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Regional anaesthesia for caesarean sections

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Summary

Regional anaesthesia procedures have been used effectively and safely for caesarean sections for many years. This article shows which pregnancy-related peculiarities must be taken into account and gives an overview of the procedures and medications used. It addresses the necessary blockade extension and shows strategies for the case of an insufficient effect. Potential side effects and complications are discussed as well as options for prevention and therapy.

Introduction

Regional procedures are the **anaesthesiological standard for caesarean deliveries** worldwide. In Germany, this applies to about 90 % of elective and 80 % of secondary caesarean deliveries [1]. **General anaesthesia** is used almost exclusively for **emergency procedures, contraindications** for neuraxial punctures or at the **express wish of the mother.** Although there is no longer any advantage over general anaesthesia with regard to severe complications [2], the following factors

- **lower maternal blood loss,**
- **lower exposure** of the child to drugs,
- possibility of quickly achieving **sufficient anaesthesia** with a catheter **already in place,** even in time-critical situations
- avoidance of **potential aspiration** and **intubation problems,** as well as
- the possibility for the mother to **actively experience** the birth of her child,

speak in favour of regional anaesthesia. Even if an individual approach may be justified in individual cases, the **same principles apply** with regard to information and consent, monitoring of vital signs and compliance with hygiene rules as **outside obstetric anaesthesia.** However, safe anaesthesia in pregnant women also requires knowledge of physiological and anatomical characteristics, of the kinetics and dynamics of the drugs used and their effect on mother and child, as well as anticipation and appropriate treatment of specific complications.

Anatomical and physiological characteristics in pregnant women

Already the **identification of the targeted intervertebral space** is sometimes difficult. The increasing tilt of the pelvis means that the line connecting the iliac crests, the Tuffier-line, which is usually used as an anatomical orientation, projects to higher spinal segments than in non-pregnant patients. And although the spine is often still palpable even in very obese patients, increased fluid retention in the subcutaneous tissue can make anatomical orientation almost impossible. Due to increased lumbar lordosis, the space between two adjacent spinous processes is reduced and the pregnant woman finds it increasingly difficult to actively flex the spine. If the **midline** approach is unsuccessful, a **paramedian approach** may be more promising. As the ligamentum flavum is softer and a

loss of resistance is not as impressive as in non-pregnant women, identification of the peridural space can also be difficult.

The use of ultrasound is helpful both for identifying the midline and the targeted intervertebral space and for estimating the necessary depth of puncture. However, the application in the spinal area under these special conditions requires some practice.

The shifted centre of gravity causes a flattening of the thoracic kyphosis so that drugs spread more cranially [3]. The increase of fatty tissue and the strongly filled veins in the epidural space cause a positive peridural pressure and a smaller volume of cerebrospinal fluid. The resulting reduced dilution of the applied drugs is considered to be the main reason for the lower requirement of local anaesthetics for spinal anaesthesia in pregnant women [4].

At term, the required local anaesthetic dose is about 25 % lower than in non-pregnant women and the duration of the blockade is significantly shorter [5].

In addition to the anatomical factors, a pregnancy-associated increased sensitivity of the nervous tissue to local anaesthetics probably also plays a role [6]. This could at least explain why lower doses of local anaesthetics are already needed in the 1st trimester. However, reliable statements about the optimal dose depending on the gestational week does not exist.

Coagulation

Despite a general hypercoagulability at the time of birth, (unrecognised) coagulation disorders can lead to serious complications during spinal cord punctures. A careful, structured history of the patient's own condition, family history and medication history should therefore be taken beforehand. A so-called coagulation questionnaire can be helpful for this purpose.

If the history of haemorrhage is negative and the pregnancy is inconspicuous, laboratory coagulation tests can be dispensed before regional anaesthesia for caesarean deliveries [7].

Patients with hypertensive pregnancy disorders often have limitations in regard of platelet coagulation. Since regional procedures are basically beneficial for them as well, both the absolute platelet count and their dynamics must be carefully observed.

An indication for a possible neuraxial blockade are stable platelet values of 70,000–80,000/µl [7,8] in the last 6–12 hours. However, these values are always only part of a careful risk-benefit assessment [7,8].

Occasionally, heparin therapy is also necessary in pregnant patients. In addition, since 2018, women at high risk of pre-eclampsia have been recommended to take 150 mg/d of acetylsalicylic acid (ASA) until 34–36 weeks' gestation for effective prevention [9]. Although these drugs are usually discontinued sufficiently long before the due date, the attending anaesthetists are occasionally confronted with a continued therapy. In principle, the recommendations of the guideline on the management of antithrombotic medication also apply to pregnant women. For the first time, the current version contains special notes in which the physiological and anatomical characteristics of obstetric patients as well as their overall lower risk for haematoma near the spinal cord are acknowledged and special recommendations are made [10].

After a careful risk-benefit assessment, regional anaesthesia close to the spinal cord can be performed in obstetric patients even with 150 mg ASA per day. If the patient is also receiving low-molecular-weight heparin (LMWH), this should be paused for a sufficiently long time and an anti-Xa level should also be determined (Tab. 1) [10].

Table 1
Recommended time intervals before or after neuroaxial puncture or catheter removal (according to [10]).

Substance	Half-life ($t_{1/2}$)	Time before neuraxial puncture / catheter removal	Time after neuraxial puncture / catheter removal	Specific laboratory values
UFH (prophylaxis)	1,5–2 h	4 h	1 h	aPTT, ACT
UFH (therapeutic)	2–3 h	i. v.: 4–6 h s. c.: 8–12 h	i. v.: 8–12 h s. c.: 6–8 h	aPTT, ACT
LMWH (prophylaxis)	4–6 h	12 h	4 h	Anti-Xa activity
LMWH (therapeutic)	4–6 h	24 h	4 h	Anti-Xa activity
ASA (100 mg/d)	Biologic lifespan of platelets	Stop not necessary, additional anticoagulants (prophylaxis) need to be stopped for 4–5 $t_{1/2}$		
ASA (150 mg/d)	Biologic lifespan of platelets	Stop not necessary, only obstetric patients, strict risk-benefit evaluation Additional stop for LMWH 36–42 h (prophylaxis) bzw. 48 h (therapeutic) Anti-Xa activity <0,1 E/ml must be present		

UFH: Unfractionated heparin; **LMWH:** Low-molecular-weight heparin; **ASA:** acetylsalicylic acid; **aPTT:** activated partial thromboplastin time; **ACT:** activated clotting time.

In patients with Von Willebrand syndrome, too, neuraxial procedures can be performed safely with structured interdisciplinary management, as demonstrated in a large case series [11].

Applied Drugs

Basic considerations

Placental transfer

Local anaesthetics are weak bases with usually a low degree of ionisation. The unbound portion circulating in maternal blood passes freely through the placenta according to Fick's law. Both the relatively small molecular size and the good fat solubility of most local anaesthetics hardly hinder this passage, so that the **concentration gradient** between **maternal** and **fetal blood** is decisive. Due to **high plasma protein binding,** especially of bupivacaine and ropivacaine, the free unbound fraction and thus the gradient is low, so that this mechanism plays only a minor role under physiological conditions and when usual dosages are used. However, if the maternal plasma concentration is high, for example in the case of **accidental intravascular injection** or the use of **exceptionally high doses,** the protein binding capacity may be exhausted and the free unbound fraction of the substance may cause undesirable effects. In addition, **pH-value-shifts** can cause altered ionisation and thus impede placental passage. In particular, fetal acidosis can prevent the local anaesthetics from diffusing back into the maternal circulation and lead to dangerous accumulation, so-called **ion trapping,** in the fetal blood.

Due to low systemic absorption of **opioids** when administered close to the spinal cord, the risk of adverse effects in the foetus is manageable, despite the fact that the placental passage is basically easily possible.

Baricity

Baricity, the ratio of the **density of the solution of a local anaesthetic** to the density of cerebrospinal fluid, influences its spread in the **intrathecal space.** While an **isobaric substance** primarily remains at the level of the injection site, a **hyperbaric substance** descends following gravity. It should be noted here, however, that the specific weights of local anaesthetic solutions given by the manufacturer are usually measured under laboratory conditions at 20 °C, which is why solutions marketed as isobaric often present themselves as slightly hypobaric at body temperature. Bupivacaine is available as an isobaric and as a hyperbaric formulation for spinal anaesthesia for caesarean section. A systematic review found no differences for conversion rate to general anaesthesia, need for analgetic supplementation, ephedrine requirement and incidence of nausea or vomiting, but a significantly shorter onset of action when using the hyperbaric solution [12]. Furthermore, since it is theoretically more feasible with this substance to influence **spinal spread** by appropriate **positioning measures,** the use of **hyperbaric bupivacaine** appears advantageous. However, baricity is influenced both by mixing with other substances (e.g. opioids) and by temperature changes, so that this advantage may not play a major role in everyday clinical practice.

Local anaesthetics (Tab. 2)

Bupivacaine

Bupivacaine has been traditionally used in obstetrics for decades. The onset of action is medium-rapid, the plasma half-life is 2–3 hours, the clinical duration of action is long at 4–6 hours. It is highly fat-soluble, but because of the high plasma protein binding, only a small proportion passes through the placenta. Because of its pronounced and long-lasting sodium channel blockade, it has the **highest cardiotoxic potential** of all local anaesthetics currently in clinical use. [13] After cases of circulatory arrest, including in pregnant women, were published in 1979 following accidental intravascular injection [14], the FDA banned the use of bupivacaine 0.75 % in pregnant women. However, there is no doubt that even lower concentrations

Table 2
Summary for local anaesthetics used in obstetric anaesthesia.

Drug	Advantages	Disadvantages	Common dose for SpA	Common dose for EA
Bupivacaine	Long clinical experience Approved for caesarean section	High cardiotoxicity (for SpA probably little clinical relevance)	8–10 mg Bupivacaine 0.5 % in combinations with opioids	12–20 ml Bupivacaine 0.5 % If nec. with opioids
Ropivacaine	Minor motoric blockade Low cardiotoxicity Approved for „surgical indication"	Little data availabe for SpA	12 mg Ropivacaine 0.5 % if combined with opioids (??) Little data availabe for dosage	12–20 ml Ropivacaine 0.75 % If nec. with opioids
2-Chloro-procaine	Rapid time of onset Lower systemic toxicity Approved for caesarean section	Limited duration Worse analgesia?	45–50 mg Chloroprocaine 1 % Combination with opiods?	12–20 ml Chloroprocaine 3 % (not approved in Germany)
Lidocaine	Rapid time of onset Lower systemic toxicity	Limited duration Worse analgesia?	Because of TNS not recommended	12–20 ml Lidocaine 2 % If nec. with bicarbonate/opioids

SpA: Spinalanaesthesia; **EA:** Epiduralanaesthesia; **TNS:** Transient neurologic symptoms.

of bupivacaine have a cardiotoxic effect. Decades of experience and the comparatively low dose required mean that bupivacaine 0.5 % still appears to be a suitable drug for spinal anaesthesia for caesarean section [7]. However, for peridural anaesthesia with higher dosages required, ropivacaine should be preferred.

Ropivacaine

Ropivacaine has similar clinical properties to bupivacaine, with a comparative analgetic potency of 0.75 [15]. Because of its lower lipophilicity, it occupies the sodium channel of neuronal and cardiac cells as quickly as bupivacaine, but leaves it again much more quickly (fast in – intermediate out). At the same time, there are indications that ropivacaine, because of its lower lipophilicity, blocks the strongly myelinated motor nerve fibres less strongly and thus causes less motor blockade than bupivacaine [16]. Ropivacaine 0.5 % is generally approved for spinal anaesthesia and can probably also be used for caesarean section. A meta-analysis showed faster motor recovery for ropivacaine than when bupivacaine was used, with a comparable onset of action and hypotension rate [17]. However, data is limited and its use for spinal anaesthesia for caesarean section does not appear to be widespread. For epidural use, ropivacaine is now a very commonly used and well studied local anaesthetic.

Lidocaine

Lidocaine is one of the most commonly used drugs worldwide for epidural anaesthesia for cesarean section. The duration of action is significantly shorter than that of bupivacaine or ropivacaine, as is the duration for the onset of action, although this can be shortened even further by the addition of bicarbonate [18]. Its use is therefore particularly advantageous in time-critical situations. However, its vasodilatory component leads to a rapid systemic absorption, thus additionally to a timely limited effect and possibly also to a less reliable intensity of effect. Because of the association with (transient) neurological symptoms, especially when using hyperbaric preparations, its use is no longer recommended for spinal anaesthesia.

2-Chloroprocaine

2-Chloroprocaine, an ester-type local anaesthetic, has been used for spinal anaesthesia for about 70 years. In the meanwhile, earlier reported cases of neurotoxicity could be attributed to the antioxidant (sodium bisulphite) which it used to contain [19]. Now that no additives are contained, the substance is experiencing a certain renaissance. Since 2017, the 1 % preparation has been approved for caesarean section; the ED_{95} is 45–50 mg [20]. The comparatively short onset of action [21] can be advantageous, especially in the case of a time delay, but the short duration of action must be taken into account. According to the pharmaceutical specifications described in the summary of product characteristics, the planned duration of surgery should not exceed 40 minutes.

The epidural application of 3 % 2-chloroprocaine is an interesting option for the injection of a peridural catheter already in place in time-critical situations because of the very short time till onset of action. This application has not yet been explicitly approved in Germany, but is certainly used internationally. Due to the short half-life, intraoperative injections via the epidural catheter must be expected.

Mepivacain

(Hyperbaric) mepivacaine is not very suitable for obstetric epidural anaesthesia because of the risk of systemic accumulation in the foetus, and its use for spinal anaesthesia is not recommended because of its association with transient neurological symptoms.

Opioids

The addition of opioids to the local anaesthetic offers a **faster onset, better and longer lasting analgesia.** At the same time, the local anaesthetic dose, including the associated risks, can be reduced [7]. The lipophilic opioids **sufentanil** and **fentanyl** are mainly used for intraoperative analgesia. Intrathecal use is an established off-label use, which is, however, explicitly recommended in the current guideline [7]. Due to its delayed onset of action (maximum effect after 60-90 min), hydrophilic **morphine** is not suitable for intraoperative analgesia, but can be used very well for postoperative pain therapy due to its long retention time close to the spinal cord. By selecting suitable dosages, e.g. 2 mg peridurally or 100 µg intrathecally, and risk-adjusted monitoring [22], long-lasting analgesia can be achieved with a simultaneously manageable risk of late maternal respiratory depression.

Other Adjuvants

A **bicarbonate additive,** e.g. 2 ml sodium bicarbonate 8.4 % in 20 ml lidocaine, leads to a **lower ionisation** of the local anaesthetic via alkalisation and thus to a **shorter duration of action** and a more effective blockade. Mixing should be done immediately before use and may not only lead to an additional delay but can also to lead to confusion, especially under time pressure. To avoid neurotoxic effects, a preservative-free preparation should be chosen. According to the technical information, an addition to ropivacaine or bupivacaine must not be made because of possible **precipitate formation.**

The use of other adjuvants such as **neostigmine, dexmedetomidine** and **clonidine** has been described, but there is little data on their efficacy and safety.

Applied procedures

Spinal anaesthesia (SpA)

Worldwide, spinal anaesthesia is probably the most frequently used anaesthetic procedure for caesarean section, in Germany for over 80 % of caesarean sections [1]. It is easy to perform and offers a rapid time of onset.

According to current guidelines, spinal anaesthesia is the procedure of choice for primary and secondary caesarean sections without a peridural catheter and in the absence of contraindications [7].

Puncture is usually performed with the patient in a **sitting position.** Alternatively, the pregnant woman can lie down, but this procedure is often considered more difficult. The **intervertebral spaces L2/L3, L3/L4 and L4/L5** are generally considered as the puncture heights. However, the extent of the spinal cord is variable, precise anatomical orientation may be difficult and the pregnancy-related differences described above may lead to a **misjudgement of the puncture height.** In a case of doubt, the **deeper (more caudal) intervertebral space** should therefore be chosen to avoid injury to the spinal cord. Only **atraumatic needles** (e.g. pencil-point needles such as the Sprotte needle) should be used for puncture. Unlike the sharp-ground needles used in the past, these allow a gentler procedure and lead considerably less often to **post-puncture headaches.**

A combination of a local anaesthetic and an opioid is usually used for spinal anaesthesia for caesarean section [7]. An example of a common mixture is 8–10 mg bupivacaine 0.5 % hyperbaric + 4–5 µg sufentanil.

After successful intrathecal injection, the patient is placed on her back and the spread of spinal anaesthesia is carefully monitored. Especially when hyperbaric local anaesthetics are used, the spread of the medication and thus the level of anaesthesia can possibly be influenced somewhat by **targeted positioning measures** within the first few minutes after injection.

Epidural anaesthesia (EA)

Many anaesthetists consider the administration of an epidural anaesthesia to be technically more demanding, the drug doses used are higher and the failure rate is greater than with a spinal anaesthesia [23]. The advantage is that the spread of the blockade can be adjusted almost at will by fractionated (re)injections via a permanently placed catheter.

Because of a slower onset and less severe **hypotension,** epidural anaesthesia is usually chosen as the primary procedure for patients with pre-existing **cardiac conditions.** However, it is most often used for secondary caesarean sections, if a catheter has already been placed in advance of the originally planned vaginal birth. This not only avoids the risk of another spinal puncture, but also allows a sufficient level of anaesthesia to be achieved within 10–15 min with a suitable choice of medication. Lidocaine and chloroprocaine offer a particularly rapid onset time in contrast to ropivacaine and bupivacaine [18].

According to current guidelines, an already placed peridural catheter should be used for anaesthesia and injection should be perforemd immediately, especially if the position is correct and its function is sufficient [7]. If the internal hospital processes function well, this procedure may well be suitable for an urgent section and may even offer a time advantage over the insertion of a new spinal anaesthetic [24].

For adminstration of this anaesthesia the pregnant woman can sit or lie on her side. In most cases, anatomical orientation is easier with the patient in a sitting position. Usually the puncture is made in the **intervertebral space L2/L3, L3/L4 or L4/L5.** The most reliable way to identify the epidural space is with the **"loss of resistance" technique** (LOR). In order to avoid incorrect positioning or even a loop formation on the one hand and unintentional slipping out on the other, the catheter should be inserted 4–6 cm beyond the LOR depth [25]. After an aspiration test (without bacterial filter), the catheter is then securely fastened and clearly labelled.

Usually, volumes of 12–20 ml are needed for an epidural anaesthesia. Examples of common mixtures are:

- **Ropivacaine 0,75 %,**
- **Lidocaine 2 % with or without bicarbonate, or**
- **3 % formula of 2-chloroprocaine (not yet explicitly approved in Germany),**

in each case with the addition of 10–20 µg sufentanil.

In contrast to epidural anaesthesia for low-pain birth, where a classic higher-percentage test dose can be dispensed with because of the low dosages [7], a **catheter defect** should be ruled out beyond doubt as far as possible before epidural anaesthesia for caesarean section. Even initially correctly positioned catheters may have migrated secondarily.

Whenever sufficient time is available, and especially if there is doubt about the correct position of a catheter, a test dose, for example with 30–45 mg lidocaine, should be applied before injecting for a caesarean section in addition to (re)aspiration. Alternatively, a fractionated administration of the targeted total dose, e.g. 3 x 5 ml ropivacaine 0.75 % plus 5 µg sufentanil at intervals of 3 min each, can be applied [7].

Combined spinal-epidural anaesthesia (CSE)

When performing CSE, the use of specially prepared sets makes it possible to apply a spinal medication as well as an epidural catheter. This makes it possible to achieve a rapid onset of action initially and to carry out a subsequent injection later if necessary. In addition, the catheter can be used for postoperative analgesia. The placement is more complex than with single spinal anaesthesia, and higher failure rates have been reported [26]. Due to the initial induction of spinal anaesthesia, it is not possible to immediately verify the correct position of the peridural catheter, so that the effect should be monitored very carefully, especially when it is used for the first time.

Selection of procedure

The choice of the appropriate procedure is the responsibility of the anaesthesist, taking into account the wishes of the woman, the urgency and the expected duration of the procedure, as well as an individual risk-benefit analysis (Tab. 3) [7].

Required extension of the blockade and testing possibilities

From an anatomical point of view, a block level of Th11–Th12 seems to be sufficient for the skin incision for caesarean section. For stretching deeper layers, loosening any adhesions and inserting blockers, a further 2–4 blocked segments are required and for intraperitoneal manipulations another 2–3 segments.

Although data in studies and classic textbooks vary greatly, a block height of Th5 to Th6 is predominantly considered necessary for a painless caesarean section [27].

There are a number of ways to assess block spread: sensing **light touch, cold or pain stimuli.** However, all tests are also based on subjective experience, suggestions and expectations and the communication skills of the patient and the anaesthesist. There still is no gold standard. However, it is advisable to carefully document the performance of the respective test and to take expressed complaints seriously.

In practice, especially in time-critical situations, the time of the spread of blockade is already used for skin disinfection and surgical preparation; cold tests with a spray can then no longer be carried out sensibly. Therefore, the surgeon usually applies a pain stimulus with (sterile) forceps at the level of the intended skin incision instead. If this is perceived as painless or not at all, experience has shown that the operation can be started but with special attention [28].

Many patients are completely pain-free intraoperatively, but can sense touching and positioning. While this can be discussed in detail in advance for elective caesarean sections, this preparation is usually completely lacking for secondary sections. Many patients are then understandably excited and anxious, almost expecting the pain. This is where **empathetic communication** with the patient is of great importance. Experience has shown that many women find it helpful to **compare the procedure with dental procedures under local anaesthesia.**

Table 3
Advantages and disadvantages of neuroaxial procedures.

	Advantages	Disadvantages
SpA	• Simple technique • Rapid onset of action • Low dose for onset of action required	• Sometimes rapid hypotension • No additional injections possible
EA	• Dose titration/additional injections possible • Slower onset and less pronounced hypotension • Possible use of catheter for postoperative pain therapy • In difficult punctures often easier than SpA	• Slow onset of action • High dose for onset of action required • Common headache after perforation of dura mater
CSE	• Dose titration/additional injections possible • Use for postoperative pain therapy possible	• Technically demanding • Possibility for failure of a component • Initially no possibility for verification of correct position of EAK

SpA: Spinal anaesthesia; **EA:** Epidural anaesthesia; **EAK:** Epidural catheter.

Insufficient Blockade

Frequencies and causes

Even after a (apparently) problem-free puncture, an insufficient blockage can result. This can be caused by

- an **insufficient level,**
- an **irregular spread** or
- an **insufficient intensity.**

A recently published systematic review reported the incidence in elective sections to be 14.6 % overall. However, definitions of inadequate effect were inconsistent across studies and ranged from a general assessment by patient or clinician, to the use of pain scales, to the need for drug supplementation. Conversion to general anaesthesia was required in only 0.1 %. The largest proportion of inadequate blocks concerned epidurals with 30.3 % compared to spinal or combined spinal-epidurals with 10.2 % [23].

The causes can be manifold and cannot always be clearly determined. In principle, **medication and batch errors** are possible, but (unnoticed) **problems during puncture** are more likely. For example, a spinal needle may be placed in such a way that the opening is just at the level of the dura and thus a CSF backflow is observed, but at the same time parts of the injected medication remain extradurally. It is also possible that the spinal needle is dislocated during the injection so that only part of the medication reaches the intrathecal level. Inadequate positioning, e.g. sitting too long after the spinal injection when using a hyperbaric drug, or a too short waiting time before the start of the operation can also be the cause.

Causes for **failure of epidural anaesthesia** are mainly **insufficient insertion depth** of multi-hole catheters, other **catheter misplacements** and **uneven distribution** of the local anaesthetic in the epidural space. MRI examinations showed that the final position of the catheter tip can vary greatly despite median puncture. A lateral catheter tip position did not necessarily lead to a unilateral blockade. Irrespective of

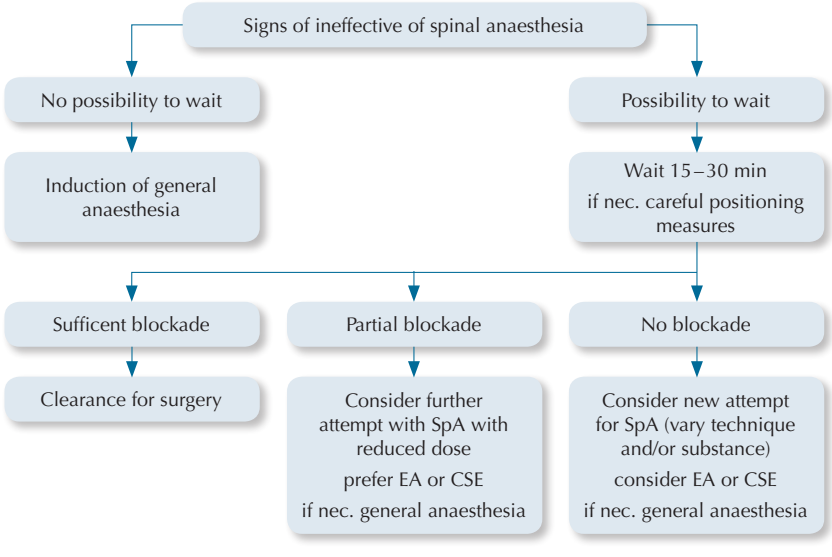
the catheter position, the spread of the local anaesthetic in the epidural space also varied greatly. Epidural fat and also the catheter itself partly hindered the spread, fibrous barriers that made spread absolutely impossible have also been described (so-called plica mediana dorsalis), but were not found in the studies mentioned [29]. Particularly in the case of secondary sections, it is occasionally not possible to achieve sufficient anaesthesia even via a previously well-functioning peridural catheter. Secondary **catheter migrations** are mainly described in cases of increased **body mass index** (BMI), but are possible in all patients over a distance of several centimetres [30]. In any case, reports of frequent bolus requests by the patient should suggest a catheter malposition.

Possible approach

If **spinal anaesthesia** does not spread sufficiently, further **waiting,** if necessary with careful **positioning manoeuvres** in the direction of the "disadvantaged" side, can be helpful. If, however, there is no effect at all 10 to 15 minutes after the puncture or if sufficient blockade is not apparent even after a prolonged waiting time, a **new puncture** can be considered after a precise risk-benefit evaluation. Particularly in the case of an existing partial blockade, the drug dose must be reduced in order to avoid a high spinal anaesthesia. Partial blockade may be limited to the sacral segments and can easily be overlooked in an orientational test only. If there is doubt about the safe and sufficient dose, EA or CSE with dose titration via the catheter can be chosen for a repeat puncture. In any case, care must be taken when positioning for a new puncture to avoid **possible motor restrictions.** A modified approach to drug selection, puncture height and/or technique may increase the chances of success of a repeat puncture (Fig. 1).

If a **epidural anaesthesia** does not show sufficient effect, an **additional bolus** can be applied on a trial basis. In the MRI studies described above, almost all uneven drug distributions in the epidural space could be corrected by injecting a larger volume [29]. **Withdrawal of the catheter** in case of unilateral effect can be attempted, but seems to have less chance of success. Positioning measures analogous to spinal anaesthesia usually have no relevant influence in epidural anaesthesia.

Figure 1



Suggestion on how to proceed in case of insufficient spinal anaesthesia.

If an insufficient blockade only becomes apparent after the start of the operation, a quick decision on the further procedure must be made in consultation with the surgeon. The extent of the lack of effect, the progress of the operation and, last but not least, the patient's ability to cooperate must be taken into account. Thus, occasionally short manipulations in the upper abdomen immediately after the start of surgery, for example for adhesiolysis, are (still) perceived as painful if the quality of anaesthesia is otherwise sufficient, but are temporarily tolerated by the patient with empathetic communication. The incipient regression of the blockade immediately before the end of the operation can usually be controlled by local infiltration with local anaesthetics by the surgeon. However, additional analgesic measures, such as intravenous administration of esketamine (e.g. 0.25 mg/kg bw) or opioids (e.g. remifentanil 0.05 µg/kg bw*min^{-1}) and occasionally, as ultima ratio, the induction of general anaesthesia are often necessary.

Hypotension following neuroaxial blockade

Basics

A major focus in obstetric anaesthesia is the **prophylaxis and treatment of maternal hypotension** after neuroaxial blockade. With occurrences in up to 80 % of patients, especially after **spinal anaesthesia** [31]. As there is no autoregulation of uteroplacental blood flow, such maternal hypotension can lead to **reduced uterine perfusion pressure** and thus to a **reduced supply to the foetus.** While the maternal symptoms, such as malaise, nausea and vomiting, are usually immediately apparent, the effects on the unborn child are only indirect, namely in **pathological CTG changes** or **impaired pH or APGAR scores.**

Although there is no uniform definition, a **drop in the systolic value of 10–20 % compared to the initial value** is usually considered to be relevant hypotension. A joint statement by several professional societies recommends that **a systolic**

value of at least 90 % of the baseline value should be aimed for in practice and considers values of less than 80 % to be in immediate need of treatment [32].

Prophylaxis and therapy of maternal hypotension (Tab. 4)

Since the drop in blood pressure is largely attributed to sympathicolysis, it seems to be a conceivable option to use the smallest possible amounts of local anaesthetics. In fact, lower doses also lead to less pronounced hypotension [33]. However, doses of less than 7–8 mg of bupivacaine carry an increased risk of intraoperative pain, and both a slower onset of action and an insufficiently long duration of action must be expected, so that such low doses are only recommended for CSE with the possibility of post-injection [34].

The use of vasopressors seems to make more sense with regard to the causative sympathicolysis. However, when using vasopressors, it must always be borne in mind that they influence uteroplacental blood flow and may also cause direct effects on the unborn child.

Internationally, the α-agonist phenylephrine is the gold standard [35]. Its effect is rapid and lasts for about 20 min. The most important side effect is a dose-dependent and sometimes very pronounced drop in heart rate and cardiac output [36]. Caution is therefore advised, especially in cases of pre-existing bradycardia.

Ephedrine acts as a sympathomimetic at β_1-receptors and thereby increases heart rate and contractility in particular [37). However, with a similar effect on maternal blood pressure as phenylephrine, a stronger impairment of the fetal parameters was observed after the use of ephedrine. This was most likely due to direct fetal ß-stimulation after placental passage [38]. The main advantage of ephedrine is that many years of clinical experience is available and its use can be considered, especially in maternal bradycardia.

In Germany, the use of cafedrine / theodrenaline (Akrinor®) is also common [7], which acts at both α and ß receptors. It increases mean arterial pressure, cardiac stroke volume and cardiac output [39]. The main clinical effect is via an increase in inotropy. Many years of clinical experience with Akrinor® is available in Germany, but there are hardly any prospectively collected data, especially for obstetric anaesthesia. A retrospective data analysis showed no significant difference for infantile pH and APGAR score in 268 patients treated with Akrinor® compared to treatment with ephedrine or phenylephrine [40].

Since 2015, data on the use of norepinephrine has increasingly been published and its use may even be more beneficial than established drugs in terms of fetal parameters [41]. The effect on maternal blood pressure is comparable to that of phenylephrine. However, since noradrenaline does not only have an α-adrenergic but also a weak ß-adrenergic effect, the sometimes typical bradycardia is less likely to occur [42]. It is likely that bolus applications lead to greater infant impairment than continuous administra-

Table 4
Summary of antihypotensiv substances used in obstetric anaesthesia.

Substance	Effect-site	Side effects	Usual dose	Annotations
Phenylephrine	Mainly α-receptors	• Drop in HR and CO • (regionally) reduced blood flow, CAVE: uteroplacental unit!	50–100 µg	• International gold standard
Ephedrine	Mainly ß- und little with α-receptors	• Tachycardia • Cardiac arrhythmia • AP-complaints • Headache	5–10 mg	• Compared to Phenylephrine unfavourable metabolic effects on the child (probably by direct ß-receptor stimulation after placental passage)
Noradrenaline	Mainly α- und little with ß-receptors	• Cardiac arrhythmia • (Regionally) Reduced blood flow, CAVE: uteroplacental unit!	4–6 µg	• Favourable pharmacological profile • Long clinical experience available especially outside the field of obstetrics • No explicit recommendation (yet) in clinical guidelines or such • Continuous administration probably more beneficial than bolus administration
Cafedrine + Theodrenaline (Akrinor®)	α- und ß-receptors at different positions of the cardiovascular system	• Cardiac arrhythmia • AP-complaints	1–2 ml of a mixture of 2 ml and 8 ml NaCl 0,9 %	• Only in Germany • Long clinical experience available • Limited prospective data • Probably no disadvantages compared to Phenylephrine and Ephedrine in relation to the childs outcome

AP: Angina pectoris; **HR:** Heartrate; **CO:** cardiac output.

tion, but the underlying mechanism has not yet been clearly elucidated [43]. Although there is only little data on the use of norepinephrine in risk groups and there is no explicit recommendation in guidelines or similar yet, the great familiarity with norepinephrine especially in Germany and the favourable pharmacological and clinical properties speak for the use of norepinephrine. Compared to phenylephrine, the effective dose is 1 : 17, the ED_{90} 6 µg [42].

Hypotension following neuroaxial blocks can potentially be exacerbated by the **Bezold-Jarisch reflex**. In this context, a decreased venous flow of blood to the left heart leads via mechanoreceptors to vasodilation and bradycardia. As **5-HT3 receptor antagonists** block this reflex, studies have been conducted on their effectiveness in this context, but with inconsistent results. A review published in 2016 described an effective reduction in hypotension and bradycardia, at least for obstetric populations [44], but further work could not confirm this effect [45].

A **prophylactic administration of infusions** is also common and has been proven to be effective. However, the guideline on intravascular volume therapy valid until 2020 significantly restricted the use of colloidal solutions due to a lack of data on the effects on the child, so that many clinics now mainly use **crystalloids.** However, due to the short intravascular duration, the rapid infusion of larger volumes (e.g. 1,000 ml–1,500 ml) is required during or immediately after puncture **(cohydration)** – a challenge that is rarely practicable in everyday clinical practice. With the update of the guideline, although data on placental passage is still not available, a recommendation was made for the use of colloids after weighing the risk and benefits for mother and child [46]. Because of their longer intravascular duration time, these can also be administered well before spinal anaesthesia is induced **(prehydration).** It seems sensible to combine both infusion solutions and, for example, infuse 500 ml of colloids and of crystalloids each as cohydration. However, volume administration alone is only effective to a limited extent and should at best be considered as an additional option to the use of vasopressors [32].

A review of 109 included studies and 8,561 patients ranked various pharmacological and non-pharmacological interventions. The most effective were **α-agonists,** followed by **leg wrapping, ephedrine administration** and **colloid infusion.** Although no correlations with dosages or routes of administration were investigated in this paper, these results also highlight the use of α-agonists as a primary intervention for the prevention of maternal hypotension. [47]

Side effects und complications

Itching

Itching is a frequent side effect of **intrathecally administered opioids.** Compared to the analgetic effect, it sets in quickly with the lipophilic substances fentanyl and sufentanil, but also subsides quickly. In contrast, itching triggered by morphine occurs only after a delay, but with a longer-lasting effect. The underlying pathomechanism is not fully understood. A histamine-mediated reaction is considered unlikely; accordingly, the therapeutic **administration of antihistamines** is usually **ineffective.** The often described effectiveness of prophylactically or therapeutically administered **$5\text{-}HT_3$-receptor antagonists** speaks for a possible direct activation of $5\text{-}HT_3$-receptors in the posterior horn by morphine or the synthetic opioids as a trigger. Treatment attempts with **naloxone** (0.08–0.2 mg i.v.) or subanaesthetic doses of **propofol** can also be successful [48].

Postdural puncture headache (PDPH)

Due to the use of atraumatic cannulae, PDPH after spinal anaesthesia is rare, but still plays an important role in **epidural catheterisation with accidental dura perforation** with an incidence of about 1 % [49]. The following factors, among others, have a favourable effect

- younger age,
- low BMI,
- multiple puncture attempts and
- lack of experience of the anaesthesist [50].

The headache usually occurs together with **neck stiffness, nausea, vomiting** and **altered hearing** within a few days and lasts 1–2 weeks without treatment.

Suitable **medications** include **paracetamol, ibuprofen, caffeine** and **theophylline** [7]. The most effective therapy, however, is an **epidural blood patch** by injecting about 20 ml of the patient's own blood under strictly sterile conditions. Ideally, (prophylactic) information should be provided at the start of drug therapy so that the patch can be applied quickly if symptoms persist. Recently, case reports have been published in which a **transnasal lidocaine blockade of the sphenopalatine ganglion** using a nebuliser was successfully performed for the treatment of PDPH, derived from migraine therapy [51]. Although larger amounts of data are not yet available and the dosages used so far only refer to published individual cases, this less invasive procedure appears to be an interesting option. In any case, careful examination and close monitoring of the patient is essential. If symptoms are typical and there is a good response to the treatment options described, further diagnostics are not absolutely necessary. However, if there is any doubt about the diagnosis, atypical symptoms, persistent or recurrent symptoms, a **neurological specialist consultation** and/or **imaging** should be performed. Because the symptoms can (re)appear with a time lag, it is imperative to inform the patient and the doctors who will continue to treat her after an accidental dural perforation [7].

High blockade and local anaesthetic intoxication

Because of dilated epidural veins and an expected difficult puncture, both intravascular and intrathecal catheter mispositioning and injections occur more frequently in pregnant than in non-pregnant women. This underscores both the importance of **aspiration sampling** and **test dosing** and the need for careful monitoring.

With an incidence of 1 : 4,336, a **high blockade** is the most common serious complication of neuraxial procedures in pregnant women. It can occur after both spinal and epidural injections. The cause is often an **unrecognised intrathecal** catheter misplacement, but obesity and spinal punctures after previous epidural anaesthesia are also among the risk factors [49]. Depending on the severity of the symptoms, treatment includes **ensuring oxygen supply** and **circulatory stabilisation** up to intubation and cardiopulmonary resuscitation. With adequate and timely therapy, the prognosis is good.

Intravascular catheter misplacements occur in up to 16 % of punctures [52] and can lead to **systemic local anaesthetic intoxications** with the typical neurological and cardiac symptoms, as can direct intravascular injections. Therapy following guidelines includes basic measures up to cardiopulmonary resuscitation and, if necessary, lipid rescue therapy (for a detailed description of this therapy concept, see [53]).

Spinal cord abscesses and haematomas and direct nerve damage

Rare but typical complications of all spinal cord procedures are **abscesses** (incidence about 1 : 63,000) and **haematoma** (incidence about 1 : 250,000) [49]. Both complications can lead to **(permanent para-)plegia,** especially if this is not recognised and treated in time and should be explicitly mentioned in the patient briefing. There is hardly any valid data on direct injuries to the spinal cord or nerve roots. The prognosis is usually unfavourable. This is most likely to be avoided by paying attention to expressed pain or paraesthesia during puncture and by careful selection of the puncture height.

Conclusion

Regional anaesthesia techniques can be used effectively and safely for anaesthesia for caesarean section. In-depth knowledge of anatomy, physiology and pharmacology is just as important as empathic, careful and anticipatory care of the patient and collegial interdisciplinary and interprofessional cooperation.

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