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ORIGINAL ARTICLE

Swedish registry study showed that 50% of paediatric operations were performed in university hospitals and mortality was low

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Abstract

Aim: To investigate the distribution of paediatric surgery in various hospitals and to study postoperative risk factors of mortality.

Methods: Retrospective registry-based cohort study of children aged 0–14 years undergoing surgery from 2017 to 2021. Data were extracted from the Swedish Perioperative Registry. A mixed logistic regression was applied for the all-risk mortality analysis.

Results: A total of 126 539 cases were identified, 50% in university, 36% in county and 14% in district hospitals. The dominating operations were appendectomy in 6667, orchidopexy in 5287, inguinal hernia repair in 4200 and gastrostomy in 1152 children. Among children under 1 year of age or American Society of Anesthesiologists Physical Status classification (ASA-PS-Class) 3–5, the majority underwent surgery in university hospitals. The 30-day mortality in university hospitals was 0.5% and in county hospitals 0%. The proportion of emergency surgery was similar in university and county hospitals. Independent risk factors of mortality were being under 1 year of age, ASA-PS-class 4–5, emergency surgery and surgery at university hospitals.

Conclusion: Half of all operations in children were performed in university hospitals, with low postoperative mortality despite effective centralisation of high risk patients <1 year of age or ASA-PS-Class 3–5.

KEYWORDS
centralisation, mortality, paediatric surgery, risk factor, university hospital

1 | INTRODUCTION

In Sweden, around 140 000 children and adolescents under the age of 18 underwent surgery every year during the years 2017–2019 before the pandemic, according to the National Board of Social Affairs and Health.[1]

In 2018, a centralisation process was performed in Sweden. Surgery for anorectal malformations, Hirschsprung's disease, oesophageal atresia, diaphragmatic hernia and bladder exstrophy were centralised from four to two paediatric surgical centres. These diagnoses account for 110–120 cases per year. The centralisation process was based on the theory that surgery performed in a high-volume

Abbreviations: ASA-PS-class, American Society of Anesthesiologists Physical Status classification; ICD-10, International Classification of Diseases, Tenth Revision (ICD-10).

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hospital would be associated with improved outcome.[2–4] Increasing hospital and surgeon volume has been associated with improved outcomes in adult patients.[5,6] A similar relationship has been shown in the paediatric population for biliary atresia and congenital diaphragmatic hernia repair.[7,8] Paediatric general and urologic surgery is not exclusively allocated to university hospitals in Sweden; some children and adolescents may undergo surgery in county and district hospitals depending on diagnosis and age.

The Swedish Guidelines of Paediatric Anaesthesia published in 2008 focus on the organisation of paediatric anaesthesia in Sweden regarding type of procedure and age group that hospitals from different categories are expected to manage.[9] Paediatric anaesthesia in private practice is rare in Sweden except for simple office-based surgery, mostly consisting of ear, nose and throat procedures.

The Swedish Perioperative Registry collects data from the vast majority of performed surgeries and non-operative procedures requiring general anaesthesia or sedation in government hospitals in Sweden.[10] A validation of the Swedish Perioperative Registry demonstrated nearly 100% data accuracy for the number and type of surgical procedures between local and central data.[10] The Registry has regular access to Swedish population indexes such as the Cause of Death Register, giving automatic updates on mortality.[10] The goal with this register is to facilitate audits and enhance the overall quality of anaesthesia and surgical care for the patients. The Registry enables an unique possibility to comprehensively audit the quantity and outcome of different types of paediatric surgical procedures performed in the university, county and district hospitals, respectively.

The aims of this study were to investigate the distribution and volume of surgical procedures in children performed in various hospitals in Sweden and to study mortality and risk factors of mortality after surgery.

Key Notes

- The Swedish Perioperative Registry was used to study the distribution of paediatric surgery in various hospitals in Sweden and to study postoperative risk factors of mortality.
- Half of all operations in children were performed in university hospitals.
- Postoperative 30-day mortality in university hospitals was low (0.5%) despite effective centralisation of high risk patients under 1 year of age or American Society of Anesthesiologists Physical Status classification 3–5.

2 | PATIENTS AND METHODS

This was a registry-based cohort study using prospectively collected data from the Swedish Perioperative Registry. The study was approved by the Swedish Ethical Review Authority (2020-01909; 2021-00801). All methods were carried out in accordance with relevant guidelines and regulations. Individual patient consent was waived by the Swedish Ethical Review Authority due to the database nature of the study. All patients were given information regarding the Registry during hospital admission and were given the option to have their data de-registered at any time, opt out. A report of all registered procedures in subjects under 15 years of age and during a time period from 1 January 2017 to 31 December 2021 was extracted from the Registry 14 April 2022. Patients with non-surgical diagnostic codes according to the Swedish versions of International Classification of Diseases, Tenth Revision (ICD-10) were excluded. Also centres that joined the Swedish Perioperative Registry later than January 2019 were excluded. Surgery during office hours was defined as surgery performed during day = 7 am–5 pm Mondays to Thursdays and 7 am–2 pm Fridays. Other = evenings, nights and weekends. Weekend = Saturdays, Sundays and public holidays.

2.1 | Statistical analysis

Descriptive data regarding sex, age, American Society of Anesthesiologists Physical Status classification (ASA-PS-class), surgical procedure category, duration and time of surgery and mortality were extracted from the register and were displayed in percent or time units.

A mixed logistic regression was applied for the all-risk mortality analysis. Both univariable and multivariable analyses were performed. The variables considered in this analysis were age, sex, ASA-PS-class, emergency or elective surgery, subclass of paediatric surgery (general, urology, congenital malformations), type of hospital (county, district, university), time of surgery (weekend, day) and duration of surgery. Paediatric urology was excluded as an explanatory factor since only one subject deceased in that category.

There were 145 751 unique patients in the data material of which 31 164 (21%) underwent surgery more than once. After exclusion of action codes that were not relevant, there were 101 625 unique patients of which 15 887 (14%) occurred more than once. No specific regard was taken to these repeated occurrences in the descriptive tables. That means that these individuals will receive a slightly larger weight in the summaries, but considering the size of the data material this should be a minor issue. However, the effect could have a larger effect if the frequency in a category is small. In the analysis for risk factors for mortality, the repeated occurrences have been taken into account.

3 | RESULTS

In total, 126 539 (62.5% boys) were identified. Half (50%) of the operations were performed in university hospitals, 36% in county hospitals and 14% in district hospitals (Table 1). Median age in the

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TABLE 1 Population characteristics of the study cohort.

Variable	Measure	Total (*N* = 126 539)	University hospital (*N* = 63 948)	County hospital (*N* = 45 127)	District hospital (*N* = 17 464)
Sex					
Boys	*n* (%)	78 772 (62.5%)	39 967 (62.6%)	27 890 (62.2%)	10 915 (62.8%)
Girls	*n* (%)	47 342 (37.5%)	23 913 (37.4%)	16 960 (37.8%)	6469 (37.2%)
Age	Median (range)	6 (0–14)	6 (0–14)	6 (0–14)	7 (0–14)
Age groups					
<1	*n* (%)	10 235 (8.1%)	9663 (15.1%)	557 (1.2%)	15 (0.1%)
1–5	*n* (%)	47 881 (37.8%)	22 127 (34.6%)	18 728 (41.5%)	7026 (40.2%)
6–10	*n* (%)	37 469 (29.6%)	16 961 (26.5%)	14 516 (32.2%)	5992 (34.3%)
11–14	*n* (%)	30 954 (24.5%)	15 197 (23.8%)	11 326 (25.1%)	4431 (25.4%)
ASA-PS-class[a]					
1	*n* (%)	77 857 (67.0%)	31 205 (54.6%)	33 964 (78.0%)	12 688 (81.7%)
2	*n* (%)	27 021 (23.3%)	15 677 (27.4%)	8609 (19.8%)	2735 (17.6%)
3	*n* (%)	10 065 (8.7%)	9042 (15.8%)	925 (2.1%)	98 (0.6%)
4	*n* (%)	1160 (1.0%)	1131 (2.0%)	29 (0.1%)	0 (0.0%)
5	*n* (%)	87 (0.1%)	86 (0.2%)	1 (0.0%)	0 (0.0%)
Type of surgical procedure					
Elective	*n* (%)	87 321 (69.0%)	42 949 (67.2%)	30 410 (67.4%)	13 962 (79.9%)
Emergency	*n* (%)	38 831 (30.7%)	20 616 (32.2%)	14 713 (32.6%)	3502 (20.1%)
Duration of surgery (hours)	Median (range)	0.6 (0–22.9)	0.8 (0–22.9)	0.5 (0–11.7)	0.4 (0–7.4)
Time of surgery					
Office hours	*n* (%)	105 452 (83.3%)	53 691 (84.0%)	36 530 (80.9%)	15 231 (87.2%)
Weekend/other	*n* (%)	21 087 (16.7%)	10 257 (16.0%)	8597 (19.1%)	2233 (12.8%)
30-day mortality	*n* (%)	314 (0.2%)	298 (0.5%)	16 (0.0%)	0 (0.0%)

Note: Absolute numbers (*n*) and percent (%) are given unless otherwise stated. Time of surgery: Office hours = 7 am–5 pm Mondays to Thursdays and 7 am–2 pm Fridays. Other = evenings, nights and weekends. Weekend = Saturdays, Sundays and public holidays.

[a]American Society of Anesthesiologists Physical Status classification.

study cohort was 6 years (0–14). As displayed in Table 1, the majority of patients under 1 year of age were operated on in university hospitals (15.1%, respectively, 1.2% and 0.1% in county and district hospitals). Similarly, patients with ASA-PS-Class > II were mainly operated in university hospitals. The overall 30-day mortality rate was 0.2%. In university hospitals, mortality was 0.5%, and in county hospitals, there was no mortality (Table 1). The proportion of emergency operations was similar in university and county hospitals, at 32.2% and 32.6% respectively (Table 1). More than 80% of the patients underwent surgery during office hours in all the hospitals (Table 1).

Table 2 shows the numbers and distribution of some common operations in the categories general paediatric surgery and urologic paediatric surgery. The most common paediatric surgical procedure was appendectomy, performed on 6667 patients followed by inguinal hernia repair on 4200 and gastrostomy performed on 1152 patients, respectively. Inguinal hernia repair and gastrostomy were more common in university hospitals than in county hospitals. A laparoscopic technique was used in 46.1% of the gastrostomies, and a percutaneous endoscopic technique was performed in 41%. Laparoscopy was the dominating technique in appendectomy (72.1%), whereas open surgery was the most common technique used in inguinal hernia repair (89.9%). Out of 303 pyloromyotomies, 301 were performed in university hospitals and two in a county hospital.

In paediatric urology, orchidopexy was the most common surgical procedure, performed in 5287 patients followed by testis detorsion in 1852 patients. Orchidopexy was more frequently performed in university hospitals than in county hospitals. The number of testis detorsions was similar in university and county hospitals.

The total number of congenital malformations operated during 2017–2021 was 435 in Stockholm, 163 in Uppsala and 109 in Gothenburg, respectively. The malformations included oesophageal atresia, diaphragmatic hernia, duodenal obstruction, abdominal wall defects, anorectal malformations, Hirschsprung's disease, biliary atresia, bladder exstrophy and sacrococcygeal teratoma.

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TABLE 2 Distribution and proportion of common general paediatric surgical and urological procedures in university and county hospitals and surgical techniques used in the study cohort.

Variable	Measure	Total ($N = 109\,075$)	University hospital ($N = 63\,948$)	County hospital ($N = 45\,127$)	District hospital ($N = 0$)
Appendectomy					
Open technique	*n* (%)	1860 (27.9%)	726 (26.4%)	1134 (28.9%)	0 (NaN%)
Laparoscopic technique	*n* (%)	4807 (72.1%)	2021 (73.6%)	2786 (71.1%)	0 (NaN%)
Total	*n*	6667	2747	3920	0
Inguinal hernia repair					
Open technique	*n* (%)	3777 (89.9%)	2546 (85.8%)	1231 (99.9%)	0 (NaN%)
Laparoscopic technique	*n* (%)	423 (10.1%)	422 (14.2%)	1 (0.1%)	0 (NaN%)
Total	*n*	4200	2968	1232	0
Gastrostomy					
Open technique	*n* (%)	149 (12.9%)	94 (9.3%)	55 (37.9%)	0 (NaN%)
Laparoscopic technique	*n* (%)	531 (46.1%)	526 (52.2%)	5 (3.4%)	0 (NaN%)
Percutan endoscopic gastrostomy	*n* (%)	472 (41.0%)	387 (38.4%)	85 (58.6%)	0 (NaN%)
Total	*n*	1152	1007	145	0
Pyloromyotomy					
Open technique	*n* (%)	253 (83.5%)	251 (83.4%)	2 (100.0%)	0 (NaN%)
Laparoscopic technique	*n* (%)	50 (16.5%)	50 (16.6%)	0 (0.0%)	0 (NaN%)
Total	*n*	303	301	2	0
Orchidopexy					
Open technique	*n* (%)	3879 (73.4%)	2525 (67.7%)	1354 (86.9%)	0 (NaN%)
Laparoscopic technique	*n* (%)	1408 (26.6%)	1203 (32.3%)	205 (13.1%)	0 (NaN%)
Total	*n*	5287	3728	1559	0
Pyeloplasty					
Open technique	*n* (%)	139 (54.1%)	139 (54.3%)	0 (0.0%)	0 (NaN%)
Laparoscopic technique	*n* (%)	104 (40.5%)	104 (40.6%)	0 (0.0%)	0 (NaN%)
Robotic	*n* (%)	14 (5.4%)	13 (5.1%)	1 (100.0%)	0 (NaN%)
Total	*n*	257	256	1	0
Nefrectomy					
Open technique	*n* (%)	105 (6.3%)	105 (7.2%)	0 (0.0%)	0 (NaN%)
Laparoscopic technique	*n* (%)	1496 (90.4%)	1291 (89.1%)	205 (99.5%)	0 (NaN%)
Robotic	*n* (%)	54 (3.3%)	53 (3.6%)	1 (0.5%)	0 (NaN%)
Total	*n*	1655	1449	206	0
Hypospadias repair	*n* (%)	1564	1564	0	0 (NaN%)
Testis detorsion	*n* (%)	1852	916	936	0 (NaN%)

In Table 3, the 30-day mortality in the different subgroups is shown. In patients under 1 year of age, 30-day mortality was 1.9% versus 0.1% in older children, emergency 0.8% versus elective 0%, university hospital 0.5% versus 0% in others, 0.7% for weekend/other versus 0.2% for surgery during office hours and 0.5% for surgeries of more than 60 min duration compared to 0.2% for surgeries lasting less than 60 min.

In Table 4, Cox regression for risk factors of 30-day mortality is demonstrated. Age <1 year, ASA-PS-class 4–5, emergency surgery and surgery at university hospital were independent risk factors in the multivariable analyses.

4 | DISCUSSION

In this retrospective registry-based cohort study of children and adolescents who underwent surgery in Sweden during 2017–2021, we found that 50% of the surgical procedures were performed in university hospitals. Virtually, all patients under 1 year of age or with ASA-PS-class 3–5 were operated in university hospitals. These findings are consistent with the guidelines from the Swedish Society for Paediatric Anaesthesia and Intensive Care.[9] They include the statement that children <1 year of age or ASA-PS-class 3–5 require specific competence in paediatric anaesthesia only

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TABLE 3 30-day mortality in the study cohort in the different subgroups.

Variable	Deceased within 30 days *N* = 314
Age group	
<1	195 (1.9%)
1–5	56 (0.1%)
6–10	31 (0.1%)
11–14	32 (0.1%)
Sex	
Boys	178 (0.2%)
Girls	136 (0.3%)
ASA-PS-class[a]	
1	2 (0.0%)
2	4 (0.0%)
3	61 (0.6%)
4	95 (8.2%)
5	37 (42.5%)
Type of surgery	
Elective	20 (0.0%)
Emergency	294 (0.8%)
General paediatric surgery	107 (0.7%)
Paediatric urology	1 (0.0%)
Congenital malformations	12 (1.7%)
Hospital	
University hospital	298 (0.5%)
County hospital	16 (0.0%)
District hospital	0 (0.0%)
Time of surgery	
Office hours	171 (0.2%)
Weekend/other	143 (0.7%)
Duration of surgery	
0–60 min	148 (0.2%)
>60 min	166 (0.5%)

[a]American Society of Anesthesiologists Physical Status classification.

available at university hospitals. For children <3 years of age, the guidelines also recommend specific competence in paediatric anaesthesia.

At university hospitals, inguinal hernia repair was the most common surgical procedure in general paediatric surgery, explained by a significant proportion of infants with inguinal hernia repair at low age. Similarly, surgery for gastrostomy was more frequent in university hospitals, which can be explained by complicated underlying conditions requiring highly specialist paediatric anaesthesia in many patients in need of a gastrostomy. In county hospitals, appendectomy was the dominating surgical procedure. Orchidopexy was the most common paediatric urological procedure in both university and county hospitals.

Overall, the 30-day mortality in our study cohort was 0.2% compared to a study by Bonasso et al. reporting a 30-day mortality rate of 0.7% in 103 444 children from the American College of Surgeons National Surgical Quality Improvement Program-Paediatric, a national database of paediatric surgical operations.[11] In the present study, we identified age <1 year, ASA-class 4–5, emergency surgery and surgery performed at university hospital as independent risk factors for 30-day mortality. ASA-PS- classification has been shown repeatedly to be highly associated with risk of death and other adverse events in children and in adults, but it is not an objective variable as it is dependent on the subjective opinion of an anesthesiologist.[12–14] Data for variables analysed in the logistic regression were complete except for ASA-PS-class where 8.2% of the data was missing.

The factors age under 1 year and higher ASA-PS class were typical characteristics of surgeries performed in university hospitals. The county and district hospitals operated half of the volume of the total volume of paediatric patients, but patients with higher risk profile were referred to university hospitals with specialist competency in paediatric anaesthesia and paediatric surgery. In contrast to our study, Goldstein et al found increased mortality for children undergoing urgent surgery during the weekend.[15]

This is the first study reporting the distribution and volume of paediatric surgical and urological procedures in Sweden based on data extracted from the Swedish Perioperative Registry. Except for a report of the COVID-19 pandemic effects on paediatric anaesthesia and surgery in Sweden,[16] previous articles based on data extracted from the Swedish Perioperative Registry have been limited to surgical procedures in adults.[17–20] Data recorded from several surgical procedures in this study cohort did not state whether any complication was noted during the perioperative and postoperative process and data regarding perioperative bleeding was missing in most patients. Thus, the Registry cannot yet be used with high certainty for studies of complications related to surgery in children. A national registry with reliable data on perioperative factors such as blood loss, transfusion volume and complications would be valuable for quality improvement in paediatric surgery, and the authors hope that studies such as the present will stimulate further development of the register's data quality by requiring input of key factors at each local surgical unit. Complete data registration could thereby contribute to increased quality of surgical care in children and adolescents undergoing surgery.

The strengths of this study were the large volume of children and adolescents included and that data on factors included in the mortality analysis were complete. Limitations of the study were that one of the four paediatric university hospitals did not enter data into the registry and that eight district hospitals and one county hospital joined the Registry too late to provide complete data for the study. Moreover, the retrospective design, missing data and inaccuracy of coding surgical procedures and diagnosis according to ICD-10 limited the possibility of detailed quality analysis of distinct surgical procedures.

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TABLE 4 Cox regression univariable and multivariable analysis of risk factors for 30-day mortality.

	Univariable			Multivariable		
Factor	**OR**	**95%-CI**	***p*-value**	**OR**	**95%-CI**	***p*-value**
Age group: <1 (ref: 1–5)	16.59	(12.41–22.55)	<0.001	2.39	(1.53–3.81)	**<0.001**
Age group: 6–10 (ref: 1–5)	0.71	(0.45–1.09)	0.122	0.92	(0.52–1.61)	0.785
Age group: 11–14 (ref: 1–5)	0.88	(0.57–1.36)	0.577	0.71	(0.39–1.28)	0.264
Sex: boys (ref: girls)	1.27	(1.02–1.59)	0.035	1.29	(0.95–1.74)	0.100
ASA-PS-class: 4 (ref: 1–3, or)	153.02	(111.53–211.11)	<0.001	24.88	(16.70–37.41)	**<0.001**
ASA-PS-class: 5 (ref: 1–3, or)	1268.24	(776.72–2065.99)	<0.001	154.19	(88.38–268.97)	**<0.001**
Type of surgery: emergency (ref: elective)	33.29	(21.75–54.10)	<0.001	6.44	(3.83–11.30)	**<0.001**
General paediatric surgery: yes (ref: no)	3.56	(2.81–4.48)	<0.001	1.14	(0.81–1.59)	0.461
Congenital malformations: yes (ref: no)	7.30	(3.86–12.48)	<0.001	0.62	(0.27–1.27)	0.224
Hospital: University hospital (ref: County/District Hospital)	18.31	(11.47–31.57)	<0.001	5.71	(2.95–12.43)	**<0.001**
Time of surgery: weekend/other (ref: Office hours)	4.20	(3.36–5.25)	<0.001	1.38	(1.00–1.91)	0.051
Duration of surgery: >60 min (ref: 0-60 min)	2.91	(2.33–3.64)	<0.001	1.01	(0.74–1.39)	0.932

Bold values indicate statistically significant of p-value < 0.05.

5 | CONCLUSION

Half of all operations in children were performed in university hospitals. Postoperative mortality in university hospitals was low despite effective centralisation of high risk patients under 1 year of age or ASA-PS-Class 3–5. The most common paediatric surgical procedure was appendectomy followed by orchidopexy, inguinal hernia repair, testis detorsion and gastrostomy.

AUTHOR CONTRIBUTIONS

Ruut-Maria Pelkonen: Writing – original draft; data curation; formal analysis. **Peter Frykholm:** Conceptualization; writing – review and editing; validation. **Gunnar Enlund:** Writing – review and editing; data curation; validation. **Helene Engstrand Lilja:** Conceptualization; writing – review and editing; validation; supervision; methodology.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

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