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RESEARCH REPORT

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Epidural versus general anesthesia for open pyloromyotomy in infants: A retrospective observational study

Philipp Opfermann[1] | Caspar Wiener[2] | Werner Schmid[1] | Markus Zadrazil[1] | Martin Metzelder[2] | Oliver Kimberger[1] | Peter Marhofer[1,3]

[1]Department of Anesthesia, General Intensive Care Medicine and Pain Therapy, Medical University of Vienna, Vienna, Austria

[2]Department of Surgery, Clinical Division of Pediatric Surgery, Medical University of Vienna, Vienna, Austria

[3]Department of Anesthesia and Intensive Care Medicine, Orthopedic Hospital Speising, Vienna, Austria

Correspondence
Peter Marhofer, Department of Anesthesia and Intensive Care Medicine, Orthopedic Hospital Speising, Speisinger Str. 109, Vienna A-1130, Austria.
Email: peter.marhofer@oss.at

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Abstract

Background: Thoracic epidural anesthesia for open infantile hypertrophic pyloric stenosis surgery is a controversial issue in the presence of little comparative data.

Aims: To compare this approach to general anesthesia for desaturation events (≤90% oxygen saturation) and absolute values of minimal oxygen saturation, minimal heart frequency, operating-room occupancy time, and durations of surgery in a retrospective study design.

Methods: Data were retrieved for patients with infantile hypertrophic pyloric stenosis managed by thoracic epidurals under sedation or general anesthesia with rapid sequence induction between 01/2007 and 12/2017. Oxygen saturation and heart rate were analyzed over eight 5-minutes intervals relative to the start of anesthesia / sedation (four-time intervals) and before discharge of the patient from the operating room (four-time intervals). Fisher's exact tests and mixed model two-way analysis of variance for repeated measures were employed for intergroup comparisons.

Results: The epidural and general anesthesia groups included 69 and 32 evaluable infants, respectively. Patients managed under epidural anesthesia had cumulatively higher minimimal mean (SD) oxygen saturation values (98.2 [2.6] % versus 96.6 [5.2] %, $p < 0.001$) and lower minimal mean (SD) heart rate values (127.9 [15.0] beats per minute versus 140.7 [17.2] beats per minute, $p < 0.001$) over time. Similarly, the frequency of desaturation events (defined as ≤90% oxygen saturation) was significantly lower for these patients during the period of 5 minutes after induction of sedation or general anesthesia (odds ratio 7.4 [2.1–25.9]; $p = 0.001$) and during the subsequent period of five minutes (odds ratio 6.2 [1.1–33.9]; $p = 0.031$). One case of prolonged respiratory weaning was observed in the general anesthesia group. The mean (SD) operating-room occupancy was 61.9 (16.6) minutes for the epidural anesthesia group versus 73.3 (22.2) minutes for the general anesthesia group ($p = 0.005$) as a result of shorter emergence from sedation.

Philipp Opfermann and Caspar Wiener contributed equally to this work

Conclusions: In our series, maintaining spontaneous breathing with minimal airway manipulation in patients undergoing open repair of hypertrophic pyloric stenosis under single-shot epidural anesthesia resulted in fewer desaturation events ≤90% than general anesthesia. In addition, this approach seems to result in shorter turnover times in the operating room.

KEYWORDS
anesthesia epidural, anesthesia general, hypertrophic, infant, pediatrics, pyloric stenosis

1 | INTRODUCTION

Infantile hypertrophic pyloric stenosis (IHPS) is a common indication for surgery with reported incidence rates of 0.9 to 5.1 per 1000 live births.[1] Its main symptoms of projectile vomiting, poor feeding, weight loss, and dehydration due to gastric outlet obstruction that usually becomes manifest at three to five weeks of age.[2] More cases in boys than in girls have been reported by a factor of four to six.[3] IHPS is treated by extramucosal incision of the pylorus muscle, known as pyloromyotomy, aimed at establishing normal patency for stomach content to pass into the duodenum. To prevent aspiration due to the gastric outlet obstruction,[4] this procedure usually takes place under general anesthesia with tracheal intubation, commonly involving rapid induction techniques to instantly secure the airway and minimize the aspiration risk.[5]

Few reports are currently available on various neuroaxial techniques, including spinal and caudal anesthesia, as alternative anesthetic approaches to IHPS surgery in the absence of tracheal intubation and mechanical ventilation.[6-9] Concerns related to spinal anesthesia include unpredictable spread of local anesthetic in a cranial direction, carrying a risk of cardiac or respiratory failure, and the subject of caudal blocks is liable to raise the issue of inadequate anesthesia. These considerations prompted us to manage IHPS patients by single-shot thoracic epidurals combined with sedation.[4] However, the relative efficiency of thoracic epidural anesthesia under sedation in comparison with general anesthesia and rapid sequence induction (RSI) continues to be poorly evaluated in infants with IHPS and remains a highly controversial issue.[10,11]

We therefore conducted an observational retrospective study to compare, based on data available from a tertiary referral center with a catchment area of 3.5 million inhabitants, general anesthesia using rapid sequence induction to single-shot epidural anesthesia combined with sedation in managing infants undergoing open pyloromyotomy. The primary objective of the investigation was to assess the frequency of desaturation events ≤90% SpO_2 and to compare the minimal SpO_2 (%) values and heart rate between the two groups during the first and the last 20 minutes of anesthesia / sedation. Secondary objective was to compare the duration of operating-room occupancy and surgery for the different anesthesia management groups.

What is already known

- Single-shot thoracic epidural anesthesia under sedation is a feasible method of anesthetic management in the surgical treatment of infantile hypertrophic pyloric stenosis (IHPS).
- However, compared to the standard approach of general anesthesia, its feasibility is poorly documented and remains a highly controversial issue.

What this article adds

- Maintaining spontaneous breathing with minimal airway manipulation can be an alternative to general anesthesia in IHPS patients that involves fewer and less severe desaturation events (≤90% SpO_2) and shorter turnaround times in the operating room.

2 | MATERIAL AND METHODS

2.1 | Study preparation

Approval of the study protocol was obtained from the institutional review board (ethics committee of Medical University of Vienna, EK1358/2018). The study was registered in the German Clinical Trial Register (DRKS00021296) and conducted at the Department of Pediatric Surgery at Vienna General Hospital (Medical University of Vienna), a tertiary referral center with a catchment area of 3.5 million inhabitants, by retrospective analysis of prospectively collected and validated data on IHPS patients who were treated by open pyloromyotomy according to the Weber-Ramstedt technique between 01/2007 and 12/2017.

2.2 | Data collection and verification

Patients were identified by systematic interrogation of the AKIM (AKH Information Management, Vienna, Austria) and IntelliSpace Critical Care and Anesthesia (Philips, Germany) databases, both

being separate systems for patient documentation and information that operate prospectively and independently of each other. Predefined datasets were extracted that included baseline characteristics (e.g., age, sex, weight) as well as intra- and postoperative data. Completeness and overlap were cross-checked between the databases to avoid selection bias. Where values were missing, alternative data sources (e.g., hospital records) were explored before inclusion was considered. Values were replaced by appropriate subgroup medians if ≤5% were missing.

2.3 | Exclusions and patient groups

Cases with >5% missing values were excluded from analysis, as were patients treated by laparoscopic surgery or managed by primary planned general in combination with caudal or epidural anesthesia (GA and after induction caudal or EA for pain management with 0.2% ropivacaine). These exclusions resulted in homogeneous groups for comparison, one managed by general anesthesia using rapid sequence induction *(GA group)* and the other one by single-shot epidural anesthesia and sedation *(EA group)*.

2.4 | Extended inclusion strategy

Given the 12-year period from 01/2007 through 12/2017, we included 20 cases already reported in our 2011 proof-of-concept study.[4] This all-inclusive strategy was useful not only to increase the sample size and reduce the interquartile ranges / standard deviations, but also to facilitate the intended comparison of epidurals-plus-sedation to general anesthesia, as the latter had been used predominantly and routinely in the anesthetic management of IHPS surgery at our institution before that original study.

Our comparison of cases is historical and includes different successive departmental strategies over time: before 2008, GA with RSI, from 2008 to 2011, a combined procedure (GA and analgesic EA performed after intubation) and since 2011 EA under sedation. In order to obtain two clearly separated and homogenous groups, the cases of combined GA and EA/caudal anesthesia conducted in the years 2008–2011 were not included in the present study. Moreover, we recorded no case of GA because of block failure of a planned EA and sedation.

As we use the epidural approach on a routine basis since 2011, excluding the preceding cases under GA would have resulted in loosing >30% of patients from the sample and increasing the risk of selection bias, aside from the fact that the respiratory endpoints analyzed in the present study were not a major focus of the original investigation.[4]

The study question in this series was to determine whether the sedated infants with an EA had any disadvantage in regard to oxygenation and airway protection compared to those managed under GA with airway protection years ago.

2.5 | Outcome measures

Oxygen saturation (SpO_2) as measured by standard pulse oximetry (Dräger Infinity®; Drägerwerk) served as the primary outcome measure of respiratory safety. As illustrated in Figures 1 and 2, the first 20 minutes into the actual anesthesia and the last 20 minutes in the operating room (before discharge to the recovery room) were divided into 5-minute intervals (2 × 4 × 5 minutes = 8 intervals in total) and the lowest SpO_2 values on record per patient per interval were gathered separately from the two aforementioned databases. Parameters for group comparison included the lowest SpO_2 values and the number of desaturation events ≤90% SpO_2 per interval. As secondary outcome measures, we analyzed the lowest heart rates (in bpm) per interval and the durations of anesthesia, the operating-room occupancy time, and the total dose of propofol administered. Patients in the EA group were followed up for potential complications such as infections or neurological deficiencies. In addition, every anesthesia record was inspected searching for any unexpected event reported, as required by department policy by each anaesthesist before saving of the document at the end of the procedure and before discharge of the patient out of the OR. These protocol sections were extracted to assess clinically apparent aspirations, that have been documented in this section. Additionally, in cases with desaturations ≤90% SpO_2 the record was scrutinized looking for any other sign of aspiration (e.g., bronchoscopy at the end of the procedure). Finally, we reviewed the hospital discharge letter for any remarks about pulmonary aspiration.

2.6 | Anesthetic management

All infants were managed by experienced pediatric consultant anesthesiologists in accordance with our departmental standard for epidurals-plus-sedation or GA.

On arrival in the OR, each infant was placed on a forced-air warming blanket (Bair Hugger; Arizant), standard monitoring (electrocardiography, SpO_2, non-invasive blood pressure) initiated, and Elo-Paed balanced plus glucose 1% (10 ml/kg/hour) administered. All infants had a gastric tube in situ when admitted to the OR for gastric emptying.

In the *GA group*, RSI was performed in accordance with the departmental standard using propofol 2–3 mg/kg, rocuronium 0.6 mg/kg, and fentanyl 0.005 mg/kg after preoxygenation. Bradycardia or hypotension to >25% below baseline were treated with atropine 0.01 mg/kg or a fluid bolus of 10 ml/kg.

The *EA group* included sedation with a loading dose of propofol 1.0–2.0 mg/kg and, if needed, supplementary doses of 0.5 mg/kg. The initial patients managed under EA and sedation received additionally 0.1 mg/kg nalbuphine. The regime was stopped after 23 patients and we continued by a "propofol" only approach. The modification in the sedation regime was based on the consideration that well-working epidural blocks do not need systemic pain therapy.

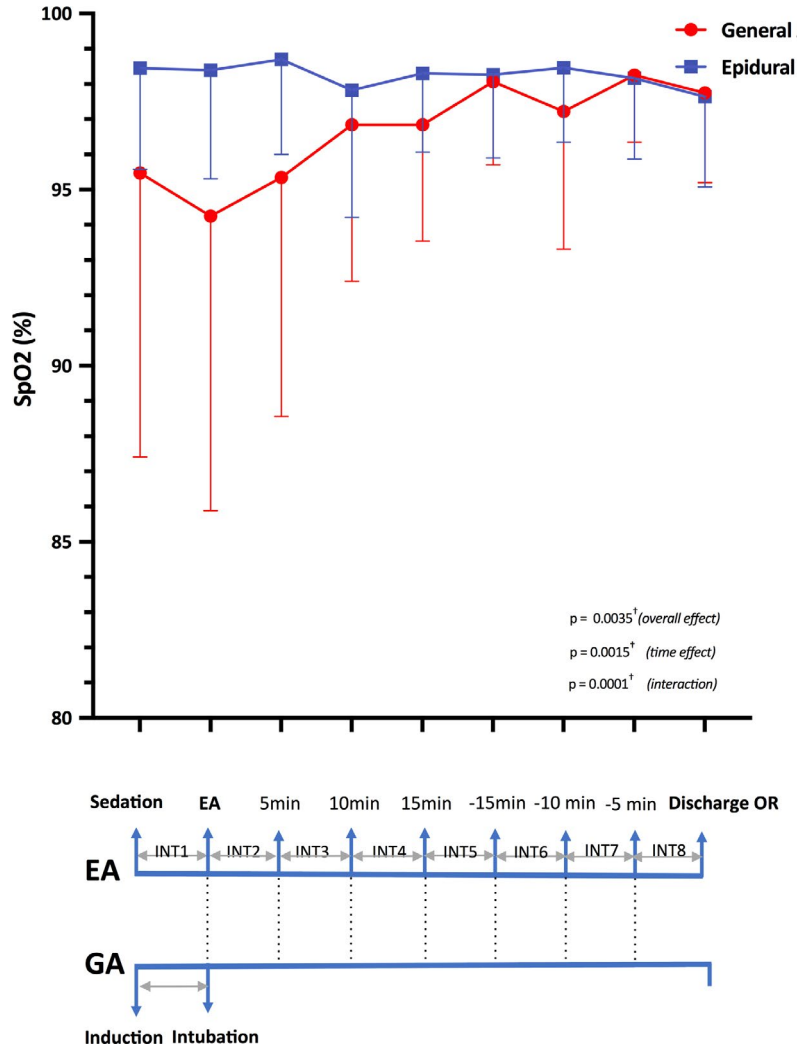

FIGURE 1 Lowest SpO_2 values within anesthesia-related intervals: Given are means (SD) indicating the lowest values of peripheral oxygen saturation (SpO_2) on record for defined anesthesia-related intervals. As the y-axis ends with 100%, the error bars (SD) are only displayed for the lower margin. EA, epidural anesthesia; GA, general anesthesia; INT, interval; OR, operating room. †Mixed model two-way analysis of variance for repeated measures and "post hoc" Bonferroni correction [Colour figure can be viewed at wileyonlinelibrary.com]

End-tidal CO_2 sampled below the facemask supplying O_2/air (FiO_2 50%) was used to continuously verify spontaneous breathing. The single-shot epidural puncture took place under sterile conditions with the child in a left lateral position, directly visualizing the neuroaxial structures through a linear transducer (38 mm, 13–6 MHz) wrapped in a sterile cover and connected to a portable ultrasound unit (M-Turbo; SonoSite) as described elsewhere.[12] No EMLA (euthetic mixture of local anesthetic) cream was used over the babies back. A loss-of-resistance technique with a small volume of saline was used for median insertion of a Tuohy needle (Perifix™ ONE Paed Set 20G, 0.9 × 50 mm; BBraun Inc.) between the T10 and T11 vertebral spaces, injecting a total of 0.75 ml/kg ropivacaine 0.38% (2:1 mixture of Naropin™ 2 mg/ml and Naropin™ 7.5 mg/ml; AstraZeneca Inc.) under paramedian ultrasound visualization, followed by supine repositioning. This technique was conducted by one anesthesiologists, who initially visualized the relevant anatomical neuroaxial structures with ultrasound, performed the loss-of-resistance puncture with saline and observed the spread of fluid in the epidural space again with ultrasound. A second anesthesiologist was responsible for airway surveillance and support, if necessary. Epidural blockade was considered adequate if the heart rate stayed within 15% of baseline and the child did not move at skin incision.

2.7 | Statistical analysis

Patient characteristics are presented in the form of conventional summary statistics as median values with interquartile ranges (IQR), mean or mean differences with corresponding standard deviations (SD) or as absolute numbers in conjunction with percentages. All data were screened for completeness, consistency, and outliers prior to analysis. Continuous variables were compared using the Mann–Whitney *U* test or *t* test stastistics if appropriate. Proportions were compared using Fisher's exact test. Risk ratios or odds ratios for dichotomous variables were reported with 95% confidence intervals. SpO_2 (%) values and heart frequency

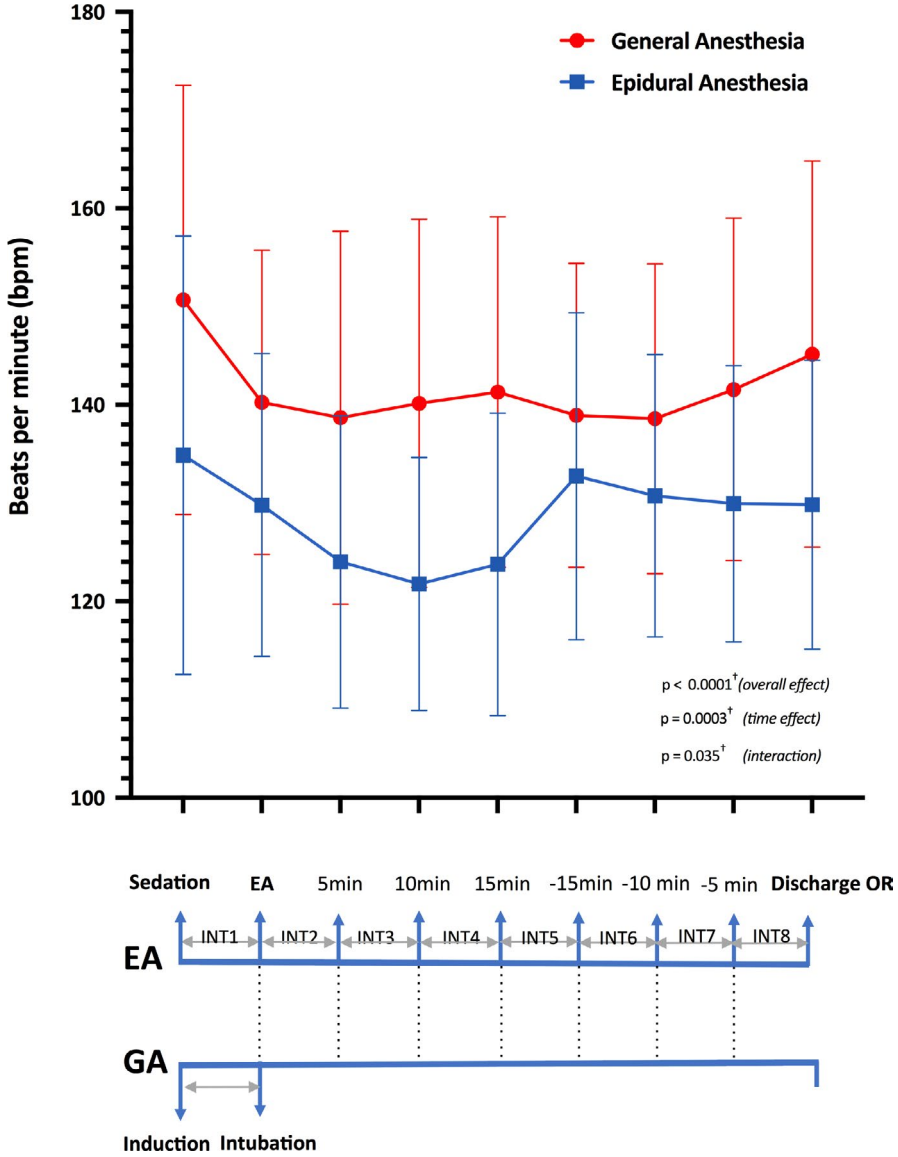

FIGURE 2 Lowest heart rates within anesthesia-related intervals: Given are means (SD) indicating the lowest heart rates (bpm) as a measure of sympatholysis on record for defined anesthesia-related intervals. EA, epidural anesthesia; GA, general anesthesia; INT, interval; OR, operating room. †Mixed model two-way analysis of variance for repeated measures and "post hoc" Bonferroni correction [Colour figure can be viewed at wileyonlinelibrary.com]

over time have been examined using mixed model two-way analysis of variance for repeated measures and "post hoc" Bonferroni correction. All tests were carried out as two-sided tests and all differences considered to be significant at $p < 0.05$. Appropriate statistical software was used for all operations in our analysis, including IBM® SPSS® Statistics (version 24.0.0.0; IBM) and GRAPHPAD PRISM® (version 8.0.2; Graphpad software).

3 | RESULTS

A total of 143 IHPS patients were originally eligible for inclusion, 42 of whom had to be excluded due to management by both primary planned combined general and epidural anesthesia (with 0.2% ropivacaine), which was the departmental standard for cases of the year 2008 till 2011.

The remaining 101 infants could be analyzed, encompassing 69 cases in the epidural versus 32 cases in the GA group. Table 1 lists selected preoperative characteristics of these patients. Table 2 illustrates anesthesia/sedation details. Changing of the sedation regime after 23 cases to a "propofol only" approach after 23 cases had no influence on the conditions for the anesthesiologist performing the EA.

The success rate of thoracic epidural anesthesia was 100%. None of the infants in the epidural group had intraoperative complications or block failure requiring "secondary" general anesthesia. Neither did this group involve any complications related to the epidurals. The GA group did show one case of prolonged weaning not permitting extubation in the operating room, the suspected reason being pulmonary infection.

TABLE 1 Preoperative patient characteristics, expressed as median values with interquartile ranges

Demographics and parameters at admission	Epidural anesthesia (*n* = 65)	General anesthesia (*n* = 32)
Boys	*n* = 56 (81.2%)	*n* = 29 (29.6%)
Age (days)	37 (28–53)	37 (29–53)
Weight (grams)	4070 (3400–4600)	4070 (3408–4488)
Pyloric thickness (mm)	5.0 (4.0–5.5)	5.0 (4.0–5.0)
Pyloric length (mm)	19.5 (17.5–20.0)	20.0 (19.2–20.0)
pH	7.4 (7.4–7.5)	7.4 (7.4–7.4)
Sodium (mmol/L)	138 (139–139)	137 (136–139)
Chloride (mmol/L)	102 (100–104)	102 (99–103)
Potassium (mmol/L)	4.9 (4.5–5.3)	5.0 (4.6–5.2)

TABLE 2 Anesthesia / Sedation details

	Epidural anesthesia (*n* = 65)	General anesthesia (*n* = 32)	*p*-Value (*t*-test)
Total propofol per body weight (mg/kg)	2.9 (2.0)	4.3 (1.4)	.002
Total Nalbuphine (mg)[a]	0.4 (0.8)	n.a.	n.a.
Ropivacaine (mg/kg)	3.1 (0.05)	n.a.	n.a.

Note: All values are mean (SD).

[a]Nalbuphine was used for the first 23 cases in the epidural anesthesia group for sedation.

TABLE 3 Desaturation events (≤ 90% SpO_2) during the first four anesthesia-related intervals analyzed

Intervals relative to the start of anesthesia	Epidural anesthesia (*n* = 69)	General anesthesia (*n* = 32)	*p*-Value (Fisher's exact test)	Odds ratio (95% CI)
INT 1	4 (5.8%)	10 (31.3%)	.001	7.4 (2.1–25.9)
INT 2	2 (2.9%)	5 (15.6%)	.031	6.2 (1.1–31.9)
INT 3	4 (5.8%)	4 (12.5%)	.218	2.3 (0.5–9.9)
INT 4	1 (1.4%)	3 (9.4%)	.093	7.0 (0.7–70.5)

Note: Values for epidural and general anesthesia are absolute numbers (%). INT1 indicates the time from sedation to the epidural or, in the general-anesthesia group, from induction to intubation; INT2–INT4 express the time intervals (5 minutes per interval) into the actual anesthesia.

Abbreviation: INT, interval.

Four patients in the EA group received supportive bag-mask ventilation as part of the desaturation events ≤90% (INT1, Table 3).

Figure 1 illustrates the chronological sequence of the lowest SpO_2 values per interval which were significantly higher in the epidural than in the GA group. The ANOVA for repeated measurements showed a significant overall (p = .0035), time (p = .0015), and interaction effect (p = .0001) for the type of anesthesia.

Table 3 reveals that fewer desaturation events (≤90% SpO2) occurred in the epidural group during the first two time intervals.

The cumulative minimal mean (SD) heart rate value of patients managed under EA was 127.9 (15.0) beats per minute versus 140.7 (17.2) beats per minute for those managed under GA (p = .000). The mean (SD) values for SpO_2 and heart rate and the mean (95%CI) differences of these values between epidural and GA groups for INT1-8 are illustrated in the Table S1.

The mean (SD) total operating-room occupancy time was 61.9 (16.6) minutes for the EA group versus 73.3 (22.2) minutes for the GA group (p = .005) due to significantly shorter mean (SD) emergence from sedation / anesthesia of 5.2 (4.3) minutes versus 29.3 (20.3) minutes (p = .000), respectively.

The total mean (SD) dose of propofol was 2.9 (2.0) mg/kg for the EA group and 4.1 (1.4) mg/kg for the GA group (p = .001). The mean difference (95% CI) for the total dose of propofol was and 1.3 (1.3–1.3) mg/kg.

4 | DISCUSSION

Compared to infants managed by GA with RSI for IHPS surgery, those managed by epidurals-plus-sedation were found to show significantly fewer and less severe desaturation events (≤90% SpO_2) and lower HR values (due to the sympatholytic effect of EA). Additionally, the epidural approach reduced the nonsurgical time spent in the operating room.

Infantile hypertrophic pyloric stenosis surgery in infants is usually managed by GA with endotracheal intubation.[5] In a recent

survey of SPA (Society for Pediatric Anesthesia) members, 85.5% of respondents indicated that they used RSI techniques in managing IHPS surgery.[13] The notion that RSI carries a high risk of airway complications and hypoxia has recently been confirmed by 40% or 15% rates of hypoxemia associated with classical or modified RSI in neonates undergoing pyloromyotomy, respectively.[5] This result further adds to the issue whether IHPS patients may incur greater risks by RSI-related problems or by complications associated with the absence of airway protection.

The present study revealed no complications except one case of prolonged respiratory weaning in the GA group, the suspected cause having been pulmonary infection. The fewer and less severe desaturation events with a SpO_2 ≤90% seen in the epidural group may be to a certain degree explainable by the sustained spontaneous breathing and supplemental oxygen by mask. However, it is not a proof of a causal relationship. While severe aspiration is rarely seen in children,[14] anesthetists will certainly subscribe to tracheal intubation in infants being a high-risk technique that requires special hand skills and experience to avoid hypoxemia.

We do concur with Bosenberg and Lonnqvist[11] that intubation should not be avoided "at all costs" and epidurals not be performed unless by experienced pediatric anesthesiologists with particular skills in neuroaxial regional anesthesia. Centers with high case loads and experienced pediatric anesthetists could, however, consider neuroaxial anesthesia in newborns under sedation as an alternative approach to GA without an apprehension of increased risk of respiratory problems and the advantage of spontaneous breathing with *minimal airway manipulation*.

Still, it is fair to ask whether neuroaxial anesthesia adds true value or may actually entail a less favorable risk-benefit profile than standard GA in IHPS patients. We identified no incidents related to the single-shot epidurals in the present study but our 69 cases cannot possibly form a basis for a final conclusion about thoracic epidurals in IHPS patients. Ho et al[15] addressed in a recent article the important problem of risk estimation when a complication of interest has had 0 occurrences after n trials. Referring to "Rule of 3" from the original work of Hanley and Lippman-Hand[16] this would imply a upper limit of the 95% CI of 0.043 (3/69) for a deleterious outcome in our series. Even though this approach may produce risk estimates that seem conservative, a risk of 4.3% for example for infections would be inacceptable high. However, depending on the complication and the risk-benefit calculus, clinicians and decision makers may not be only interested in the worst-case scenario.[17] Nevertheless, the above mentioned illustrates that we have to be aware that even if a potential complication has not occurred yet, does not imply that the risk does not exist at all.

The 2007 United Kingdom audit revealed 56 incidents in 10.633 epidurals in children.[18] Out of the 529 epidurals in neonates—which included six incidents (1.13%)—75 were thoracic and involved one minor incident related to a drug error. The results of this UK audit for epidural catheter insertion under general anesthesia are not comparable to the risk rates of our technique of single-shot ultrasound controlled EA under sedation.[4] In any case, pediatric epidural anesthesia is a technique, which is performed only by a minority of anesthetists who are specialized in the field of pediatric anesthesia. Therefore, epidural anesthesia in sedated—nonintubated—children is still performed only by specialized centers in this field.[19] Thus, it is not expected that in the near future large multicenter studies comparing the risks of EA under GA with that of ultrasound controlled EA under sedation will be published. However, there are recently upcoming smaller studies that report encouraging data addressing the management of neonates with hypertrophic pyloric stenosis without GA.[6,20] Sanchez-Conde et al[20] found a significant reduction of apnea and desaturation episodes after spinal anesthesia (SA) under sedation compared to patients with hypertrophic pyloric stenosis managed with GA. These authors presented similar SpO_2 trends for GA and SA compared to our data with higher SpO_2 values seen in patients under SA and sedation.[20] We appreciate the work of Sanchez-Conde and coworkers and sympathize with the views an advantages of a management of hypertrophic pyloric stenosis patients without the use of GA. However, we have some concerns about SA in infants predominantly as related to the danger of high spinal block,[6] the short block duration limited to 1–1.5 hours,[21] the specific anatomical variations of the spinal axis between neonates and infants compared to the adult population[21] and—not least—because we have not enough personal experience with SA in newborn.

Neonates and infants are at increased risk of local anesthetic systemic toxicity. [22] In this context, the lesser amount of local anesthetics used for block has been proposed to be an advantage of SA compared to the epidural approach. As established doses for SA, exemplary, 0.5% hyperbaric or hypobaric bupivacaine 0.2–0.6 mg/kg have been reported.[21,23] However, Bosenberg et al[24] reported that after continuous epidural infusion of ropivacaine 0.2% (0.2–0.4 mg/kg/hour) for 48–72 hours the plasma concentrations of unbound ropivacaine were well below threshold concentrations associated with systemic CNS toxicity in adults (≥0.35 mg/L). We used a dose of 0.75 ml/kg of 0.375% ropivacaine to perform either epidurals or caudals under sedation without GA to achieve an adequate surgical tolerance, which is considerably above the ASRA/ESRA guideline from 2018.[25] However, the guideline itself states that there is no high-level evidence yet available to guide dosage of LA used in regional blocks in children.[25] Compared to the dose of Bosenberg et al[24] our dose regime means a increase of the dose for the single-shot epidural of almost 29%. We know extrapolating from peak plasma concentrations obtained in another age group is open to criticism but pharmacokinetic data from our department showed that, at least in children of 30–50 kg bodyweight, peak plasma levels measured after the caudal administration of 1 ml/kg ropivacaine 3.1% were within a safe range.[26]

Pyloric stenosis can result in metabolic alkalosis that favors respiratory depression and this can be amplified by the use of opioids.[20,27] Epidural as well as spinal anesthesia provides the advantage of opioid free or opioid reduced anesthesia.

Looking beyond medical issues neuroaxial anesthesia for IHPS in our study reduced significantly the total durations of operating-room occupancy by a median of 15 minutes. The shorter postsurgical stay due to uninterrupted spontaneous breathing reduces the total durations of treatment and the time spent in operating

rooms for nonsurgical reasons. A similarly timesaving effect of neuroaxial anesthesia in the management of open pyloromyotomy has been reported by Kachko et al.[6]

Some limitations of our study are worth considering. This was not a randomized controlled trial but a historical comparison between a group given a GA before 2008 and another managed under two different sedation regimes (propofol + nalbuphine, propofol) since 2011. The retrospectively collected data are subject to variability in documentation practice, and constraints also arise from which data are routinely recorded. Additionally, the retrospective character of this present study limits its proposition and any assumption of causation must be treated cautiously. While we addressed these former issue by systematically reviewing all records for plausibility and consistency, there was no way for us to categorically rule out any bias due to artifactually false or inaccurately low SpO_2 values (e.g., due to patient movements). Another limitation is due to resolution of our anesthesia recorder, which collected vital signs in one-minute intervals, so that the truly lowest SpO_2 values and heart rates may occasionally not have been captured within the defined intervals.

5 | CONCLUSION

In specially trained hands, single-shot thoracic epidural anesthesia under sedation maintaining spontaneous breathing can be considered as alternative to general anesthesia in children.

CONFLICT OF INTEREST

None to declare.

DATA AVAILABILITY STATEMENT

The original data are available upon request.

ORCID

Werner Schmid https://orcid.org/0000-0002-8868-5942
Peter Marhofer https://orcid.org/0000-0002-1647-3780

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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