ORIGINAL ARTICLE

Decision-to-Delivery Time and Perinatal Complications in Emergency Cesarean Section

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SUMMARY

Background: A decision-to-delivery interval (DDI) of no more than 20 minutes has long been considered a requirement for cesarean sections, even though there have hardly been any studies on this topic. We retrospectively investigated data relevant to DDI for emergency cesarean sections performed for the most common indications, namely, suspected and documented fetal asphyxia.

Methods: We analyzed data on emergency in-hospital cesarean sections in the period 2008–2015. Low 5- and 10-minute Apgar scores (a scheme with points awarded for breathing, heart rate, muscle tone, skin coloration, and the elicibility of reflexes) were the primary endpoints; acid–base status in arterial cord blood and in-hospital neonatal death were the secondary endpoints. The raw analysis was supplemented by an analysis adjusted for various factors including gestational age, maternal age, and obstetrical presentation.

Results: Data from 39 291 neonates were included. The DDI was up to 10 minutes in 64.6% of cases, from 11 to 20 minutes in 34.3%, and over 20 minutes in 1.1%. Low Apgar scores were less common in children whose emergency cesarean sections were performed within 10 minutes or within 20 minutes. For example, the adjusted odds ratio for a 10-minute Apgar score below 4 was 0.49 (95% confidence interval [0.25; 0.96] when a DDI of more than 20 minutes was used as the reference criterion.

Conclusion: This is the largest population-based, risk-adjusted analysis to be carried out on this topic to date. It reveals, for the first time, an association between DDI of 20 minutes or less and the avoidance of outcomes that are dangerous to the child. As it is not possible to predict such obstetrical emergencies in advance, it seems reasonable to ensure the availability of care-delivery structures that make it possible for emergency cesarean sections to be performed within 20 minutes of the decision to do so.

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A decision-to-delivery interval (DDI) of 20 minutes has been a quality indicator for emergency cesarean sections in the statutory quality assurance program in Germany for years (1), but scientific evidence to support this threshold value is sparse (2).

A 2011 guideline of the National Health Service (NHS) in the UK recommends a DDI of 30 minutes in case of an immediate threat to the life of the mother or the fetus or both. Otherwise, a DDI of 75 minutes is usually sufficient and in rare cases a 30 minute interval is appropriate. These NHS guideline threshold values were only meant as an audit standard and were not intended to be used per se to assess the multidisciplinary team or individual emergency cesarean sections (3). A systematic review and meta-analysis from 2014 concluded that internationally a 30-minute interval is frequently not achieved and that its benefits are uncertain since shorter DDIs were often not associated with improved outcomes for newborns or mothers (2).

Thus, the aim of this study was to present risk-adjusted empirical analyses based on an extensive data pool. This data pool should be sufficient to confirm the association between a DDI of ≤ 20 minutes and improved newborn outcome in cases with suspected or confirmed fetal asphyxia, the by far most common indication for emergency cesarean section. This scientific study appears to be an indispensable step to ensure that this quality indicator can be upheld in the future.

Methods

For the purpose of this study, data from the German Perinatal Survey of the years 2008–2015 were used. Since 2001, the perinatal survey has been mandatory for all inpatient deliveries in the context of statutory quality assurance. In the annually revised perinatal survey, information about the mother, the current pregnancy and delivery and the newborn are documented by completing a number of data fields, most recently 189. These data are used to assure and improve the quality of care by means of systematic quality analyses and subsequent feedback processes (4–10).

Newborns with a gestational age of 24–45 completed weeks of gestation were included if one of the

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following (primary) indications for emergency cesarean section applied:

- Abnormal cardiotocography (CTG) findings
- Abnormal fetal heart rate
- Asphyxia detected by fetal blood analysis.

For the perinatal survey, DDI data are collected exact to the minute. The following exclusion criteria were defined:

- Emergency cesarean sections with DDI of >3 hours
- Stillbirths with time of death prior to admission to hospital or prior to delivery or unknown
- Newborns with congenital malformations.

Congenital malformations were coded according to the International Classification of Disease (ICD), defined within the routine data-based quality assurance procedure where in a multi-stage panel process a malformation list had been compiled based on established malformation lists and empirical analyses of hospital reimbursement data pursuant to section 301, German Social Code (SGB) V with a 1-year follow-up. Both methodological and medical experts were involved in this process (11–13).

Low 5-minute and 10-minute Apgar scores (score with the components respiration, heart rate, muscle tone, skin color, and reflexes) were used as the primary endpoints of analysis. The secondary endpoints were death of the newborn in hospital and acidosis with arterial cord blood pH <7.0 or base excess below –16 mmol/L.

Using logistic regressions, bivariate and risk-adjusted analyses were performed. Risk adjustment models were developed taking into account the risk factors discussed in the literature and documented in the perinatal survey (14). These are listed in *Table 1* (full details in *eTable 1*). The final models included only significant risk factors with plausible associations with the outcomes under investigation. These final risk adjustment variables are stated in the legends of *Tables 2–4*.

Because of the low power of our study, initial analyses were performed for the DDIs 10, 20 and 30 minutes. Subsequently, the analyses were restricted to endpoints with a prevalence of at least 2% and associations for DDIs not exceeding 5, 10, 15, and 20 minutes. To be able to evaluate the effects of changes to the DDIs on neonatal outcome from a public health perspective, the results to be expected based on logistic regression analyses were calculated under ideal condition. Ideal condition means that all emergency cesarean deliveries were performed within the defined DDI. These expected values were subtracted from the currently observed events and reported as potentially preventable events or percentages of potentially preventable events (15).

Results

Altogether 39 291 newborns were included in the analysis. The distribution of the DDIs was as follows:

- 12.2%: ≤5 minutes
- 52.4%: 6–10 minutes
- 24.6%: 11–15 minutes
- 9.7%: 16–20 minutes.

For 296 newborns (0.8%), a DDI of 21–30 minutes was reported and for only 120 (0.3%) newborns a DDI >30 minutes. Of the newborns included in the analysis, 225 (0.6%) died during the hospital stay, 1151 had a 10-minute Apgar score <7 (2.9%) and 435 (1.1%) a 10-minute Apgar score <4. For 1768 newborns (4.5%), a pH <7.0 was reported and for 1124 (2.9%) a base excess of less than –16 mmol/L.

According to the commonly used definition of growth retardation, the 10% of newborns with the lowest birth weight, adjusted for gestational age, were classified as growth retarded (n = 8344).

Table 2 shows the relationship between DDIs with various threshold values (10, 20 and 30 minutes) and neonatal outcome (full details in *eTable 2*). Lower Apgar scores were less frequently observed in newborns with DDIs of not more than 10 or 20 minutes. In newborns with DDIs of 20 minutes or less, risk-adjusted analyses found the strongest protective effect for the 5-minute Apgar score <4 (odds ratio (OR): 0.48; 95% confidence interval (CI): [0.28; 0.82]). With the same DDI, the result for the endpoint of a 10-minute Apgar score <4 was almost identical (OR: 0.49 [0.25; 0.96]).

Altogether in 39 of the 42 calculated associations for various endpoints and threshold values, protective effects were found for lower DDIs.

In almost all risk-adjusted analyses, the risk of unfavorable neonatal outcomes was reduced compared with the corresponding bivariate analyses (*eTable 2*).

The analysis of prevalent outcomes demonstrated dose–effect relationships. Accordingly, for the 5-minute Apgar score <4 the odds ratio increased from 0.44 for DDIs ≤ 5 minutes, 0.45 for DDIs 6–10 minutes, 0.52 for DDIs 11–15 minutes, and 0.56 for DDIs 16–20 minutes to 1 for DDIs of >20 minutes as a reference category (*Table 3*).

For DDIs of ≤ 20 minutes, the analysis found 2–16 potentially preventable events or percentages of potentially preventable events of 0–1%. The comparatively small size of these effects can be explained by the fact that almost 99% of emergency cesarean sections were performed within 20 minutes. These figures/percentages steadily increased for lower threshold values. For DDIs of ≤ 5 minutes, 60–330 potentially preventable events or percentages of potentially preventable events of 7–13% were found (*Table 4*). To achieve this, however, 88% of all emergency cesarean sections have to be performed within a shorter DDI (*Table 1*).

Discussion

To the best of our knowledge, our study was the first to demonstrate a relationship between DDIs of ≤ 20 minutes and improved neonatal outcome in a large

TABLE 1

**Emergency cesarean sections for suspected^{*1} or confirmed^{*2} asphyxia:
Data of the external program for quality assurance in inpatient care in Germany from 2008–2015**

	Number (%)	95% CI	Number of neonatal deaths (%)	95% CI
Patient population	39 291 (100.0)			
Death in hospital	225 (0.6)	[0.5; 0.7]	225 (100.0)	
5-minute Apgar score				
<7	3321 (8.5)	[8.2; 8.7]	197 (5.9)	[5.2; 6.8]
<4	788 (2.0)	[1.9; 2.2]	175 (22.2)	[19.4; 25.3]
Not stated	337 (0.9)	[0.8; 1.0]	16 (4.8)	[2.7; 7.6]
10-minute Apgar score				
<7	1151 (2.9)	[2.8; 3.1]	183 (15.9)	[13.8; 18.1]
<4	435 (1.1)	[1.0; 1.2]	156 (35.9)	[31.4; 40.6]
Not stated	389 (1.0)	[0.9; 1.1]	20 (5.1)	[3.2; 7.8]
Arterial cord blood pH				
<7.0	1768 (4.5)	[4.3; 4.7]	61 (3.5)	[2.7; 4.4]
Not stated	485 (1.2)	[1.1; 1.3]	83 (17.1)	[13.9; 20.8]
Base excess				
Base excess below –16 mmol/L	1124 (2.9)	[2.7; 3.0]	45 (4.0)	[2.9; 5.3]
Not stated	5066 (12.9)	[12.6; 13.2]	107 (2.1)	[1.7; 2.6]
DDI				
≤ 5 minutes	4803 (12.2)	[11.9; 12.6]	36 (0.8)	[0.5; 1.0]
6–10 minutes	20 589 (52.4)	[51.9; 52.9]	105 (0.5)	[0.4; 0.6]
11–15 minutes	9671 (24.6)	[24.2; 25.0]	51 (0.5)	[0.4; 0.7]
16–20 minutes	3812 (9.7)	[9.4; 10.0]	30 (0.8)	[0.5; 1.1]
21–30 minutes	296 (0.8)	[0.7; 0.8]	2 (0.7)	[0.1; 2.4]
>31 minutes	120 (0.3)	[0.3; 0.4]	1 (0.8)	[0.0; 4.6]

Apgar score, a score with the components respiration, heart rate, muscle tone, skin color, and reflexes;

CTG, cardiotocography; DDI, decision-to-delivery interval; CI, confidence interval

^{*1}abnormal CTG or abnormal heart rate;

^{*2} by fetal blood analysis

population-based data pool. Since these results are highly relevant for the organization of medical care in obstetrics, we think a detailed critical discussion is needed.

Completeness of documentation

The data pool that served as the basis for this study contains data of more than 99% of all inpatient deliveries in Germany during the above-mentioned period (4–10). Accordingly, this study provides a comprehensive population-based analysis. Thus, data completeness bias seems unlikely. It was not possible to directly assess to what extent emergency cesarean sections were not documented as such. In comparison with international studies, our analysis showed lower Apgar scores in similar frequency (2, 14). Combined with the experiences of the German expert group for perinatal medicine gathered on a federal level, relevant incompleteness of emergency cesarean section documentation seems rather unlikely.

Transfer of newborns/completeness of recorded deaths

The perinatal survey exclusively reflects the period of inpatient stay in the department of obstetrics. Neonatal deaths after this stay, for example after transfer of the newborn to another hospital or department, may be relevantly underrepresented. However, transfers may be arranged for reasons other than medical. If required, newborns delivered in peripheral hospitals may be transferred to neonatal units to ensure the necessary resources for immediate treatment of potential complications are readily available. Consequently, we did not select transfer as an endpoint and mortality not as a primary endpoint of our analysis; instead, we selected low Apgar scores as the primary endpoint.

Data validity

A common criticism of studies based on DDIs or data of the German Perinatal Survey is related to concerns about the validity of the underlying data. In response, data

TABLE 2

Association between DDIs and neonatal outcome in emergency cesarean sections for suspected^{*1} or confirmed^{*2} asphyxia: Data of the external program for quality assurance in inpatient care in Germany from 2008–2015

	Number of neonatal outcomes with DDIs ≤ 10	DDIs ≤ 10 vs. >10 minutes	Number of neonatal outcomes with DDIs ≤ 20	DDIs ≤ 20 vs. >20 minutes	Number of neonatal outcomes with DDIs ≤ 30	DDIs ≤ 30 vs. >30 minutes
		Odds ratio, 95% CI		Odds ratio, 95% CI		Odds ratio, 95% CI
		adjusted		adjusted		adjusted
Death in hospital ^{*3}	141	0.83 [0.63; 1.10]	222	0.80 [0.25; 2.57]	224	0.66 [0.09; 4.89]
5-minute Apgar score <7 ^{*4}	2102	0.88 [0.81; 0.95]	3272	0.64 [0.47; 0.87]	3308	0.67 [0.37; 1.20]
5-minute Apgar score <4 ^{*5}	494	0.83 [0.72; 0.97]	773	0.48 [0.28; 0.82]	785	0.67 [0.21; 2.15]
10-minute Apgar score <7 ^{*6}	708	0.81 [0.71; 0.91]	1131	0.56 [0.35; 0.89]	1146	0.62 [0.25; 1.55]
10-minute Apgar score <4 ^{*7}	274	0.87 [0.71; 1.06]	426	0.49 [0.25; 0.96]	434	1.30 [0.18; 9.53]
Arterial cord blood pH <7.0 ^{*8}	1148	0.99 [0.89; 1.09]	1746	0.81 [0.52; 1.26]	1761	0.70 [0.32; 1.52]
Base excess below -16 ^{*9} mmol/L	724	0.93 [0.82; 1.05]	1110	0.83 [0.48; 1.42]	1119	0.68 [0.28; 1.68]

Apgar score, a score with the components respiration, heart rate, muscle tone, skin color, and reflexes; BMI, body mass index; CTG, cardiotocography; DDI, decision-to-delivery interval; CI, confidence interval; SGA, small for gestational age

^{*1} abnormal CTG or abnormal heart rate

^{*2} by fetal blood analysis

^{*3} adjusted for: sex (female vs. other), multiple birth status (single birth vs. other), gestational age (24–31, 32–36, reference ≥ 37 weeks' gestation), presentation (cephalic vs. other), maternal BMI (<20, 20–24 vs. ≥ 25), year of birth (2009 vs. other)

^{*4} adjusted for: sex (female vs. other), multiple birth status (single birth vs. other), developmental status (growth retardation vs. other), gestational age (24–31, 32–36, reference ≥ 37 weeks' gestation), presentation (cephalic vs. other), anesthesia (general vs. other), maternal BMI (<20, 20–24, 25–29 vs. ≥ 30), previous cesarean delivery (status post cesarean section vs. other), parity (first birth vs. other), year of birth (2008, 2014 vs. other)

^{*5} adjusted for: sex (female vs. other), multiple birth status (single birth vs. other), gestational age (24–31, 32–36, reference ≥ 37 weeks' gestation), presentation (transverse lie vs. other), anesthesia (general vs. other), maternal BMI (20–24 vs. other), parity (first birth vs. other), maternal age

^{*6} adjusted for: sex (female vs. other), multiple birth status (single birth vs. other), gestational age (24–31, 32–36, reference ≥ 37 weeks' gestation), presentation (cephalic vs. other), anesthesia (general vs. other), maternal BMI (missing data vs. other), parity (first birth vs. other)

^{*7} adjusted for: sex (female vs. other), multiple birth status (single birth vs. other), gestational age (24–31, 32–36, reference ≥ 37 weeks' gestation), anesthesia (general vs. other), maternal BMI (20–24, 25–29 vs. other), parity (first birth vs. other)

^{*8} adjusted for: sex (female vs. other), gestational age (24–31, 32–36, reference ≥ 37 weeks' gestation), anesthesia (general vs. other), maternal BMI (<20, 20–24 vs. other), previous cesarean delivery (status post cesarean section vs. other), parity (first birth vs. other), year of birth (2008 vs. other), maternal age

^{*9} adjusted for: sex (female vs. other), developmental status (SGA vs. other), gestational age (24–31, 32–36, reference ≥ 37 weeks' gestation), previous cesarean delivery (status post cesarean section vs. other), parity (first birth vs. other), year of birth (2008 vs. other), maternal age

TABLE 3

Association between DDIs in 5-minute intervals^{*1} and prevalent^{*2} neonatal outcomes for emergency cesarean sections for suspected^{*3} or confirmed^{*4} asphyxia: Data of the external program for quality assurance in inpatient care in Germany from 2008–2015

	≤ 5 minutes	6–10 minutes	11–15 minutes	16–20 minutes	>20 minutes
	Odds ratio 95% CI	Odds ratio 95% CI	Odds ratio 95% CI	Odds ratio 95% CI	
5-minute Apgar score <7 ^{*5}	0.57 [0.41; 0.79]	0.62 [0.46; 0.85]	0.69 [0.50; 0.94]	0.69 [0.50; 0.96]	Reference
5-minute Apgar score <4 ^{*6}	0.44 [0.25; 0.77]	0.46 [0.27; 0.78]	0.52 [0.30; 0.89]	0.56 [0.32; 0.99]	Reference
10-minute Apgar score <7 ^{*7}	0.51 [0.31; 0.84]	0.52 [0.33; 0.83]	0.62 [0.39; 1.00]	0.67 [0.41; 1.09]	Reference
Arterial cord blood pH <7.0 ^{*8}	0.70 [0.44; 1.11]	0.83 [0.54; 1.30]	0.80 [0.51; 1.25]	0.84 [0.53; 1.34]	Reference
Base excess below -16 ^{*9} mmol/L	0.75 [0.42; 1.32]	0.82 [0.47; 1.41]	0.85 [0.49; 1.48]	0.91 [0.51; 1.60]	Reference

Apgar score, a score with the components respiration, heart rate, muscle tone, skin color, and reflexes; BMI, body mass index; CTG, cardiotocography; DDI, decision-to-delivery interval; CI, confidence interval

^{*1} with DDIs ≥ 20 minutes as reference category

^{*2} with a frequency of >2%

^{*3} abnormal CTG or abnormal heart rate

^{*4} by fetal blood analysis

^{*5} adjusted for: sex (female vs. other), multiple birth status (single birth vs. other), developmental status (growth retardation vs. other), gestational age (24–31, 32–36, reference ≥ 37 weeks' gestation), presentation (cephalic vs. other), anesthesia (general vs. other), maternal BMI (<20, 20–24, 25–29 vs. ≥ 30), previous cesarean delivery (status post cesarean section vs. other), parity (first birth vs. other), year of birth (2008, 2014 vs. other)

^{*6} adjusted for: sex (female vs. other), multiple birth status (single birth vs. other), gestational age (24–31, 32–36, reference ≥ 37 weeks' gestation), presentation (transverse lie vs. other), anesthesia (general vs. other), maternal BMI (20–24 vs. other), parity (first birth vs. other), maternal age

^{*7} adjusted for: sex (female vs. other), multiple birth status (single birth vs. other), gestational age (24–31, 32–36, reference ≥ 37 weeks' gestation), presentation (cephalic vs. other), anesthesia (general vs. other), maternal BMI (missing data vs. other), parity (first birth vs. other)

^{*8} adjusted for: sex (female vs. other), gestational age (24–31, 32–36, reference ≥ 37 weeks' gestation), anesthesia (general vs. other), maternal BMI (<20, 20–24 vs. other), previous cesarean delivery (status post cesarean section vs. other), parity (first birth vs. other), year of birth (2008 vs. other), maternal age

^{*9} adjusted for: sex (female vs. other), developmental status (growth retardation vs. other), gestational age (24–31, 32–36, reference ≥ 37 weeks' gestation), previous cesarean delivery (status post cesarean section vs. other), parity (first birth vs. other), year of birth (2008 vs. other), maternal age

validation studies were performed as pilot projects in the context of the statutory program for quality assurance in inpatient care and subsequently introduced into standard operation (16). Most recently, the 2012 perinatal survey was externally validated by comparing the quality assurance data against the corresponding information in the patient records on the basis of a multi-stage random sample with a size of 1039 newborns and including 19 emergency cesarean sections (17, 18). Data validity for the data fields sex, gestational age, birth weight, number of multiple births, mortality as well as 5-minute Apgar score, arterial cord blood pH and base excess was found to be good to very good. Only the data related to DDIs were reported as in need of improvement. The reanalyses of these data we performed for this study compared DDIs based on quality assurance data with DDIs based on patient records. Overall, a trend to report shorter DDIs in the quality assurance data was noted as compared to patient record data. However, comparison of DDIs according to the perinatal survey (quality assurance data) and those from patient records revealed that with regard to the threshold values analyzed in our study, DDIs were classified correctly in 18 of the 19 cases of emergency cesarean section (94.7%) (*eFigure*). These results do not indicate that data validity issues resulted in significant bias.

An additional point for discussion could be that the percentage of female newborns among these emergency cesarean sections is comparably small. However, this is in line with the known fact that the mortality among male neonates is higher than that among female newborns.

Against this background, the question arises why this relationship has not been identified in the studies published so far.

Risk adjustment

One answer to this question could be that the level of objective threat to health of an emergency cesarean section varies significantly by indication, but also by other, patient-related factors such as gestational age. Many of the available studies lack risk adjustment for such factors (19–27). Some studies differentiate according to the urgency of the procedure (14, 28, 29). It should be noted, however, that the perceived urgency of a procedure is a very subjective parameter and only to a limited extent reflective of the actual threat. Therefore, we limited our analysis to the most common primary indication for emergency cesarean section: suspected or confirmed fetal asphyxia. This indication accounts for about two-thirds of all emergency cesarean sections, both in our dataset and in other publications (14). In addition, risk adjustment for other relevant risk factors was performed. Although it should not be assumed that because of this all analyzed emergency cesarean sections became fully comparable in every aspect, it can be argued that in our analysis any existing differences in risk have been balanced out to a considerable extent. The fact that almost all risk-adjusted associations showed a stronger protective effect for shorter DDIs, may be taken as an indication of the significance of

such analyses. At the same time, this could explain why in earlier studies without such risk adjustment the connection between DDI and perinatal outcome was less pronounced.

Statistical power

Looking at the numbers of emergency cesarean sections included in earlier studies, the suspicion arises that the sample sizes and with them the statistical power of most published studies were too small to identify actually existing effects with sufficient probability (2, 14, 19–30). Assuming an expected reduction in risk of 30% with an occurrence of the analyzed endpoint of 2%—such as a 5-minute Apgar score <4—the minimum sample size for a one-side test with a significance level of 95% and a power of 80%—without taking any risk adjustment into account—is greater than 6000 emergency cesarean sections. This applies to both the group above and below the evaluated threshold value. To the best of our knowledge, none of the existing studies has yet fulfilled this condition with regard to sample size. Thus, even if in no study a significant protective effect associated with a DDI ≤20 minutes has been detected, it should not be concluded that such a connection does actually not exist. This minimum number of cases was not reached for all threshold values and endpoints in our study either. Because of the low to borderline statistical power of our study, we did not attempt to identify an optimum DDI threshold value. We limited our analysis to 5- and 10-minute intervals, thereby including the threshold values discussed in the literature (2–10, 19–30).

With regard to the power of the study, it should also be discussed that our data pool only contained 416 cases and 120 cases with a DDI >20 and >30 minutes, respectively. This limits the power of our study, regardless of the results of inferential statistics. However, it should also be taken into account that almost all available studies have comparably few cases below the threshold values analyzed (2, 14, 19–30). Thus, the logical consequence of our analyses would be to call for shorter DDIs because dose–effect relationships were shown for prevalent outcomes, while at the same time the greatest absolute effects and the most reliable effects were described for 5- or 10-minutes intervals (*Table 3 and 4*).

Finally, it may come as a surprise that especially low 5- and 10-minute Apgar scores led to significant results, while the associations found for mortality and acidosis parameters were less pronounced.

However, this can be explained by the fact that it was not possible to include all deaths among newborns transferred to other hospitals and that the power of our data pool was insufficient for this endpoint.

Furthermore, several studies have indicated that acidosis measured in arterial cord blood is less strongly associated with later mortality and morbidity compared with the newborn's Apgar score

TABLE 4

Observed, expected and potentially preventable events with DDIs of ≤ 5, 10, 15, and 20 minutes for emergency cesarean sections with suspected^{*1} or confirmed^{*2} asphyxia: Data of the external program for quality assurance in inpatient care in Germany from 2008–2015

	Observed events	DDIs ≤ 5			DDIs ≤ 10		
		Expected events ^{*3}	Potentially preventable events, 95% CI ^{*3, 4}	Percentage of preventable events (%), 95% CI ^{*3, 4}	Expected events ^{*3}	Potentially preventable events, 95% CI ^{*3, 4}	Percentage of preventable events (%), 95% CI ^{*3, 4}
5-minute Apgar score <7 ^{*5}	3321	2991	330 [302; 359]	10 [9; 11]	3194	127 [97; 158]	4 [3; 5]
5-minute Apgar score <4 ^{*6}	788	728	60 [53; 67]	8 [7; 9]	743	45 [38; 53]	6 [5; 7]
10-minute Apgar score <7 ^{*7}	1151	1072	79 [69; 90]	7 [6; 8]	1072	79 [68; 89]	7 [6; 8]
Arterial cord blood pH <7.0 ^{*8}	1768	1532	236 [221; 251]	13 [12; 14]	1764	4 [–14; 21]	0 [–1; 1]
Base excess below –16 ^{*9} mmol/L	1124	1038	86 [75; 97]	8 [7; 9]	1096	28 [16; 39]	2 [1; 3]

	Observed events	DDIs ≤ 15			DDIs ≤ 20		
		Expected events ^{*3}	Potentially preventable events, 95% CI ^{*3, 4}	Percentage of preventable events (%), 95% CI ^{*3, 4}	Expected events ^{*3}	Potentially preventable events, 95% CI ^{*3, 4}	Percentage of preventable events (%), 95% CI ^{*3, 4}
5-minute Apgar score <7 ^{*5}	3321	3280	41 [10; 72]	1 [0; 2]	3305	16 [–16; 47]	0 [0; 1]
5-minute Apgar score <4 ^{*6}	788	768	20 [13; 28]	3 [2; 4]	780	8 [0; 15]	1 [0; 2]
10-minute Apgar score <7 ^{*7}	1151	1121	30 [19; 41]	3 [2; 4]	1143	8 [–3; 20]	1 [0; 2]
Arterial cord blood pH <7.0 ^{*8}	1768	1758	10 [–7; 27]	1 [0; 2]	1764	4 [–13; 21]	0 [–1; 1]
Base excess below –16 ^{*9}	1124	1111	13 [2; 25]	1 [0; 2]	1122	2 [–9; 14]	0 [–1; 1]

Apgar score, a score with the components respiration, heart rate, muscle tone, skin color, and reflexes; BMI, body mass index; CTG, cardiotocography; DDI, decision-to-delivery interval; CI, confidence interval

^{*1} abnormal CTG or abnormal heart rate

^{*2} by fetal blood analysis

^{*3} rounded values; calculated based on logistic regressions

^{*4} negative values indicate additionally occurring events

^{*5} adjusted for: sex (female vs. other), multiple birth status (single birth vs. other), developmental status (growth retardation vs. other), gestational age (24–31, 32–36, reference ≥ 37 weeks' gestation), presentation (cephalic vs. other), anesthesia (general vs. other), maternal BMI (<20, 20–24, 25–29 vs. ≥ 30), previous cesarean delivery (status post cesarean section vs. other), parity (first birth vs. other), year of birth (2008, 2014 vs. other)

^{*6} adjusted for: sex (female vs. other), multiple birth status (single birth vs. other), gestational age (24–31, 32–36, reference ≥ 37 weeks' gestation), presentation (transverse lie vs. other), anesthesia (general vs. other), maternal BMI (20–24 vs. other), parity (first birth vs. other), maternal age

^{*7} adjusted for: sex (female vs. other), multiple birth status (single birth vs. other), gestational age (24–31, 32–36, reference ≥ 37 weeks' gestation), presentation (cephalic vs. other), anesthesia (general vs. other), maternal BMI (missing data vs. other), parity (first birth vs. other)

^{*8} adjusted for: sex (female vs. other), gestational age (24–31, 32–36, reference ≥ 37 weeks' gestation), anesthesia (general vs. other), maternal BMI (<20, 20–24 vs. other), previous cesarean delivery (status post cesarean section vs. other), parity (first birth vs. other), year of birth (2008 vs. other), maternal age

^{*9} adjusted for: sex (female vs. other), developmental status (growth retardation vs. other), gestational age (24–31, 32–36, reference ≥ 37 weeks' gestation), previous cesarean delivery (status post cesarean section vs. other), parity (first birth vs. other), year of birth (2008 vs. other), maternal age

(31–35). Consequently, lower arterial cord blood pH values or base excesses should be associated with DDI to a lesser degree because as proxies for neonatal morbidity and mortality they are less suitable than the Apgar score.

Furthermore, it is discussed whether the event-to-decision-to-delivery interval (EDDI) is a more useful quality indicator compared with the decision-to-delivery interval (DDI). Usually, there is agreement that operationalizing EDDI is even more difficult. That notwithstanding, the association between DDI and neonatal outcome discussed above indicates that DDI is a useful quality indicator.

Conclusion

In our risk-adjusted analyses regarding the association between DDI and neonatal outcome, we found

significantly better results for 5- and 10-minute Apgar scores with a DDI ≤ 20 minutes for prevalent outcomes.

As far as we know, this is the first study to empirically confirm that a DDI with a threshold value of ≤ 20 minutes has a protective effect in emergency cesarean section for suspected or confirmed fetal asphyxia. At the same time, this study is the largest one addressing this question.

Our analyses seem to support the introduction and implementation of a DDI of ≤ 20 minutes as a quality indicator. It is not possible to predict the non-occurrence of an obstetric emergency, such as abnormal CTG findings, abnormal fetal heart rate or acidosis determined by fetal blood gas analysis, based on prelabor factors (36). Therefore, hospitals regularly providing obstetric care should establish structures ensuring that an emergency cesarean section can be performed within 20 minutes.

KEY MESSAGES

- A decision-to-delivery interval (DDI) for emergency cesarean sections of ≤ 20 minutes has been a requirement in Germany for many years.
- However, empirical evidence in support of this requirement is scarce. Internationally, a 30-minute limit is commonly used.
- For emergency cesarean sections due to suspected or confirmed fetal asphyxia, an association was demonstrated between DDIs of ≤ 10 minutes or ≤ 20 minutes and the prevention of low 5-minute and 10-minute Apgar scores (a score with the components respiration, heart rate, muscle tone, skin color, and reflexes).
- To date, this is the most comprehensive study evaluating the impact of DDIs of various durations.
- For obstetric units, structures allowing to perform emergency cesarean sections within 20 minutes seem to be advisable.

Conflict of interest statement

Dr. Heller has received reimbursement of conference fees and travel expenses from KelCon GmbH.

The remaining authors declare that no conflict of interest exists.

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Supplementary material

eTables, eFigure:
www.aerzteblatt-international.de/17m0589

Supplementary material to:

Decision-to-Delivery Time and Perinatal Complications in Emergency Cesarean Section

by Günther Heller, Erik Bauer, Stefanie Schill, Teresa Thomas, Frank Louwen, Friedrich Wolff, Björn Misselwitz, Stephan Schmidt, and Christof Veit

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eTABLE 1

**Emergency cesarean sections for suspected^{*1} or confirmed^{*2} asphyxia:
Data of the external program for quality assurance in inpatient care in Germany from 2008–2015**

	Number (%)	95% CI	Number of neonatal deaths (%)	95% CI
Patient population	39 291 (100.0)			
Death in hospital	225 (0.6)	[0.5; 0.7]	225 (100.0)	
5-minute Apgar score				
<7	3321 (8.5)	[8.2; 8.7]	197 (5.9)	[5.2; 6.8]
<4	788 (2.0)	[1.9; 2.2]	175 (22.2)	[19.4; 25.3]
Not stated	337 (0.9)	[0.8; 1.0]	16 (4.8)	[2.7; 7.6]
10-minute Apgar score				
<7	1151 (2.9)	[2.8; 3.1]	183 (15.9)	[13.8; 18.1]
<4	435 (1.1)	[1.0; 1.2]	156 (35.9)	[31.4; 40.6]
Not stated	389 (1.0)	[0.9; 1.1]	20 (5.1)	[3.2; 7.8]
Arterial cord blood pH				
<7.0	1768 (4.5)	[4.3; 4.7]	61 (3.5)	[2.7; 4.4]
Not stated	485 (1.2)	[1.1; 1.3]	83 (17.1)	[13.9; 20.8]
Base excess				
Base excess below –16 mmol/L	1124 (2.9)	[2.7; 3.0]	45 (4.0)	[2.9; 5.3]
Not stated	5066 (12.9)	[12.6; 13.2]	107 (2.1)	[1.7; 2.6]
DDI				
≤ 5 minutes	4803 (12.2)	[11.9; 12.6]	36 (0.8)	[0.5; 1.0]
6–10 minutes	20 589 (52.4)	[51.9; 52.9]	105 (0.5)	[0.4; 0.6]
11–15 minutes	9671 (24.6)	[24.2; 25.0]	51 (0.5)	[0.4; 0.7]
16–20 minutes	3812 (9.7)	[9.4; 10.0]	30 (0.8)	[0.5; 1.1]
21–30 minutes	296 (0.8)	[0.7; 0.8]	2 (0.7)	[0.1; 2.4]
≥ 31 minutes	120 (0.3)	[0.3; 0.4]	1 (0.8)	[0.0; 4.6]
Risk factors^{*3}				
Female sex of newborn	16 163 (41.1)	[40.6; 41.6]	116 (0.7)	[0.6; 0.9]
Single birth	37 821 (96.3)	[96.1; 96.4]	214 (0.6)	[0.5; 0.7]
Diabetes and gestational diabetes	5609 (14.3)	[13.9; 14.6]	36 (0.6)	[0.5; 0.9]
Status post cesarean section/uterine surgery	4968 (12.6)	[12.3; 13.0]	39 (0.8)	[0.6; 1.1]
Primiparae	13 471 (34.3)	[33.8; 34.8]	100 (0.7)	[0.6; 0.9]
Maternal age				
≤ 26 years	10 125 (25.8)	[25.3; 26.2]	54 (0.5)	[0.4; 0.7]
27–30 years	9792 (24.9)	[24.5; 25.4]	51 (0.5)	[0.4; 0.7]
31–34 years	10 080 (25.7)	[25.2; 26.1]	59 (0.6)	[0.5; 0.8]
≥ 35 years	9294 (23.7)	[23.2; 24.1]	61 (0.7)	[0.5; 0.8]

	Number (%)	95% CI	Number of neonatal deaths (%)	95% CI
Gestational age (completed weeks of gestation)				
24–31	1280 (3.3)	[3.1; 3.4]	74 (5.8)	[4.6; 7.2]
32–36	3875 (9.9)	[9.6; 10.2]	47 (1.2)	[0.9; 1.6]
37–41	33 730 (85.8)	[85.5; 86.2]	104 (0.3)	[0.3; 0.4]
42–45	406 (1.0)	[0.9; 1.1]	0 (0.0)	[0.0; 0.9]
Growth retardation* ⁴	8344 (21.2)	[20.8; 21.6]	63 (0.8)	[0.6; 1.0]
Fetal position				
Cephalic presentation	37 463 (95.3)	[95.1; 95.6]	175 (0.5)	[0.4; 0.5]
Breech presentation	1420 (3.6)	[3.4; 3.8]	39 (2.8)	[2.0; 3.7]
Transverse lie	292 (0.7)	[0.7; 0.8]	10 (3.4)	[1.7; 6.2]
Other	116 (0.3)	[0.2; 0.4]	1 (0.9)	[0.0; 4.7]
Performance of emergency cesarean section under general anesthesia	35 308 (89.9)	[89.6; 90.2]	209 (0.6)	[0.5; 0.7]
Maternal body mass index at initial examination				
<20	4579 (11.7)	[11.3; 12.0]	21 (0.5)	[0.3; 0.7]
20–24	17 575 (44.7)	[44.2; 45.2]	80 (0.5)	[0.4; 0.6]
25–29	8335 (21.2)	[20.8; 21.6]	52 (0.6)	[0.5; 0.8]
>29	5363 (13.7)	[13.3; 14.0]	39 (0.7)	[0.5; 1.0]
Missing data	3439 (8.8)	[8.5; 9.0]	33 (1.0)	[0.7; 1.3]
Survey year				
2008	4293 (10.9)	[10.6; 11.2]	24 (0.6)	[0.4; 0.8]
2009	4272 (10.9)	[10.6; 11.2]	35 (0.8)	[0.6; 1.1]
2010	4534 (11.5)	[11.2; 11.9]	24 (0.5)	[0.3; 0.8]
2011	4745 (12.1)	[11.8; 12.4]	26 (0.6)	[0.4; 0.8]
2012	4845 (12.3)	[12.0; 12.7]	25 (0.5)	[0.3; 0.8]
2013	5185 (13.2)	[12.9; 13.5]	29 (0.6)	[0.4; 0.8]
2014	5600 (14.3)	[13.9; 14.6]	30 (0.5)	[0.4; 0.8]
2015	5817 (14.8)	[14.5; 15.2]	32 (0.6)	[0.4; 0.8]

Apgar score, a score with the components respiration, heart rate, muscle tone, skin color, and reflexes; CTG, cardiotocography; DDI, decision-to-delivery interval; CI, confidence interval

*¹ abnormal CTG or abnormal heart rate

*² by fetal blood analysis

*³ These risk factors were used for the development of logistic regressions. The final models included only significant parameters with plausible associations with the outcomes under investigation. These final risk adjustment variables are stated in the legends of *Tables 2–4*.

*⁴ <10th birth weight percentile of all births, adjusted for gestational age

ETABLE 2

Association between DDIs and neonatal outcome in emergency cesarean sections for suspected^{*1} or confirmed^{*2} asphyxia: Data of the external program for quality assurance in inpatient care in Germany from 2008–2015

	Number of neonatal outcomes with DDIs ≤ 10	DDIs ≤ 10 vs. >10 minutes		Number of neonatal outcomes with DDIs ≤ 20	DDIs ≤ 20 vs. >20 minutes		Number of neonatal outcomes with DDIs ≤ 30	DDIs ≤ 30 vs. >30 minutes	
		Odds ratio, 95% CI			Odds ratio, 95% CI			Odds ratio, 95% CI	
		raw	adjusted		raw	adjusted		raw	adjusted
Death in hospital ³	141	0.92 [0.70; 1.22]	0.83 [0.63; 1.10]	222	0.79 [0.27; 3.88]	0.80 [0.25; 2.57]	224	0.68 [0.12; 27.37]	0.66 [0.09; 4.89]
5-minute Apgar score <7 ⁴	2102	0.94 [0.87; 1.01]	0.88 [0.81; 0.95]	3272	0.69 [0.51; 0.95]	0.64 [0.47; 0.87]	3308	0.76 [0.42; 1.47]	0.67 [0.37; 1.20]
5-minute Apgar score <4 ⁵	494	0.92 [0.79; 1.07]	0.83 [0.72; 0.97]	773	0.54 [0.32; 0.99]	0.48 [0.28; 0.82]	785	0.80 [0.27; 3.93]	0.67 [0.21; 2.15]
10-minute Apgar score <7 ⁶	708	0.87 [0.77; 0.98]	0.81 [0.71; 0.91]	1131	0.59 [0.38; 0.99]	0.56 [0.35; 0.89]	1146	0.69 [0.29; 2.18]	0.62 [0.25; 1.55]
10-minute Apgar score <4 ⁷	274	0.93 [0.76; 1.14]	0.87 [0.71; 1.06]	426	0.50 [0.26; 1.11]	0.49 [0.25; 0.96]	434	1.34 [0.23; 53.30]	1.30 [0.18; 9.53]
Arterial cord blood pH <7.0 ⁸	1148	1.01 [0.91; 1.12]	0.99 [0.89; 1.09]	1746	0.82 [0.53; 1.33]	0.81 [0.52; 1.26]	1761	0.77 [0.36; 1.96]	0.70 [0.32; 1.52]
Base excess below -16 ⁹ mmol/L	724	0.95 [0.83; 1.07]	0.93 [0.82; 1.05]	1110	0.78 [0.45; 1.44]	0.83 [0.48; 1.42]	1119	0.66 [0.27; 2.10]	0.68 [0.28; 1.68]

Apgar score, a score with the components respiration, heart rate, muscle tone, skin color, and reflexes; BMI, body mass index; CTG, cardiotocography; DDI, decision-to-delivery interval; CI, confidence interval

^{*1} abnormal CTG or abnormal heart rate

^{*2} by fetal blood analysis

^{*3} adjusted for: sex (female vs. other), multiple birth status (single birth vs. other), gestational age (24–31, 32–36, reference ≥37 weeks' gestation), presentation (cephalic vs. other), maternal BMI (<20, 20–24 vs. ≥ 25), year of birth (2009 vs. other)

^{*4} adjusted for: sex (female vs. other), multiple birth status (single birth vs. other), developmental status (growth retardation vs. other), gestational age (24–31, 32–36, reference ≥37 weeks' gestation), presentation (cephalic vs. other), anesthesia (general vs. other), maternal BMI (<20, 20–24, 25–29 vs. ≥30), previous cesarean delivery (status post cesarean section vs. other), parity (first birth vs. other), year of birth (2008, 2014 vs. other)

^{*5} adjusted for: sex (female vs. other), multiple birth status (single birth vs. other), gestational age (24–31, 32–36, reference ≥37 weeks' gestation), presentation (transverse lie vs. other), anesthesia (general vs. other), maternal BMI (20–24 vs. other), parity (first birth vs. other), maternal age

^{*6} adjusted for: sex (female vs. other), multiple birth status (single birth vs. other), gestational age (24–31, 32–36, reference ≥37 weeks' gestation), presentation (cephalic vs. other), anesthesia (general vs. other), maternal BMI (missing data vs. other), parity (first birth vs. other)

^{*7} adjusted for: sex (female vs. other), multiple birth status (single birth vs. other), gestational age (24–31, 32–36, reference ≥37 weeks' gestation), anesthesia (general vs. other), maternal BMI (20–24, 25–29 vs. other), parity (first birth vs. other)

^{*8} adjusted for: sex (female vs. other), gestational age (24–31, 32–36, reference ≥37 weeks' gestation), anesthesia (general vs. other), previous cesarean delivery (status post cesarean section vs. other), parity (first birth vs. other), year of birth (2008 vs. other), maternal age

^{*9} adjusted for: sex (female vs. other), developmental status (growth retardation vs. other), gestational age (24–31, 32–36, reference ≥37 weeks' gestation), previous cesarean delivery (status post cesarean section vs. other), parity (first birth vs. other), year of birth (2008 vs. other), maternal age

Comparison of the decision-to-delivery intervals (DDIs) in the perinatal survey (quality assurance [QA] data) and in the patient records for 19 emergency cesarean sections in the context of extended data validation of the perinatal survey of the survey year 2012 (17, 18) (own calculations)