Anaesthesist
https://doi.org/10.1007/s00101-018-0499-1
Received: 8 July 2018
Revised: 18 September 2018
Accepted: 27 September 2018

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Epidural needle insertion

A large registry analysis

Introduction

Epidural anesthesia as a commonly used procedure in anesthesia improves analgesia [2] and can reduce morbidity and mortality after major surgery [17, 21]; however, administration of an epidural anesthetic imposes certain risks and can occasionally cause complications [8, 15]. Previous estimates of the incidence of vascular puncture were between 0.6% and 16% and of accidental dural puncture between 0.4% and 2.7% [5, 9, 11, 12, 15, 23, 27]. Reports of paraesthesia during midline insertion vary widely between 0.16% up to more than 50% [3, 27]. The need for multiple skin punctures, as an indicator of difficulty, ranges from 10% to 60% [4, 15, 28]. Previous studies were limited by being restricted to specific populations (e.g. obstetrics), small sample sizes (typically less than a few hundred patients), unclear spinal segment and patient characteristics that were not described in sufficient detail [3–5, 9, 11, 12, 15, 23, 27, 28]. Knowing the expected insertion depth in specific patients for certain segments might help clinicians avoid complications, such as dural puncture. A few studies have tried to estimate the correct insertion depth using mathematical models or imaging methods, such as computed tomography, magnetic resonance imaging and ultrasound [16, 24, 28]; however, none of these methods has become a part of the normal clinical routine. The relationship between midline needle insertion depth and various complications has not previously been reported in a large study population. This study therefore analyzed a large sample from the German Network of Regional Anesthesia (NRA) registry. Complications including dural puncture, vascular puncture, paraesthesias and multiple skin punctures and how each was related to midline needle insertion depth in surgical and obstetric patients were evaluated.

Material and methods

Ethics

Ethical approval for this study (Ethics Committee Kenn-Nr. 50/11) was provided by the Ethics Committee of the Saarland Medical Chamber, Faktoreistr. 4 in 66111 Saarbrücken, Germany (Chairperson San.-Rat Prof. Dr. Hermann Schieffer) on 22 March 2011. Written consent was waived as the data were anonymous, according to the regulatory proof of protection of data privacy (Saarland commissioner, 12-MAR-2014).

Study design

This study was a retrospective registry analysis of the German NRA, which was established in 2007 by the German Society for Anesthesiology and Intensive Care Medicine and the Professional Association of German Anesthesiologists. The database of the NRA collects preoperative, intraoperative, and postoperative data from treating physicians or pain nurses at 25 German centers using a standard form [29].

Participants and measurement

The registry included 129,786 patients from September 2007 to October 2015.

Published online: 18 October 2018

Table 1 Population characteristics. Continuous variables are expressed as means ± standard deviation. Categorical variables are presented as numbers of patients with percentages in parentheses. Some patients experienced more than one complications or unwanted event. Therefore, the total number of reported cases in **Table 1** is higher than the number of patients.. Other departments include, thoracic surgery, pediatric surgery, and vascular surgery

Population characteristics	No epidural complications/no unwanted events	Vascular puncture	Dural puncture	Multiple skin punctures	Paraesthesia
Cohort with complete covariables (*n* = 14,503)	**(*n* = 10,248)**	**(*n* = 126)**	**(*n* = 85)**	**(*n* = 4077)**	**(*n* = 181)**
Female (%)	5943 (58)	80 (64)	60 (71)*	2077 (51)**	133 (74)**
Age (years)	55 ± 18	54 ± 20	57 ± 20	57 ± 17**	45 ± 18**
Body mass index (kg/m^2)	26.8 ± 5.4	27.2 ± 5.0	27.4 ± 6.6	27.6 ± 5.5**	26.7 ± 5.2
ASA physical status ≥2	8877 (87)	118 (94)*	74 (87)	3739 (92)**	153 (85)
Upper thoracic (%)	575 (6)	3 (2)	3 (3)	319 (8)**	11 (6)
Middle/low thoracic (%)	5466 (53)	56 (45)	48 (57)	2706 (66)**	75 (41)*
Lumbar (%)	4207 (41)*	67 (53)	34 (40)	1052 (26)**	95 (53)*
General surgery (%)	2637 (26)	14 (11)**	33 (39)*	1375 (34)**	32 (18)*
Obstetrics (%)	1776 (17)	26 (21)	15 (18)	560 (14)**	75 (41)**
Gynecology (%)	874 (9)	6 (5)	11 (13)	346 (8)	18 (10)
Urology (%)	1383 (13)	21 (17)	3 (3)*	738 (18)**	22 (12)
Traumatology and orthopedics (%)	1716 (17)	28 (22)	12 (14)	277 (7)**	5 (3)**
Other departments (%)	1862 (18)	31 (24)	11 (13)	781 (19)	29 (16)
Year of procedure					
2007/2008	1648 (16)	19 (15)	16 (19)	602 (15)	49 (27)**
2009	1711 (17)	19 (15)	8 (9)	617 (15)*	29 (16)
2010	1775 (17)	26 (21)	16 (19)	735 (18)	39 (22)
2011	1096 (11)	19 (15)	6 (7)	471 (12)	17 (9)
2012	1103 (11)	13 (10)	7 (8)	375 (9)*	16 (9)
2013	1240 (12)	13 (10)	9 (11)	521 (13)	12 (7)*
2014/2015	1675 (16)	17 (14)	23 (27)*	756 (18)*	19 (10)*

ASA American Society of Anesthesiologists
*$p < 0.05$ versus No Epidural complications/No Unwanted events
**$p < 0.001$ versus No Epidural complications/No Unwanted events

Patients who had midline cannulation of epidural space with a specified spinal level and had information about insertion depth were considered. Inclusion criteria for the analysis were complete information about age, sex, body mass index (BMI), American Society of Anesthesiologists (ASA) physical status, obstetrical indications, surgical department, year of procedure, hospital center, vascular puncture, dural puncture, paraesthesia, midline insertion depth, systemic toxicity from local anesthetics, epidural hematoma and post-dural puncture headache. Exclusion criteria were age under 18 years and over 100 years, any neuraxial technique other than epidural, paramedian insertion or missing information on insertion technique and implausible data. Paramedian cases were not included and compared on the basis of low case numbers, i.e. 6844 out of 34,221 cases. Especially after applying all confounders there were not enough cases left to collect meaningful statistics.

Data sources and bias

Data were collected at the point of care. Data integrity was evaluated according to specific rules to minimize inclusion of erroneously entered data and delete cases lacking critical information. Rules to test plausibility of data included the following: discrepancies on entries concerning spinal level and exact spinal height (e.g. third lumbar vertebra but thoracic spinal level), cases stated as epidural but with no entry of loss of resistance, single shots per se, except for 61 cases where the rest of the data entry gave clear evidence for epidural procedure and free text statements. Midline epidural insertion depth was recorded in millimeters and entered by the clinician who inserted the epidural catheter. Depths from 2.0 cm to 15.0 cm were included in the study. Depths outside this arbitrary range were excluded as anatomically implausible. The relationship between age, height, weight, and sex was verified. Patients with a BMI of 15.2–69.9 kg/m^2 were included.

Cannulation-related complications

The primary outcomes were:
1. Vascular puncture: aspiration of bloody fluid by the puncture needle or catheter;
2. Accidental dural puncture: unintentional needle or catheter insertion through the dura mater and free

Abstract · Zusammenfassung

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Epidural needle insertion. A large registry analysis

Abstract

Background. Dural puncture, paraesthesia and vascular puncture are the most common complications of epidural catheter insertion. Their association with variation in midline needle insertion depth is unknown.

Objective. This study evaluated the risk of dural and vascular punctures and the unwanted events paraesthesia and multiple skin punctures related to midline needle insertion depth.

Material and methods. A total of 14,503 epidural catheter insertions including lumbar (L1–L5; $n = 5367$), low thoracic (T7–T12, $n = 8234$) and upper thoracic (T1–T6, $n = 902$) insertions, were extracted from the German Network for Regional Anaesthesia registry between 2007 and 2015. The primary outcomes were compared with logistic regression and adjusted (adj) for confounders to determine the risk of complications/events. Results are presented as odds ratios (OR, [95% confidence interval]).

Main results. Midline insertion depth depended on body mass index, sex, and spinal level. After adjusting for confounders increased puncture depth (cm) remained an independent risk factor for vascular puncture (adjOR 1.27 [1.09–1.47], $p = 0.002$) and multiple skin punctures (adjOR 1.25 [1.21–1.29], $p < 0.001$). In contrast, dural punctures occurred at significantly shallower depths (adjOR 0.73 [0.60–0.89], $p = 0.002$). Paraesthesia was unrelated to insertion depth. Body mass index and sex had no influence on paraesthesia, dural and vascular punctures. Thoracic epidural insertion was associated with a lower risk of vascular puncture than at lumbar sites (adjOR 0.39 [0.18–0.84], $p = 0.02$).

Conclusion. Variation in midline insertion depth is an independent risk factor for epidural complications; however, variability precludes use of depth as a reliable guide to insertion in individual patients.

Keywords

Lumbar · Thoracic · Regional anesthesia · Complication · Dural

Epidurale Punktion. Eine registerbasierte Analyse

Zusammenfassung

Hintergrund. Durapunktion, Parästhesie und Gefäßpunktion sind die häufigsten Komplikationen der Periduralkatheteranlage. Ein möglicher Zusammenhang zwischen diesen Komplikationen und der medianen Einstichtiefe ist nicht bekannt.

Fragestellung. Wir untersuchten das Risiko für Dura- und Gefäßpunktion, sowie Parästhesie und die Notwendigkeit von Mehrfachpunktionen in Abhängigkeit zur Einstichtiefe bei medianen Periduralpunktionen.

Material und Methoden. Ausgewertet wurden 14.503 zwischen 2007 und 2015 vorgenommene, im Deutschen Register für Regionalanästhesie dokumentierte epidurale Prozeduren: lumbal, L1–L5; $n = 5367$, tief thorakal: Th7–Th12, $n = 8234$, und hoch thorakal: Th1–Th6, $n = 902$, für chirurgische und geburtshilfliche Eingriffe. Das Risiko für Durapunktionen, Gefäßpunktionen und Parästhesien wurden mithilfe logistischer Regression verglichen. Störgrößen wurden adjustiert (adj). Die Ergebnisse werden dargestellt als „odds ratios" (OR) mit 95 % Konfidenzintervallen.

Ergebnisse. Die Punktionstiefe bei medianen Periduralpunktionen hängt vom „body mass index" (BMI), vom Geschlecht des Patienten und dem Wirbelkörperabschnitt ab. Gefäßpunktionen und die Inzidenz von Mehrfachpunktionen sind häufiger bei tieferem Nadelvorschub zur Identifizierung des Periduralraumes. Nach Adjustierung von Störgrößen blieb als unabhängiger Risikofaktor für Gefäßpunktion (adjOR 1,27 [1,09–1,47], $p = 0{,}002$) und Mehrfachpunktion (adjOR 1,25 [1,21–1,29], $p < 0{,}001$) eine längere Punktionsstrecke.
Im Gegensatz hierzu kommen ungewollte Durapunktionen bei signifikant niedrigeren Einstichtiefen gehäuft vor (adjOR 0,73 [0,60–0,89], $p = 0{,}002$). Die Punktionstiefe hat keinen Einfluss auf das Auftreten von Parästhesien. Geschlecht und BMI haben keinen Einfluss auf das Auftreten von Dura- bzw. Gefäßpunktionen und Parästhesien. Bei thorakalen Punktionen ist das Risiko für Gefäßpunktionen niedriger als bei lumbalen (adjOR 0,39 [0.18–0,84], $p = 0{,}02$).

Fazit. Unterschiedliche Punktionstiefen sind ein unabhängiger Risikofaktor für Komplikationen bei epiduralen Katheteranlagen. Allerdings schließt die individuelle Variabilität der Patienten die vorhersagbare Punktionstiefe als verlässliche Hilfe bei der Punktion aus.

Schlüsselwörter

Lumbal · Thorakal · Regionalanästhesie · Komplikation · Dural

cerebrospinal fluid flow or aspiration through needle or catheter;
3. Paraesthesia during needle or catheter insertion: an unexpected painful, unpleasant, or electrical sensation within the area innervated by the nerve(s) affected by the regional anaesthesia;
4. Multiple skin punctures: more than one attempt at puncture.

The secondary outcomes were:
1. Systemic local anesthetic toxicity: symptoms of intoxication (neurological and/or cardiovascular) after injection of the local anesthetic.
2. Epidural hematoma

Data analysis

The insertion depth at each spinal level (lumbar L1–5, low thoracic T7–12, and upper thoracic T1–6) and its association with sex, age, BMI, ASA physical status and obstetrical indications were compared. The BMI for the analysis of midline insertion depth was subdivided into the following groups according to the World Health Organization classification [31]: 1) underweight, 15.2–18.49 kg/m^2, 2) normal weight, 18.5–24.9 kg/m^2, 3) overweight, 25.0–29.9 kg/m^2, and 4) obese, 30.0–69.9 kg/m^2. Sex was

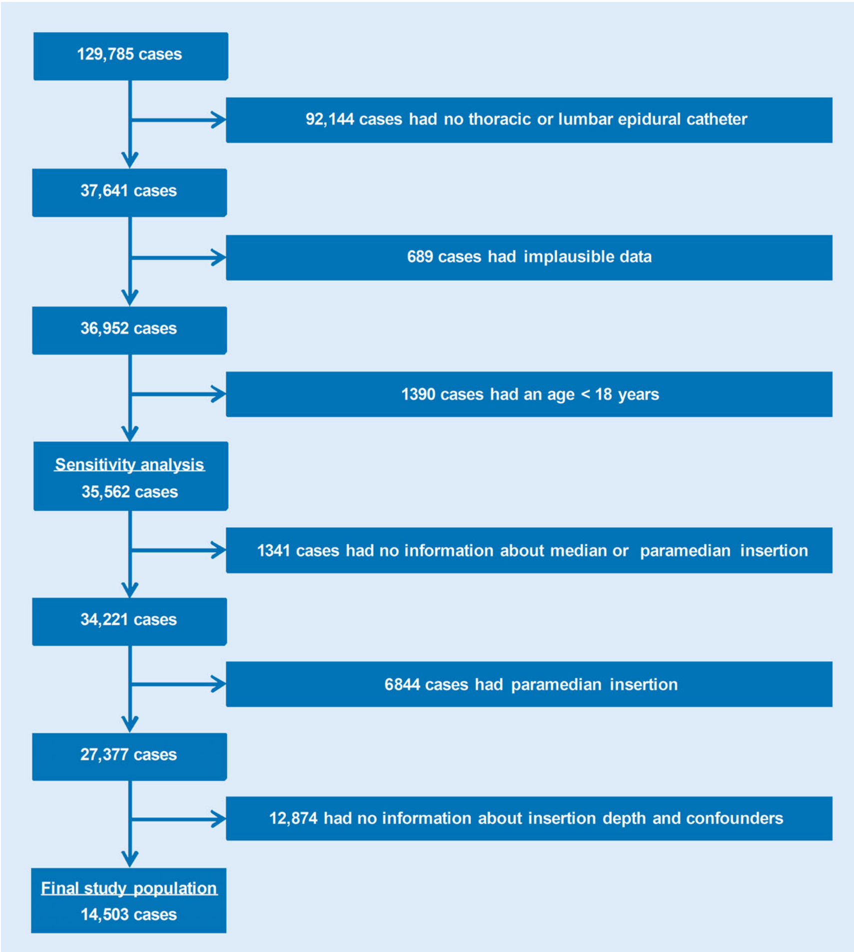


Fig. 1 ▲ Case selection. *BMI* body mass index

grouped into female vs. male. Age was subdivided in 18–39 years vs. 40–64 years vs. 65–74 years vs. >75 years. The ASA physical status score was subdivided into I vs. II vs. III vs. IV and two groups were compared using Student's *t*-test, three or more groups were compared by one-way ANOVA, followed by post-hoc analysis, including Bonferroni correction for multiple comparisons.

Binary variables in **Table 1** were compared with χ^2-tests. Continuous variables in **Table 1** were compared using Student's *t*-test. Continuous variables are expressed as mean ± standard deviation (SD). Categorical variables are presented as numbers of patients with percentages in parentheses.

Logistic regression analysis was used to calculate univariable and adjusted odds ratios (aOR) with 95% confidence intervals (CI). Calculation of ORs was made between cases with and without complications. The analysis was adjusted for age, sex, BMI, ASA physical status, spinal segments, obstetrical indications, surgical department, year of procedure, and hospital centre. Insertion depth, age and BMI were included as continuous variables, all other variables as categorical variables. Pairwise correlation coefficients were calculated for the set of confounder variables prior to inclusion in multiple regression analysis to determine whether there was much multicollinearity. Correlation coefficients exceeding +0.5 or less than −0.5 were prospectively considered to be problematic. The following correlation coefficients were calculated: Pearson or Spearman (quantitative vs. quantitative variables), H (quantitative vs. binary variables), or Cramer-V (binary vs. binary variables). All data analyses were performed using IBM SPSS Statistics, version 19 and R 2.10.1 for Windows (IBM Corp., Armonk, NY, USA). Statistical significance was accepted at a global two-sided significance level of 0.05.

Results

Participants

The final study population was 14,503 cases with full confounder information and known midline insertion depth (**Fig. 1**).

Midline insertion depth

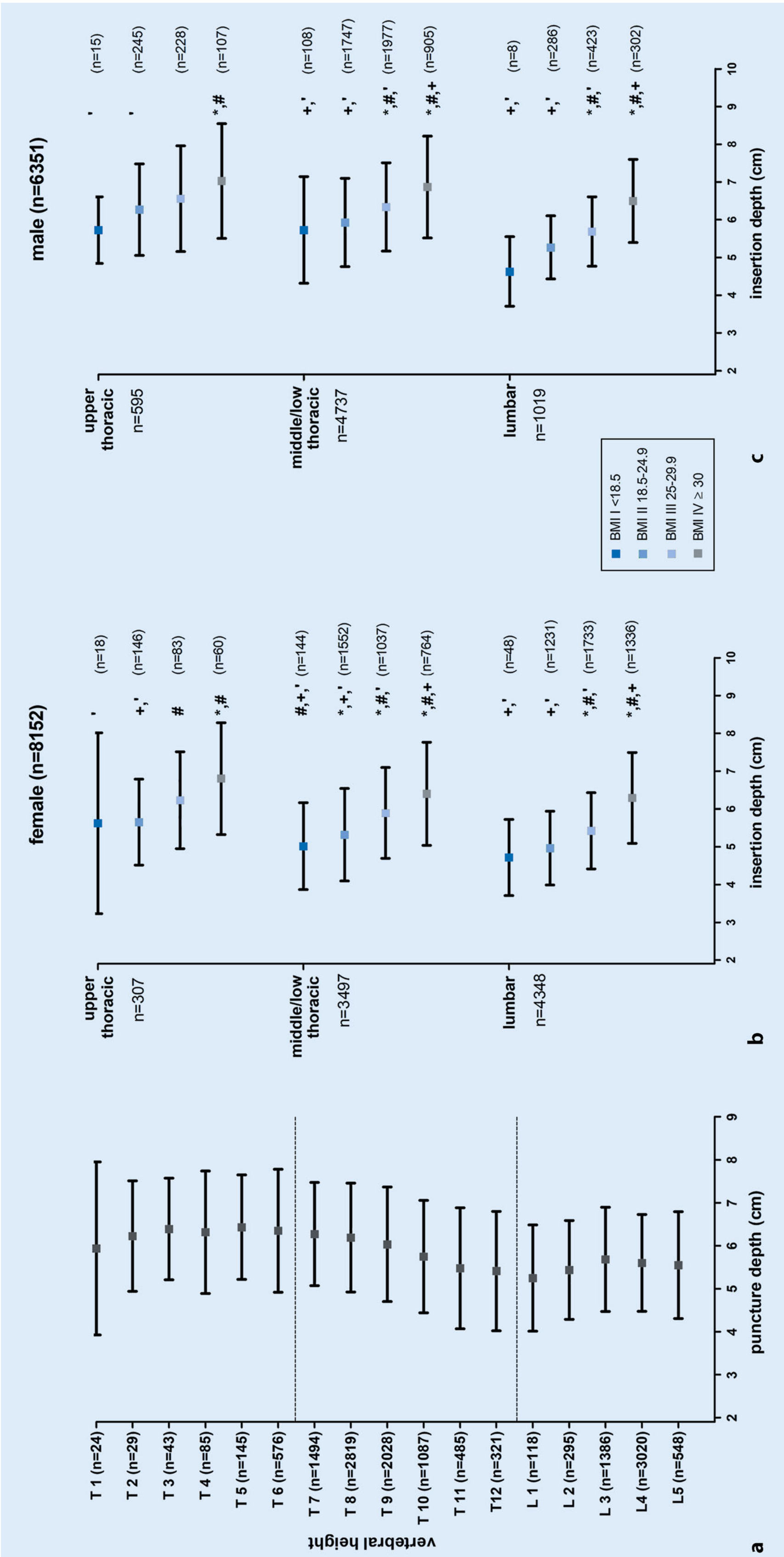
Insertion depth significantly increased from lumbar (L1–L5) to low thoracic (T7–T12) to upper thoracic (T1–T6) segments, was higher in males compared to females (6.2 ± 1.3 cm vs. 5.6 ± 1.3 cm, respectively, $p < 0.001$) and increased with rising BMI (**Fig. 2**). No influence on the insertion depth was found for the age groups (18–39 years vs. 40–64 years vs. 65–74 years vs. >75 years), ASA physical status score (I vs. II vs. III vs. IV) and obstetric compared with non-obstetric cases.

Complications and unwanted events

To ensure the results of the incidences of vascular puncture (0.9%), dural puncture (0.6%), paraesthesia (1.2%) and multiple skin punctures (28%) in the final study population of 14,503 cases, they were compared to a much larger cohort ($n = 35{,}562$), which still included patients with incomplete details of covariables and paramedian insertion technique. In this group the incidences were comparable to the final findings, with vascular puncture occurring in 0.7%, dural puncture in 0.5%, paraesthesia in 1.0% and multiple skin punctures in 29% of cases. In the final study population, the incidence of dural puncture in lumbar sites between obstetrics (0.6%) and other females (0.8%) was not significantly different ($p = 0.59$).

Potential confounders

Vascular punctures occurred more often at lumbar sites and affected patients had a significantly higher ASA physical status score (**Table 1**). Dural punctures



were most common in women. Patients requiring multiple skin punctures were significantly more often male, were older, had a higher BMI, higher ASA physical status score and more often had thoracic procedures. Paraesthesia occurred significantly more often in women, in younger patients and in obstetric patients with lumbar procedures. After adjustment for confounders, higher ASA physical status score and lumbar vs. thoracic site remained independent risk factors for vascular puncture (Table 2). Being male, a higher BMI and ASA physical status scores and thoracic vs. lumbar insertion remained independent risk factors for multiple skin punctures.

Complications and unwanted events related to midline insertion depth

In cases of inadvertent dural puncture, it was surprisingly found that needle insertion depth was generally shorter than in cases without dural penetration (Fig. 3 and Table 3). In contrast, needle insertion depth was generally deeper in cases where vascular punctures occurred compared to cases with a single uncomplicated puncture. Also, the necessity for multiple skin punctures was higher when the epidural space was deeper. Paraesthesia showed no correlation with insertion depth.

There was one case of systemic toxicity from local anesthetic and no cases of epidural hematoma in the final study population. There was little correlation among independent variables, and the absolute value of all correlation coefficients was less than 0.5.

Abb. 2 ◀ **a** Midline epidural needle insertion depth (cm) in all patients of the final study population. **b, c** Body mass index (BMI) dependent midline insertion depth (cm) in female (**b**) and male (**c**) patients. Data are presented as mean and standard deviation. $^{*}p < 0.05$ versus BMI <18.5 kg/m^2. $^{\#}p < 0.05$ versus BMI 18.5–24.9 kg/m^2. $^{+}p < 0.05$ versus BMI 25–29.9 kg/m^2. $'p < 0.05$ versus BMI ≥30 kg/m^2

Table 2 Confounder for puncture-related complications. Data are presented as odds ratios (OR) with 95% confidence interval (CI). The analysis was adjusted for age, sex, body mass index, American Society of Anaesthesiologists physical status, spinal segments, obstetrical indications, surgical department, year of procedure, and hospital centre

Confounder								
Cohort with complete covariables ($n = 14{,}503$)								
	Vascular puncture	***p*-value**	**Dural puncture**	***p*-value**	**Multiple skin puncture**	***p*-value**	**Paraesthesia**	***p*-value**
	Adjusted OR (95%CI)		**Adjusted OR (95%CI)**		**Adjusted OR (95%CI)**		**Adjusted OR (95%CI)**	
Female	1.37 (0.89–2.12)	$p = 0.16$	1.71 (1.00–2.90)	$p = 0.05$	**0.89 (0.81–0.98)**	$\boldsymbol{p = 0.01}$	1.24 (0.79–1.94)	$p = 0.36$
Age (years)	1.00 (0.99–1.01)	$p = 0.89$	1.01 (0.99–1.03)	$p = 0.21$	1.00 (0.99–1.00)	$p = 0.81$	0.99 (0.98–1.00)	$p = 0.15$
Body mass index (kg/m^2)	0.99 (0.96–1.02)	$p = 0.55$	1.01 (0.97–1.05)	$p = 0.66$	**1.04 (1.03–1.04)**	$\boldsymbol{p < 0.001}$	0.98 (0.95–1.01)	$p = 0.11$
ASA physical status ≥2	**2.80 (1.32–5.96)**	$\boldsymbol{p = 0.007}$	0.99 (0.48–2.07)	$p = 0.99$	**1.43 (1.24–1.64)**	$\boldsymbol{p < 0.001}$	1.53 (0.98–2.40)	$p = 0.06$
Obstetrics	0.60 (0.22–1.63)	$p = 0.32$	2.10 (0.63–7.02)	$p = 0.23$	1.12 (0.90–1.39)	$p = 0.32$	1.66 (0.80–3.43)	$p = 0.18$
Upper thoracic	**0.22 (0.06–0.81)**	$\boldsymbol{p = 0.02}$	0.59 (0.15–2.36)	$p = 0.46$	**1.64 (1.33–2.03)**	$\boldsymbol{p < 0.001}$	1.56 (0.65–3.74)	$p = 0.32$
Middle/low thoracic	**0.39 (0.18–0.84)**	$\boldsymbol{p = 0.02}$	1.15 (0.49–2.70)	$p = 0.75$	**1.52 (1.29–1.80)**	$\boldsymbol{p < 0.001}$	1.30 (0.64–2.62)	$p = 0.47$
Lumbar	1	–	1	–	1	–	1	–

Bold print indicates significant results
ASA American Society of Anesthesiologists, *OR* odds ratio, *CI* confidence interval

Table 3 Complications and depth of insertion. Data are presented as odds ratios (OR) with 95% confidence interval (CI). The analysis was adjusted for age, sex, body mass index, American Society of Anaesthesiologists physical status, spinal segments, obstetrical indications, surgical department, year of procedure, and hospital centre

Complications and depth of insertion (cm)		
	All spinal segments	***p*-value**
	($n = 14{,}503$)	**Complication vs no complication**
Vascular puncture (%)	126 (0.9)	–
Crude OR (95% CI)	**1.14 (1.00–1.30)**	**0.045**
Adjusted OR (95% CI)	**1.27 (1.09–1.47)**	**0.002**
Dural puncture	85 (0.6)	–
Crude OR (95% CI)	**0.73 (0.61–0.88)**	**0.001**
Adjusted OR (95% CI)	**0.73 (0.60–0.89)**	**0.002**
Multiple puncture	**4077 (28.1)**	–
Crude OR (95% CI)	**1.32 (1.28–1.36)**	**<0.001**
Adjusted OR (95% CI)	**1.25 (1.21–1.29)**	**<0.001**
Paraesthesia	181 (1.2)	–
Crude OR (95% CI)	**0.88 (0.78–0.99)**	**0.04**
Adjusted OR (95% CI)	0.99 (0.86–1.13)	0.83

Bold print indicates significant results

Discussion

Variation in midline insertion depth is an independent risk factor for accidental dural, vascular and multiple skin punctures. Paraesthesia is unrelated to insertion depth. Higher BMI does not augment risk for paraesthesia, vascular puncture or dural puncture but patients with higher BMI generally required deeper needle insertion and multiple insertion attempts for successful epidural cannulation. The insertion depths observed are consistent with previous studies conducted at various spine levels, as was the relationship to BMI and sex [1, 13, 20, 24].

The observed incidences of paraesthesia, vascular, dural and multiple skin punctures in each of the three spinal levels are largely consistent with previous studies [3–5, 9, 11, 12, 15, 23, 27, 28]. The 0.9–1.8% incidence is at the lower end of a large range of previous reports on paraesthesia with incidences from 0.16% up to more than 50% [3, 27]. A reason may be that patients were not specifically questioned about paraesthesia. Specifically eliciting paraesthesia is important because Bouman et al. [5] showed that the incidence doubles when patients are explicitly asked. The risk of vascular puncture was significantly lower in the low thoracic spinal segments than in lumbar segments. This can be easily explained by the increased density of epidural veins at lumbar sites. In contrast, multiple skin punctures were required twice as often at low thoracic than lumbar sites, suggesting that these insertions were more difficult, presumably consequent to anatomical disposition of the spinous processes as they usually run steeper and lie closer to each other at thoracic segments [7, 10, 30].

Patients with a higher BMI more often required multiple skin punctures than lean patients. In the obese, anatomic landmarks are often hard to identify, excess tissue complicates needle guidance and optimal positioning is sometimes difficult [22, 25]. It might thus be expected that insertion-related complica-

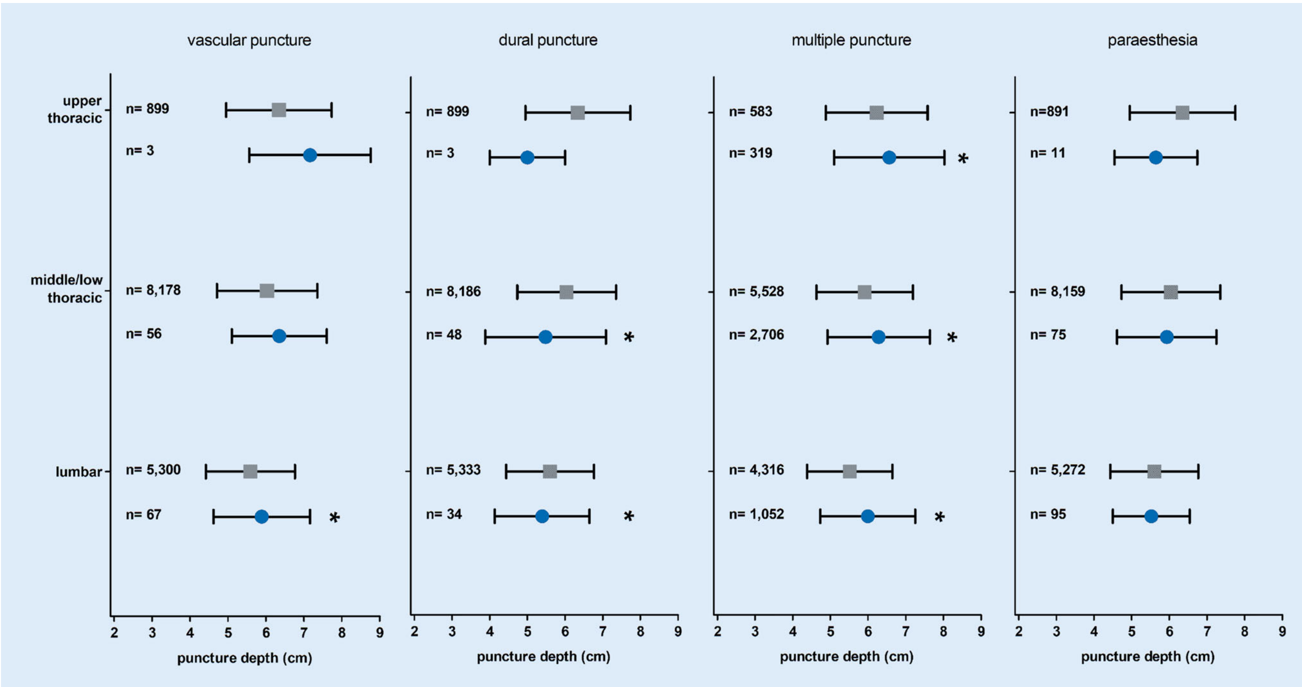


Fig. 3 ▲ Complications and midline insertion depth (cm). Data are presented as mean and standard deviation. *Blue circle*: complication. *Grey square*: no complication. $^{*}p < 0.05$ versus no complication

tions would be more common in the obese but surprisingly, higher BMI did not increase risk for paraesthesia, vascular punctures or dural punctures. The results are consistent with two large obstetrical studies, both of which also concluded that there is no important influence of BMI on accidental dural puncture [18, 19]. Similarly, Kang et al. report no influence of BMI on postoperative neurologic deficits [15].

There are contradictory reports about the relationship of accidental dural puncture and insertion depth. In a 1991 retrospective study of 3011 obstetrics patients, Sutton and Linter reported that 16% of patients had an unusually shallow epidural space and were three times as likely to have a dural puncture [26]. In contrast, two more recent large retrospective studies of 46,686 and 18,109 obstetric cases by Orbach-Zinger et al. [19]and Hollister et al. showed that dural punctures most often occurred at deeper needle insertion [14]. In the present study, mean insertion depths in cases of accidental dural puncture were lower for all spine levels (although significantly only for low thoracic and lumbar sections), thus supporting the findings of Sutton and Linter; however, there was also considerable overlap between the depths for successful placement and for dural puncture. It is thus apparent that inadvertent dural penetration is largely due to individual anatomical features of the patient rather than an unreasonably deep needle insertion.

It was found that vascular punctures occurred with deeper cannulation but only significantly so at lumbar sites. Cannulation difficulties appear unrelated to patient discomfort since paraesthesia did not correlate with insertion location or multiple skin punctures. Multiple skin puncture was associated with deeper needle insertion, possibly because practitioners expect to enter the epidural space at some point and reinsert the needle rather than inserting deeper on the initial trajectory. This matches the conclusion in this study that multiple attempts are more often required at the more difficult thoracic levels.

Several studies have tried to estimate distance from the skin surface to the epidural space with mathematical models or imaging methods, including computerized tomography, magnetic resonance imaging and ultrasound imaging [16, 24, 28]. Although ultrasound imaging by Tawfik et al. for online measurement showed no benefit, the total study population with only 108 patients was too small to determine if ultrasound might improve epidural catheterization [28]. It also has to be considered that visualization of skin to epidural space distance is not necessarily equal to the distance that has to be covered by the needle feed rate. The angular position especially in thoracic segments might cause a discrepancy between imaged and actual penetration distance. Nevertheless, ultrasound imaging could be the future to determine insertion depth and reduce the risk of complications. Especially the detection of anatomical variations such as unusually shallow epidural spaces might be helpful in the prevention of inadvertent dural punctures.

Strengths and limitations

First of all, there might be an inaccuracy of identification of vertebral height by the practitioner as shown in a study from Broadbent et al. [6] A lumbar marker was only identified correctly in 29%, in 50% of cases it differed by one lumbar vertebral height and there was no report of misjudging with thoracic heights. By grouping vertebral heights in upper and low thoracic and lumbar sites in this study the risk for this error was minimized.

The registry does not systematically include long-term neurological disorders, duration of hospitalization or mortality. Consequently, it cannot be determined whether periprocedural factors were linked to more severe outcomes. Moreover, the sample size of upper thoracic epidural cases was limited ($n = 902$) compared with middle/low thoracic ($n = 8234$) and lumbar ($n = 5367$) cases.

As in any non-randomized analysis, residual confounders may introduce error which is not eliminated by multivariable logistic regression analysis. Underreporting of complications in the registry is possible, despite prospective data collection using formal case report forms. The term paraesthesia could be incorrectly used in daily practice. It cannot be proven whether all users are able to differentiate pain caused by the penetration of a needle through nonneural tissue and pain caused by the physical contact to a nerve structure. The latter is radiating and was defined as paraesthesia. Consequently, these results should be interpreted with caution; however, the reported incidences are consistent with previous studies. In a sensitivity analysis of 35,562 cases, the incidences of complications were similar to those in the final study population.

Although epidural anesthesia has been a well-established technique for decades in anesthesiology with no ground breaking innovations in recent years, there might have been slight improvements in skills and materials during the 8-year observation period; however, the results were adjusted for the year of procedure. Results may differ for various experienced centers. Therefore, the hospital centers were added as a confounder in the multivariate analysis. Registries critically depend on the quality of data entry and handling. The validity of registry analyses thus always depends on the quality of the underlying data. In this case, insertion depth, site and complications data in the registry were specifically collected concurrent with patient care using a priori definitions and are therefore presumably reliable.

In summary, midline insertion depth is an independent risk factor for accidental dural, vascular and multiple skin punctures but not for paraesthesia. Higher BMI does not augment risk of paraesthesia, vascular puncture or dural punctures; however, higher BMI increases the risk of needing multiple skin punctures. There is considerable interindividual variation and overlap in insertion depth for successful blocks and for attempts that result in complications. It is thus concluded that clinicians cannot use estimated needle depth as a guide to safe insertion in individual patients, even considering intended insertion site and known patient features such as BMI and sex.

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Acknowledgements. The NRA investigators are all 19 participating hospital centers that collected data for the present study: Berlin—Charité CCM/CVK, Univ. Prof. Dr. Claudia Spies; Berlin—DRK Kliniken Westend, Prof. Dr. med. Arnd Timmermann; Bad Saarow—HELIOS Klinikum, Dr. med. Stefan Wirtz; Dresden—Uniklinikum, Prof. Dr. med. Thea Koch; Erfurt—HELIOS Klinikum, Prof. Dr. med. Andreas Meier-Hellmann and Dr. med. Simone Liebl-Biereige; Frankfurt—Orthopädische Uniklinik, Prof. Dr. med. Paul Kessler; Freiburg—Uniklinikum, Prof. Dr. med. Hartmut Bürkle; Hamburg—UKE, Univ.-Prof. Dr. med. Alwin E. Goetz; Hannover—Diakoniekrankenhaus Friederikenstift gGmbH, PD. Dr. med. André Gottschalk; Hannover—Ambulatory surgery centers; Homburg—UKS, Univ.-Prof. Dr. med. Thomas Volk; Jena—Uniklinikum, Prof. Dr. med. Winfried Meissner M.D.; Lengerich—HELIOS Klinikum, Dr. med. Albrecht Pfeiff; Ludwigsburg—Klinikum, Prof. Dr. med. Götz Geldner; Marburg—Uniklinikum, Prof. Dr. med. Hinnerk F. W. Wulf; Memmingen—Klinikum, Prof. Dr. med. Lars Fischer; Siegen—St. Marien-Krankenhaus, Prof. Dr. med. Werner Hering; Städtisches Klinikum Solingen gGmbH, Prof. Dr. med. Thomas Standl; Ulm—Rehabilitationskrankenhaus, Dr. med. Jörg Winckelmann

Compliance with ethical guidelines

Conflict of interest. H. Bomberg, N, Paquet, A. Huth, S. Wagenpfeil, P. Kessler, H. Wulf, T. Wiesmann, T. Standl, A. Gottschalk, J. Döffert, W. Hering, J. Birnbaum, B. Kutter, J. Winckelmann, S. Liebl-Biereige, W. Meissner, O. Vicent, T. Koch, H. Bürkle, D. I. Sessler, A. Raddatz and T. Volk declare that they have no competing interests.

Ethical approval for this study (Ethics Committee Kenn-Nr. 50/11) was provided by the Ethics Committee of the Saarland Medical Chamber, Faktoreistr. 4 in 66111 Saarbrücken, Germany (Chairperson San.-Rat Prof. Dr. Hermann Schieffer) on 22 March 2011. Written consent was waived as the data were anonymous, according to the regulatory proof of protection of data privacy (Saarland commissioner, 12-MAR-2014).

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