline authors recommend offering pregnant women the option of inducing labor from 41 + 0 and state that induction of labor must be recommended by 41 + 3 at the latest. From 42 + 0 onwards, induction is indicated.

We assumed when induction of labor indication is specified as "post-term pregnancy", it is unlikely that more

Table 2 Mode of delivery and perinatal interventions following spontaneous labor or induction of labor

Outcome	Secondary cesarean delivery					Operative vaginal delivery				
Onset of labor	Spontaneous	Induced	OR	95% CI	*p* value	Spontaneous	Induced	OR	95% CI	*p* value
Gestational age	*n* (%)	*n* (%)				*n* (%)	*n* (%)			
37 + 0–37 + 6	3915 (20.0)	980 (21.2)	1.08	0.99–1.16	0.068	1084 (5.5)	372 (8.1)	1.49	1.32–1.69	<0.001
38 + 0–38 + 6	7237 (14.4)	1744 (20.6)	1.53	1.45–1.63	<0.001	3079 (6.1)	648 (7.6)	1.26	1.16–1.38	<0.001
39 + 0–39 + 6	9976 (10.0)	2615 (21.2)	2.43	2.32–2.55	<0.001	7085 (7.1)	1094 (8.9)	1.28	1.20–1.37	<0.001
40 + 0–40 + 6	12,803 (11.5)	5473 (24.6)	2.52	2.43–2.61	<0.001	9151 (8.2)	2018 (9.1)	1.12	1.06–1.18	<0.001
41 + 0–41 + 6	6103 (14.9)	7260 (24.5)	1.85	1.78–1.92	<0.001	3899 (9.5)	3061 (10.3)	1.09	1.04–1.15	<0.001
≥42 + 0	219 (22.4)	678 (35.9)	1.94	1.62–2.31	<0.001	82 (8.4)	202 (10.7)	1.31	1.00–1.71	0.051
Outcome	Epidural analgesia[a]					Fetal scalp blood testing				
Onset of labor	Spontaneous	Induced	OR	95% CI	*p* value	Spontaneous	Induced	OR	95% CI	*p* value
Gestational age	*n* (%)	*n* (%)				*n* (%)	*n* (%)			
37 + 0–37 + 6	1777 (11.3)	746 (20.4)	2.02	1.83–2.21	<0.001	326 (1.7)	157 (3.4)	2.08	1.71–2.52	<0.001
38 + 0–38 + 6	4625 (10.7)	1431 (21.2)	2.24	2.09–2.39	<0.001	920 (1.8)	295 (3.5)	1.93	1.69–2.21	<0.001
39 + 0–39 + 6	9868 (10.9)	2199 (22.6)	2.38	2.26–2.51	<0.001	2013 (2.0)	477 (3.9)	1.96	1.77–2.17	<0.001
40 + 0–40 + 6	12,078 (12.2)	3552 (21.2)	1.93	1.85–2.01	<0.001	2838 (2.5)	940 (4.2)	1.69	1.57–1.82	<0.001
41 + 0–41 + 6	4593 (13.2)	4359 (19.5)	1.59	1.52–1.67	<0.001	1290 (3.1)	1296 (4.4)	1.41	1.30–1.52	<0.001
≥42 + 0	90 (11.9)	278 (23.0)	2.21	1.71–2.86	<0.001	23 (2.4)	120 (6.4)	2.81	1.79–4.43	<0.001

[a]Based on vaginal deliveries only, secondary cesareans excluded

OR odds ratio, *CI* confidence interval

serious pathologies or urgent indications for induction like pre-eclampsia, hypertension, gestational diabetes, or premature rupture of the membranes were present. Thus, we compared the obstetric outcomes after induction of labor due to post-term pregnancy with that of induction of labor for any reasons in all deliveries at gestational age ≥40 + 0 (Table 6). Induction of labor due to post-term pregnancy was similarly associated with adverse outcomes. Epidural analgesia and admission to the neonatal intensive care unit were even more frequent when labor was induced due to post-term pregnancy, while fetal scalp blood testing was significantly less common in this group and comparable to spontaneous onset of labor.

Discussion

The present study represents the first large-scale observational study on maternal and neonatal outcomes following induction of labor from a german-speaking country, and indicates that induction of labor at term and beyond is associated with increased odds of adverse obstetric outcomes. In a single center retrospective case–control study conducted in Austria including 410 women beyond term (gestational age ≥41 + 3), epidural analgesia, cesarean delivery, and operative vaginal delivery (vacuum extraction) were significantly increased in the induction group compared with the control group of women with spontaneous onset of labor [19]. A recent observational study from Germany demonstrated that an observed increase in rates of induction of labor at term from 2005 to 2012 was not associated with a decline in perinatal mortality [20].

Our study confirms the previous observations that induction of labor compared with spontaneous labor is associated with increased rates of cesarean deliveries and epidural analgesia [5–7, 21–24]. Moreover, an increased rate of operative vaginal deliveries has been shown in observational studies [7, 22, 24]. The observed association between the mode of onset of labor and admission to neonatal intensive care unit is in agreement with the previous reports from various countries [7, 21, 22, 24, 25]. Elevated rates of other adverse neonatal outcomes following induction of labor have been shown occasionally (e.g., fetal scalp blood testing [23] and umbilical artery pH <7.1 [24]), while other reports found no association or reduced odds of adverse neonatal outcomes [5–7].

The increased rates of perinatal interventions such as epidural analgesia and fetal scalp blood testing are in line with the suggested cascade of interventions, the tendency of interventions to accumulate during labor [26, 27]. The association between induction of labor and high rates of epidural analgesia has been observed previously; however, it is unclear if induction influences epidural analgesia or vice versa. It is plausible that women who request

Table 3 Maternal complications in women undergoing vaginal delivery

Outcome	Episiotomy nullipara					Episiotomy primi-/multipara				
Onset of labor	Spontaneous	Induced	OR	95% CI	*p* value	Spontaneous	Induced	OR	95% CI	*p* value
Gestational age	*n* (%)	*n* (%)				*n* (%)	*n* (%)			
37 + 0–37 + 6	1902 (24.4)	478 (24.5)	1.01	0.90–1.13	0.883	501 (6.4)	95 (5.7)	0.88	0.70–1.10	0.267
38 + 0–38 + 6	5185 (26.5)	936 (27.2)	1.03	0.95–1.12	0.433	1521 (6.6)	218 (6.7)	1.02	0.88–1.19	0.755
39 + 0–39 + 6	11,663 (29.2)	1619 (31.2)	1.10	1.03–1.17	0.004	3641 (7.4)	299 (6.8)	0.91	0.81–1.03	0.149
40 + 0–40 + 6	14,020 (31.6)	2,710 (32.7)	1.06	1.00–1.11	0.035	4458 (8.3)	706 (8.5)	1.02	0.94–1.11	0.575
41 + 0–41 + 6	5839 (35.0)	4,297 (36.2)	1.05	1.00–1.11	0.034	1635 (9.1)	876 (8.5)	0.92	0.85–1.01	0.067
≥42 + 0	120 (30.2)	263 (38.0)	1.42	1.09–1.84	0.010	33 (9.3)	43 (8.5)	0.91	0.57–1.47	0.704
Outcome	3rd/4th-degree lacerations nullipara					3rd/4th-degree lacerations primi-/multipara				
Onset of labor	Spontaneous	Induced	OR	95% CI	*p* value	Spontaneous	Induced	OR	95% CI	*p* value
Gestational age	*n* (%)	*n* (%)				*n* (%)	*n* (%)			
37 + 0–37 + 6	122 (1.6)	32 (1.6)	1.05	0.71–1.55	0.808	24 (0.3)	7 (0.4)	1.36	0.59–3.17	0.469
38 + 0–38 + 6	384 (2.0)	64 (1.8)	0.95	0.72–1.24	0.683	130 (0.6)	15 (0.5)	0.82	0.48–1.40	0.472
39 + 0–39 + 6	975 (2.4)	157 (3.0)	1.24	1.05–1.47	0.013	385 (0.8)	29 (0.6)	0.84	0.58–1.23	0.368
40 + 0–40 + 6	1300 (2.9)	256 (3.1)	1.06	0.92–1.21	0.424	474 (0.9)	69 (0.8)	0.94	0.73–1.21	0.610
41 + 0–41 + 6	544 (3.2)	418 (3.5)	1.08	0.95–1.23	0.232	172 (1.0)	114 (1.1)	1.15	0.91–1.46	0.245
≥42 + 0	14 (3.5)	20 (2.9)	0.82	0.41–1.64	0.573	1 (0.3)	7 (1.4)	4.94	0.61–40.33	0.098

Outcome	Retained placenta				
Onset of labor	Spontaneous	Induced	OR	95% CI	*p* value
Gestational age	*n* (%)	*n* (%)			
37 + 0–37 + 6	631 (4.1)	201 (5.6)	1.40	1.19–1.64	<0.001
38 + 0–38 + 6	1465 (3.4)	316 (4.7)	1.40	1.23–1.58	<0.001
39 + 0–39 + 6	2868 (3.2)	447 (4.7)	1.47	1.33–1.63	<0.001
40 + 0–40 + 6	3289 (3.4)	750 (4.5)	1.36	1.26–1.48	<0.001
41 + 0–41 + 6	1225 (3.5)	1027 (4.6)	1.32	1.22–1.44	<0.001
≥42 + 0	25 (3.3)	68 (5.7)	1.75	1.09–2.79	0.018

OR odds ratio, *CI* confidence interval

elective induction of labor are more likely to additionally request adequate pain relief. However, the higher rate of epidural analgesia might also be reflective of higher levels of actual labor pain experienced following induction or a higher perception of the anticipated severity of pain [22, 23, 28].

The increased rate of fetal scalp blood sampling might be due to the fact that induced labor is continuously monitored by CTG [23], leading to a higher odd for recording a suspicious fetal heart rate. According to the AWMF Guideline on CTG, fetal scalp blood sampling should be done if the CTG pattern is pathological [29].

Our findings of increases odds for retained placenta after induction compared with spontaneous onset of labor are in line with the previous identification of labor induction as a risk factor for retained placenta [30]. Of note, retained placenta is associated with postpartum hemorrhage (ICD-10 code O72.0), and both, induction of labor and retained placenta were found to be significant risk factors for postpartum hemorrhage [31].

Rates of secondary cesarean sections were only different from 38 + 0 weeks of gestation on, but not at week 37 + 0–37 + 6. This was due to a relatively high section rate at 37 + 0–37 + 6 of about 20% irrespective of mode of labor onset that is followed by a decline of section rate to 10% at 39 + 0–39 + 6 after spontaneous onset of labor, whereas section rates after induction of labor remain about 20%. As reported for various European countries and the United States, overall, cesarean section rate decreases with increasing gestational age to a nadir at 40 week before rising again at 41 weeks and above [32]. In Austria, early term deliveries (week 37 + 0–38 + 6) have similarly high section rates as late preterm deliveries (week 32 + 0–36 + 6) [32], indicating that in clinical routine, early term deliveries are frequently managed similar to late preterm deliveries. Our findings, that this decline is also observed for secondary

Table 4 Neonatal outcomes after vaginal delivery

Onset of labor Outcome/gestational age	Spontaneous *n* (%)	Induced *n* (%)	OR	95% CI	*p* value
5 min APGAR <7					
37 + 0–37 + 6	80 (0.5)	29 (0.8)	1.56	1.02–2.39	0.039
38 + 0–38 + 6	158 (0.4)	43 (0.6)	1.74	1.24–2.44	0.001
39 + 0–39 + 6	334 (0.4)	61 (0.6)	1.70	1.29–2.23	<0.001
40 + 0–40 + 6	380 (0.4)	118 (0.7)	1.83	1.49–2.26	<0.001
41 + 0–41 + 6	167 (0.5)	138 (0.6)	1.29	1.03–1.62	0.027
≥42 + 0	1 (0.1)	4 (0.3)	2.49	0.28–22.36	0.398
Umbilical artery pH <7.1					
37 + 0–37 + 6	254 (1.7)	76 (2.1)	1.28	0.99–1.66	0.063
38 + 0–38 + 6	702 (1.7)	169 (2.6)	1.54	1.30–1.82	<0.001
39 + 0–39 + 6	1,773 (2.1)	225 (2.4)	1.18	1.02–1.35	0.022
40 + 0–40 + 6	2,233 (2.4)	527 (3.3)	1.40	1.27–1.54	<0.001
41 + 0–41 + 6	912 (2.7)	807 (3.7)	1.38	1.25–1.52	<0.001
≥42 + 0	15 (2.1)	35 (3.0)	1.45	0.78–2.67	0.234
Admission to neonatal intensive care unit					
37 + 0–37 + 6	738 (5.3)	294 (9.4)	1.85	1.61–2.13	<0.001
38 + 0–38 + 6	1370 (3.6)	371 (6.3)	1.81	1.61–2.03	<0.001
39 + 0–39 + 6	2560 (3.2)	421 (5.0)	1.58	1.42–1.76	<0.001
40 + 0–40 + 6	2860 (3.3)	688 (4.8)	1.48	1.36–1.61	<0.001
41 + 0–41 + 6	1088 (3.5)	865 (4.5)	1.28	1.17–1.40	<0.001
≥42 + 0	22 (3.2)	59 (5.4)	1.71	1.04–2.82	0.033

OR odds ratio, *CI* confidence interval

Table 5 Obstetric outcomes of singleton pregnancies delivered at gestational age ≥37 + 0 following spontaneous labor or induction of labor

Outcome	Spontaneous (%)	Induced (%)	OR	99% CI	*p* value	Adjusted OR[a]	99% CI	*p* value
Secondary cesarean delivery	12.6	23.8	2.17	2.12–2.23	<0.001	1.53	1.45–1.60	<0.001
Operative vaginal delivery	7.6	9.3	1.25	1.20–1.29	<0.001	1.21	1.15–1.27	<0.001
Epidural analgesia[b]	11.7	20.8	1.99	1.93–2.05	<0.001	2.12	2.03–2.22	<0.001
Fetal scalp blood testing	2.3	4.1	1.85	1.75–1.95	<0.001	1.40	1.28–1.52	<0.001
Episiotomy[b]	17.7	20.6	1.21	1.17–1.24	<0.001	1.01	0.96–1.05	0.73
Retained placenta[b]	3.3	4.6	1.41	1.33–1.49	<0.001	1.32	1.22–1.41	<0.001
5 min APGAR <7[b]	0.4	0.6	1.65	1.42–1.92	<0.001	1.55	1.27–1.89	<0.001
Umbilical artery pH <7.1[b]	2.2	3.1	1.47	1.37–1.58	<0.001	1.26	1.15–1.38	<0.001
Admission to neonatal intensive care unit[b]	3.5	5.2	1.52	1.44–1.62	<0.001	1.41	1.31–1.51	<0.001

[a]Adjusted for gestational age, age of the mother, body mass index, parity, duration of labor, birth weight, mode of delivery, and year of birth

[b]Based on vaginal deliveries only, secondary cesareans excluded

OR odds ratio, *CI* confidence interval

cesarean sections after spontaneous onset of labor, but not after induction of labor, are in line with results from a previous retrospective cohort study from Norway [33].

In contrast to our findings, several observational studies found decreased risks of cesarean delivery and other adverse outcomes after induction of labor [10, 11, 34, 35]. However, these studies used a different study design comparing "elective" induction of labor with expectant management, meaning that the control group did not consist of spontaneous labor at the same gestational age but of all deliveries at a higher gestational age, irrespective of the mode of onset of labor. Of note, the association of induction of labor and obstetric outcomes in particular cesarean delivery varies dependent on the used control

Table 6 Obstetric outcomes of singleton pregnancies delivered at gestational age ≥40 + 0 following spontaneous labor, induction of labor, or induction of labor indicated as post-term

Onset of labor	Spontaneous	Induced	Induced "post-term"	Induced vs. induced "post-term"		
Outcome	*n* (%)	*n* (%)	*n* (%)	OR	95% CI	*p* value
Secondary cesarean delivery	19,125 (12.5)	13,411 (24.9)	1951 (24.1)	0.95	0.90–1.01	0.081
Operative vaginal delivery	13,132 (8.6)	5281 (9.8)	814 (10.0)	1.02	0.95–1.11	0.554
Epidural analgesia[a]	16,761 (12.5)	8189 (20.3)	1365 (22.1)	1.11	1.04–1.19	0.001
Fetal scalp blood testing	4151 (2.7)	2356 (4.4)	236 (2.9)	0.65	0.57–0.75	<0.001
Retained placenta[a]	4539 (3.4)	1845 (4.6)	257 (4.2)	0.90	0.79–1.03	0.126
5 min APGAR <7[a]	548 (0.4)	260 (0.6)	43 (0.7)	1.08	0.78–1.49	0.640
Umbilical artery pH <7.1[a]	3160 (2.4)	1369 (3.5)	193 (3.2)	0.92	0.79–1.07	0.268
Admission to neonatal intensive care unit[a]	3970 (3.3)	1612 (4.6)	382 (6.6)	1.45	1.29–1.62	<0.001

[a]Based on vaginal deliveries only, secondary cesareans excluded

group, e.g., if spontaneous labor at the same gestational week is included in the expectant management group or not [12, 14, 25, 36]. Furthermore, the definition of "elective" or "non-medically indicated" induction of labor is critical and often based on the absence of clear medical indications in the medical records. Since we did not focus on "elective" induction of labor but aimed to depict obstetric outcomes after induction in general, and expectant management is often not an option in case of medically indicated inductions, spontaneous onset of labor at the same gestational week was selected as the appropriate control group for the present study.

Findings from randomized controlled trials appear to support the findings from observational studies with expectant management as control group. A systematic review of randomized controlled trials demonstrated that induction of labor is associated with fewer perinatal deaths and cesarean sections compared with expectant management [37]. However, these findings were mainly based on trials including late-term pregnancies, since randomized trials investigating induction of labor before gestational age 41 + 0 are scarce. Saccone et al. [9] performed a meta-analysis of randomized controlled trials at full term (39 + 0–40 + 6) and found no significant difference in cesarean section rates between induction of labor versus expectant management. However, this analysis included only five trials with three of them having been performed in the 1970s. Only one of the included trials, the most recent one by Miller et al. [38] published in 2014, had a cesarean section rate of more than 7%. Interestingly, in this study, induction of labor was associated with an increased risk for cesarean delivery of 30.5% compared with 17.7% in the expectant management group. Although not statistically significant (relative risk 1.72, 95% confidence interval 0.96–3.06), this finding indicates that induction of labor before 40 + 0 might be associated with increased rates of cesarean sections even when compared with expectant management.

In the present study, due to the stratification by gestational weeks, it becomes apparent that patients might benefit from expectant management if induction is not medically indicated dependent on gestational age. For instance, rate of cesarean delivery after induction of labor is similar at gestational age 40 + 0–40 + 6 and 41 + 0–41 + 6 but higher compared to spontaneous onset of labor at any gestational age. Thus, a policy of watchful waiting for a couple of days or even a week might provide a chance to develop spontaneous onset of labor without increased odds of cesarean delivery if labor has to be induced later. Similarly, in the induction of labor, group rates of epidural analgesia decline form gestational age 39 + 0–39 + 6 to 41 + 0–41 + 6 and rates of retained placenta are comparable form 38 + 0–41 + 6.

The major limitation of the present study is that in the observation group, all cases with induction of labor were included, regardless of their indications. Thus, the increased odds for several negative outcomes observed might, at least in part, represent the risk for certain diseases during pregnancy or obstetrical complications that require induction of labor, but not the risk for induction of labor itself. However, since indications were not sufficiently documented in the Perinatal Registry, it was not possible to stratify the data by indication for induction of labor. Therefore, we addressed this issue of possible confounding by pregnancy risks by an additional analysis of a subgroup with indication "post-term", assuming that these women would not have more urgent medical indications for induction. Our finding that induction of labor indicated as "post-term" was associated with a similar increase in odds of adverse outcomes compared to general induction of labor suggests that inducing labor adds risk regardless of prior or existing pathologies. Consistently, "elective" induction of

labor has been shown to carry similar obstetric and neonatal risks as medically indicated induction [7, 24]. However, potential residual confounding by certain diseases during pregnancy or obstetrical complications could not be completely excluded by this approach.

Further limitations of the present study are its retrospective nature, possible coding errors, and missing information on applied induction method. Data were retrieved from the Austrian Perinatal Registry and thus not collected for scientific purposes but primarily for benchmark and quality assurance. The study was designed as a population-based retrospective cohort study without randomization or matching of the groups. Thus, multivariate analysis was applied to adjust for differences in demographic parameters listed on Table 1; however, potential other confounding factors including Bishop Score or interhospital variations might have impacted the results. The findings of this study are only applicable to singleton pregnancies and to countries with comparable healthcare status.

In conclusion, this study demonstrates that in Austria, induction of labor is associated with increased odds of adverse maternal and neonatal outcomes. However, it remains unclear whether this increased risk is caused primarily by induction of labor or by certain diseases or complications that require labor induction. To answer this issue by means of a population-based study will require accurate documentation of indications for induction in the Perinatal Registry. Currently, from our data, no recommendations for treatment can be derived.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval For this type of study, formal consent is not required.

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