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Abstract:

Background: Surgical care is an essential component to achieve universal health coverage. An increase in children's surgical burden is recognized worldwide, but changes in the epidemiological profile associated with global geographic heterogeneity are to be expected. The aims of this study are to analyse the prevalence and epidemiological changes of surgical activity in a tertiary center in Mexico.

Methods: Ambispective cohort study. Institutional records were reviewed searching for children's surgeries in the period comprising 2001-2017. The variables analyzed were age, sex, number of surgeries per subject, and mortality rate; regarding the interventions, kind of inward stay, kind of surgery (ICD 9 CM), ward or department responsible, and perioperative mortality rate (POMR).

Results: Of the 104,578 institutional admissions, 37% were surgical procedures of preschool-aged children (30.2%), and infants (27.3%). These tended to decrease, while for adolescents to increase. A total of 84,859 surgeries were performed (1.36 per operating room/day), averaging 4.992 per year, with a marginal tendency to increase. 65.8% of procedures required hospitalization. The systems more frequently intervened were: musculoskeletal system (20.1%, tending to increase), digestive system (19.5%), and cardiovascular system (11.3%). The overall mortality rate of surgical admissions was 5.5%, with POMR of 1.54%.

Conclusion: The institutional epidemiological profile has changed, and relevant trends were identified. We corroborated the presence of global geographic heterogeneity with analogous hospitals

Keywords

Surgery, Pediatrics, Surgical procedures operative, Statistics. Surgical epidemiology

Background

On May 22, 2015, in the plenary session of the 68th World Health Assembly (WHO), a resolution was adopted on the need to strengthen surgical care as an overarching component of universal health coverage [1]. Each year throughout the world, more than 234 million surgeries are performed for all socioeconomic and ethnic groups, and that number has undergone considerable annual increases [2]. It is estimated that at least 11% of the global disease burden is due to conditions that can be treated by surgery [1]. In fact, surgical intervention is, at some point, a possible treatment or coadjuvant for almost all diseases included in the 2010 study of the global burden of disease [1].

Because of the impact of surgery, the WHO recognizes that strengthening the surgical capacity of health systems is a cost-efficient way to reduce the global burden of disease and should be considered a priority activity of health care. Access to safe surgical care at the appropriate time is curative and avoids disabilities resulting from many diseases; however, evaluations conducted in low- and middle-income countries have identified significant deficiencies in infrastructure/human resources, skills, equipment, medications and other supplies, but above all, a lack of the information necessary to identify areas of opportunity [3].

Managing the global or specific strategies that tend to improve surgical capacity requires information. According to the General Directorate of Health Information of the Ministry of Health (Secretaría de Salud) (Mexico), since 2011 in Mexico, an average of 1.6 million surgical procedures per year have been performed, and between 14-15% of those are performed on patients between 0 and 17 years of age [4]. We could not locate national information on the characteristics of the surgical interventions performed on children and the possible changes in these data over time.

The National Institute of Paediatrics (Instituto Nacional de Pediatría, INP) is one of the largest tertiary care hospitals in Mexico, targeting an open population between 0 and 17 years of age. The INP has 235 beds and recorded 5705 new institutional admissions in 2017; that same year, 5225 surgeries were performed in its central operating room, representing 31% of the procedures reported in Mexico City for that age group and year of reference [5]. This study was performed with the objective of analysing the prevalence of and epidemiological changes in surgical activity performed by a Mexican specialized paediatric hospital.

Methods

Design and study population

This ambispective cohort study included the electronic records of patients admitted to the NIP from January 2001 to December 2017 who underwent a surgical intervention in the "Central Operating Room"

In preparation for this study, the institutional data were divided into three tables: a) "Control of Surgery" in the "Hospital Administration System" database, b) "Control of Mortality" from the Pathology Department, and c) "Record of admissions" from the clinical file. The file number in table (c) was used to verify consistency with the other tables and detect inconsistencies in names, dates, ages, sex, etc. With the refined tables, a relational database was created, with which it was possible to perform the analysis of the variables of interest.

Using the integrated database, a manual paired analysis was performed by two previously standardized observers to corroborate that the first 2 digits recorded for surgical interventions agreed with the International Classification of Diseases 9th edition Clinical Modification Volume 3 (ICD-9- CM-Vol 3).

The INP has 10 rooms in its central operating room and 11 services that depend on the Surgery Department. In this hospital, surgical and anaesthetic procedures are performed in other areas, such as endoscopy rooms or haemodynamics units; these areas were not included. The analysis over time was conducted for individual years and for three-year periods in accordance with the National Health Programmes that are developed with each sexennial change of government in our country.

The variables considered for the analysis of surgical admissions were age group (neonates, infants, preschoolers, school children, adolescents), sex, number of surgeries per subject (one intervention/two or more interventions), overall mortality rate (institutional deaths/institutional admissions) and surgical mortality rate (surgical admission deaths/surgical admissions). For the analysis of surgical interventions, the following variables were included: kind of inward stay (outpatient or admission), kind of surgery according to the first two digits of the ICD-9-CM Vol 3, ward or department responsible (Cardiovascular Surgery, General Surgery, Oncologic Surgery, Plastic and Reconstructive Surgery, Stomatology, Thoracic Surgery, Neurosurgery, Ophthalmology, Otolaryngology and Urology) and the perioperative mortality rate or POMR (deaths during the postoperative hospital stay or in the first 30 days postoperative/total of procedures per year).

We excluded the records of patients who did not have concordance among the databases analysed and those for which the type of intervention performed could not be codified using the available information (186 surgical interventions). To define overall mortality or POMR, the mortality recorded in "Control of Deaths" was used.

Statistical analysis

The variables are described as percentages and tabular representations. To establish changes in the variables as a function of year, a linear regression analysis was used. To analyse changes based on three-year periods, we used the X^2 trend.

Results

Among a total of 104,578 institutional admissions between January 2001 and December 2017, 38,691 subjects (37%) underwent one or more surgeries. With an average of 2,276 surgical admissions per year (ranges from 1.827 to 2.476), the annual percentage of surgical/institutional admissions varied between 26.7% and 46.7%, and no trend was observed over the analysed period ($R^2=0.01$, $p=0.68$, $CI^{95\%}=0.63$ to 0.42). In the analysis by three-year periods, a difference was observed between the 2001-2003 period, which had 7,230 subjects, and the 2004-2006 period, which had 6,558 subjects; the rest of the three-year periods presented ranges between 6,842 and 6,988 subjects ($p=0.01$).

Of the 38,691 subjects who underwent surgery, 57.8% were male (22,401 subjects), a proportion that prevailed over time ($R^2=0.17$, $p=0.096$, $CI^{95\%}=-0.19$ - 0.02) and for the three-year periods ($p=0.14$). Most of the surgical interventions were for preschoolers, with 30.2% (11,691 subjects), followed by infants, with 27.3% (10,598 subjects). Although preschoolers comprised the largest group, there was a decreasing tendency over time ($R^2=0.57$, $p=0$, $CI^{95\%}=-0.37$ to -0.13) and by three-year periods ($p=0.0007$); a similar trend was also observed for the group of neonates by year ($R^2=0.35$, $p=0.013$, $CI^{95\%}=-0.17$ to -0.02) and by three-year periods ($p=0.01$). In the last three-year period analysed (2013-2015), the number of adolescent subjects increased from 1,142 to 1,229 compared to the previous three-year period; although this increase was marginal, it showed a trend over time ($R^2=0.43$, $p=0.004$, $CI^{95\%}=0.7$ to 0.31) and differed among the three-year periods ($p=0.035$).

Of the subjects who underwent surgery, 63.4% received only one surgical intervention (24,513 subjects). A total of 14,178 (36.6%) patients underwent repeated interventions, ranging from 2 to 38 procedures. The number of

subjects who underwent surgery on more than one occasion increased with the institutional monitoring time ($R^2= 44$, $p=0.004$, $CI^{95\%}=-37.07$ to -8.77) (Fig. 1).

Surgical interventions

During the analysed time period, 84,859 surgical interventions were performed in the central operating room, with an average of 1.36 operations per operating room/day (range from 1.09 to 1.54). A total of 11,491 interventions were performed in children who were admitted to the NIP in years previous to the time analysed (13.5%).

An average of 4,992 surgical procedures per year were performed, with ranges between 4,007 and 5,745 and a tendency to increase over time ($R^2=0.39$, $p=0.008$, $CI^{95\%}=18.3$ to 100.6) (Fig. 1). The number of interventions differed over the three-year periods ($p=0.0$), with ranges from 12,804 in 2004-2006 to 16,101 in 2007-2009. A total of 15,790 interventions were performed in the 2010-2012 three-year period, and 15,447 interventions were performed in the 2013-2015 three-year period.

In terms of the type of hospital stay, 65.8% of the interventions required at least one day of hospital stay or were performed on subjects who were hospitalized at the time of the intervention (55,920 surgeries). An average of 1,703 outpatient operations were performed per year (range between 1,355 and 1,961). For the three-year periods, the number of interventions increased from 4,842 (2001-2003) to 5,213 (2013-2015) ($X^2=11.47$, $p=0.00071$). The annual percentage of outpatient procedures ranged between 29.3% and 39.3% (2001 and 2002, respectively), with no tendency to increase ($R^2=0.08$, $p=0.264$, $CI^{95\%}=-8.37$ to 28.33).

The most frequent types of interventions were for the musculoskeletal system, 20.1% (17,030 operations), followed by interventions for the digestive system (19.5%; 16,516 operations) and the cardiovascular system (11.3%); 9,611 operations). The most common intervention for the musculoskeletal system was the reduction of fractures and dislocations, with 8,130 interventions; for the digestive system, the most common intervention was appendectomy, with 3,514 interventions; and for the cardiovascular system, vessel punctures for the placement of vascular accesses accounted for 6,364 interventions. Together, these three types of interventions represented 21.2% of the procedures performed in the central operating room of this institution (18,008 interventions).

The number of procedures for the digestive system and the haematic/lymphatic system showed no changes or significant increase among the three-year periods ($p=0.97$ and $p=0.92$, respectively) . The number of procedures

performed for the endocrine system and the male genital organs differed among the three-year periods ($X^2=94.76$ $p<0.0001$ and $X^2=13.06$, $p=0.0003$, respectively) but did not show any tendency over time. The types of interventions that showed a decreasing tendency over the three-year periods were for the nervous system ($p<0.0001$); the ear ($p<0.0001$); the nose, mouth and pharynx ($X^2=38.57$, $p<0.0001$); the respiratory system ($X^2=58.93$, $p<0.0001$); and the integumentary system ($X^2=24.46$, $p<0.0001$). The interventions that showed an increasing tendency over the three-year periods were for the eye ($X^2=112.74$ $p=0.0$); the cardiovascular system ($X^2=153.74$, $p<0.0001$); the urinary system ($X^2=25.62$, $p<0.0001$); the female genital organs ($X^2=10.54$, $p=0.00117$); and the musculoskeletal system ($X^2=4.48$; $p=0.03424$). The annual trend by type of surgical interventions can be seen in Table 1.

A total of 55.7% of the surgical activity during the analysed period was performed by three surgical departments: General Surgery (24,903 operations), Traumatology and Orthopaedics (11,935 operations) and Plastic/Reconstructive Surgery (9,918 operations). The interventions performed by the departments of Cardiovascular Surgery, General Surgery and Otorhinolaryngology showed no changes or significant increases over the three-year periods ($p=0.82$, $p=0.10$ and $p=0.43$, respectively). The departments of Oncology ($R^2=0.37$, $p=0.01$, $CI^{95\%}=0.05-0.32$), Ophthalmology ($R^2=0.61$, $p<0.0001$, $CI^{95\%}=0.14-0.36$), Orthopaedics/Traumatology ($R^2=0.25$, $p=0.039$, $CI^{95\%}=0.01-0.36$) and Urology ($R^2=0.82$, $p<0.0001$, $CI^{95\%}=0.13-0.22$) showed changes among the three-year periods, with an annual trend towards increased activity. Differences in activity among the three-year periods were also observed for Plastic Surgery ($X^2= 52.67$, $p=0.0$), Stomatology ($X^2=74.74$, $p<0.0001$), Thoracic Surgery ($X^2=575.18$ $p<0.0001$), and Neurosurgery ($X^2= 79.71$ $p<0.0001$), but the annual trend showed a decrease in their activity.

Mortality

The overall mortality during the studied time period was 4.09% (4,278/104,578 subjects), and the surgical mortality was 5.5% (2,159/38,691 subjects). The lowest surgical mortality occurred during the 2001-2003 three-year period, with a rate of 3.2. The highest rate was observed for the 2010-2012 three-year period, with 7.1. Over time, surgical mortality showed a tendency to increase ($R^2=0.28$, $p=0.031$ $CI^{95\%}=-583.8$ to -30.51) (Fig.2). Twenty patients died in association with associated with an outpatient procedure (20/28,944 subjects).

The POMR for the analysed period was 1.54% (1,309 children). The annualized POMR ranges varied between 0.83 and 2.2% (for 2002 and 2011, respectively). The POMR did not show a trend over time ($R^2=0.04$, $p=0.46$, $CI^{95\%}=-101.41$ to 48.84) (Fig.2); however, it differed among the three-year periods (2001-2003=1.18, 2004-2006=1.45, 2007-2009=1.68, 2010-2012=1.98, 2013-2015=1.64; $X^2= 4.6$, $p=0.031$).

Discussion

According to the WHO, the global burden of surgical conditions has increased, and member states recognize the need to strengthen surgical care [3]. Weiser et al. [2] estimated that in 2004, one surgical intervention was performed for every 25 people worldwide. According to the WHO, this proportion could increase to more than 45% by 2030 [3]. The impact appears to be greater for the paediatric population of low- and middle-income countries [6]. In a recent survey, an unmet need for paediatric surgical care was estimated in 62% of children in low-income countries [7]. Without significant changes in the regional health structure and a marginal increase in the surgical load observed, we assume that the expected increase in the need for child surgical care will translate into long institutional waiting times, or even worse, that children will not have access to specialized surgical care [7]. In addition, this study found an index of 1.36 procedures per day/operating room/year and a global POMR of 1.54%, which emphasizes the value of resolution WHA 68.15 on the need to strengthen surgical care for children [1, 6].

In addition to the expected increase in the global surgical burden, the epidemiological profile [8, 9] and the methods for evaluating postoperative results [9, 10] are radically changing surgical planning for children [6]. In our case, the trend analysis identified changes in demographic characteristics and surgical interventions, as have also been observed in other populations [11, 12]. This information is relevant when analysing risks [9, 13] and establishing institutional health policies [6]. In recent years, concern about the increased costs of medical care worldwide has stimulated interest in increasing the practice of outpatient surgery [11]. Since 1968, Marks et al. [14] have documented the benefits of outpatient surgery. With an average of 34% of outpatient interventions performed at this institution and the associated low surgical mortality (0.07%), the creation of specific areas and programmes that incentivize and improve outpatient surgery can strengthen institutional surgical care. Since 2012, the Mexican NOM-026-SSA3-2012 has recognized the practice of outpatient surgery as a strategy to reduce the cost of surgical treatment, increase the productivity and efficiency of health personnel and reduce waiting lists, thus increasing the capacity to provide surgical care for the population [15]. For paediatric patients, the benefits are greater; outpatient

surgery can reduce the potential exposure to nosocomial pathogens, the costs to caregivers, and the emotional impact on children by requiring them to spend less time in a hospital and by increasing the comfort of the hospital stay with the design of special play areas paediatric surgical outpatients [11].

The analysis of the types of interventions performed identified that 21.2% of the interventions were related to the placement of central venous access devices, the reduction of fractures/dislocations (both of which showed a tendency to increase over time) and the performance of appendectomies. Regarding the last two procedures, similar impacts have been reported for other child populations [7]. The placement of a central venous access device is a very common procedure in children. In 2013, the National Healthcare Safety Network reported the placement of more than 2.7 millions of these devices in 82 hospitals in the US [16]. In a recent systematic review, Ullman et al. [17] concluded that these devices are associated with a high rate of failure and complications in children (1 out of 4 implanted devices) and proposed evidence-based changes to improve their insertion and maintenance. As one of the most frequent surgical interventions and one with high morbidity, this procedure could be an indicator of quality in paediatric surgical care.

A little-described aspect that is nonetheless recognized by paediatric surgeons is the need to perform more than one surgical intervention in children admitted to a specialized medical institution. Among surgical patients who were followed up for up to 17 years, 38% were reoperated on 2 or more occasions, and the reoperation rate showed a tendency to increase with increasing years of follow-up. Surgical care for the treatment of congenital anatomical abnormalities and cancer requires addressing not only specific morbidity but also the wide range of morbidity associated with follow-up. According to Ijsselstijn et al. [18], paediatric surgical care institutions should standardize their follow-up programmes with a multidisciplinary approach to stratify long-term risks, including reoperations.

In addition to improving the population's access to surgical care, the WHO initiative "Safe Surgery Saves Lives" recognizes the need to improve the quality of surgical care and proposes using the POMR as a relevant indicator [19]. Due to its impact, it is recognized as an indicator that allows knowing the baseline conditions of surgical care, proposing solution strategies and knowing the impact of its implementation [20]; however, this indicator is a comparator that is hard to interpret due to the heterogeneity of the population that could be analysed, the form in which it was obtained and its definition [13]. Few reports exist in our setting, possibly associated with difficulty in generating reports of adverse events and institutional errors, fear of legal problems, or unfavourable comparisons with other institutions [21]. With a global POMR of 1.54% in the analysed population, similar to the

one identified by Medina-Franco in a Mexican tertiary care hospital for adults (1.82%) [21], but higher than that reported by Kraemer in a group of paediatric hospitals in US (0.34%) [22]; requires identifying associated risk factors, similar to that proposed by the American College of Surgery in "National Surgical Quality Improvement Program Paediatric (ACS NSQIP Paediatric)"

Finally, the results of this study are limited because it is an ambispective study with information biases and the absence of a prior procedure for the validation of electronic records. We identified selection biases due to possible underreporting in the databases "Control of Surgery" and "Control of Deaths". We believe that the number of deaths may be higher.

Conclusions

We conclude that the surgical care profiles of this institution changed over time. In our case, the analysis allowed us to identify trends and corroborate geographic heterogeneity with other similar hospitals worldwide [23]. As proposed in WHO resolution 65/15, we need to strengthen surgical care by implementing strategies with a regional focus as well as ensuring funding and long-term monitoring.

Declarations

Ethical approval and consent to participate

This study was conducted according to the guidelines established in the Declaration of Helsinki, and all procedures involving human subjects/patients were approved by Institutional Review Board of the National Institute of Pediatrics (IRB 8064, approval number INP 020/2017). All data were recorded anonymously

The investigation included a secondary data analysis. No informed consent was obtained from the subjects.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request

Competing interest

The authors declare that they have no competing interests.

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Author contributions

MTP and RESR designed the study and collected the information; SCL and SMVM designed the study, analyzed the data and wrote the manuscript, MEA analyzed the data, and wrote the manuscript, MMLS and RRJ collected the information and analyzed the data, MFPA and JFGZ designed the study, collected the information, analyzed the data, and wrote the manuscript.

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Figure captions

Figure 1.- 2001-2017 Institutional admissions. National Institute of Paediatrics (Instituto Nacional de Pediatría, INP)

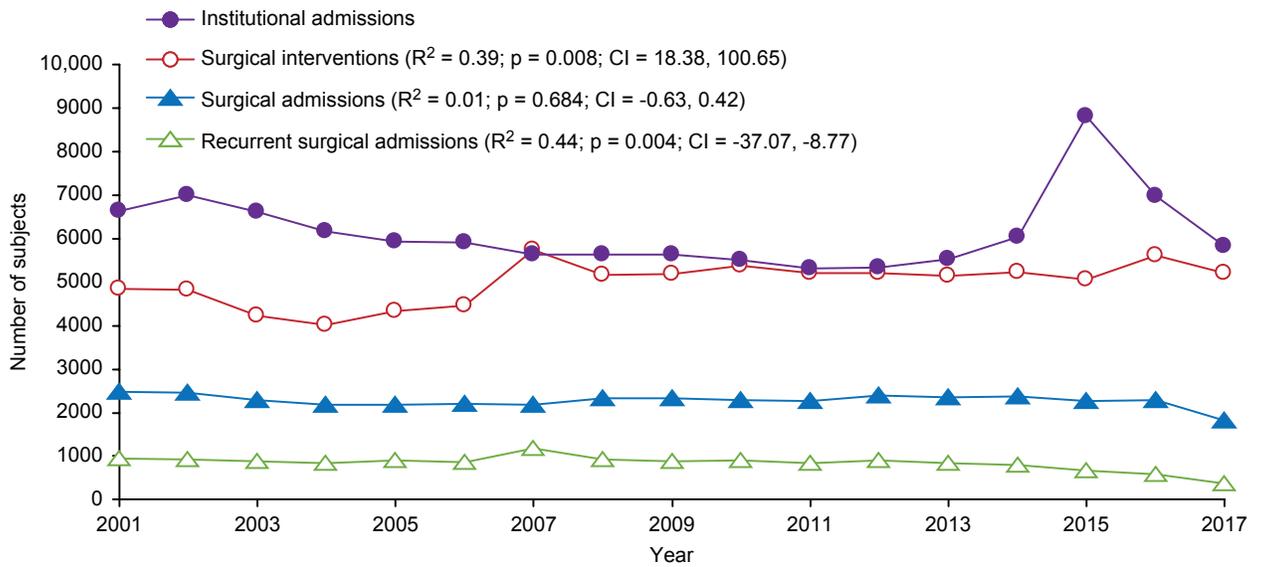


Figure footnote: Surgical admission: Institutional admission involving one surgical intervention; recurrent surgical admission: surgical admission involving 2 or more interventions, Surgical interventions: procedures performed in the INP central operating room

Figure 2.- 2001-2017 Institutional mortality. National Institute of Paediatrics (Instituto Nacional de Pediatría, INP)

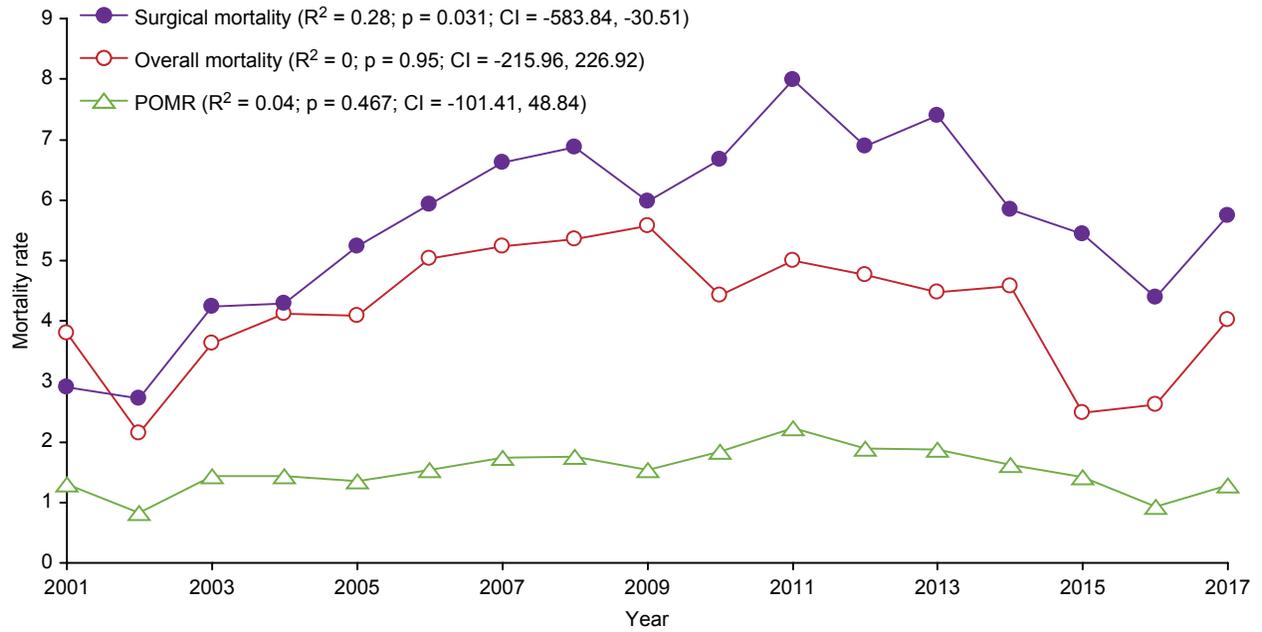


Figure footnote: Surgical mortality: deaths/surgical admissions, Overall mortality: deaths/institutional admissions, POMR: deaths during the hospital preoperative stay or first 30 days posoperatively

**Table 1. Types of surgical interventions (ICD-9-MC Volume 3) 2001-2017.
National Institute of Paediatrics**

Type of surgical intervention	n=	Tendency	R ²	p	Confidence interval	
Total operations	84,859	+	0.39	0.008	18.38	100.65
Nervous system	5819	-	0.27	0.032	-0.38	-0.02
Endocrine system	751	0	0.09	0.254	-0.26	0.07
Eye	7341	+	0.56	0.001	0.12	0.35
Ear	2718	-	0.61	0	-0.18	-0.07
Nose, mouth and pharynx	8744	-	0.38	0.009	-0.26	-0.05
Respiratory system	2819	-	0.46	0.003	-0.19	-0.05
Cardiovascular system	9611	+	0.26	0.039	0.01	0.42
Haemic and lymphatic system	1163	0	0.04	0.439	-0.04	0.02
Digestive system	16516	0	0.06	0.342	-0.09	0.24
Urinary system	4727	+	0.68	0	0.07	0.15
Male genital organs	3560	0	0.21	0.062	-0.12	0
Female genital organs	716	0	0.22	0.06	0	0.04
Musculoskeletal system	17030	+	0.28	0.028	0.03	0.45
Integumentary system	2872	-	0.27	0.032	-0.2	-0.01

Figure footnote: R² Linear regression analysis per year. Tendency: (+) = increase, (-) = decrease, 0 = no changes

Figures

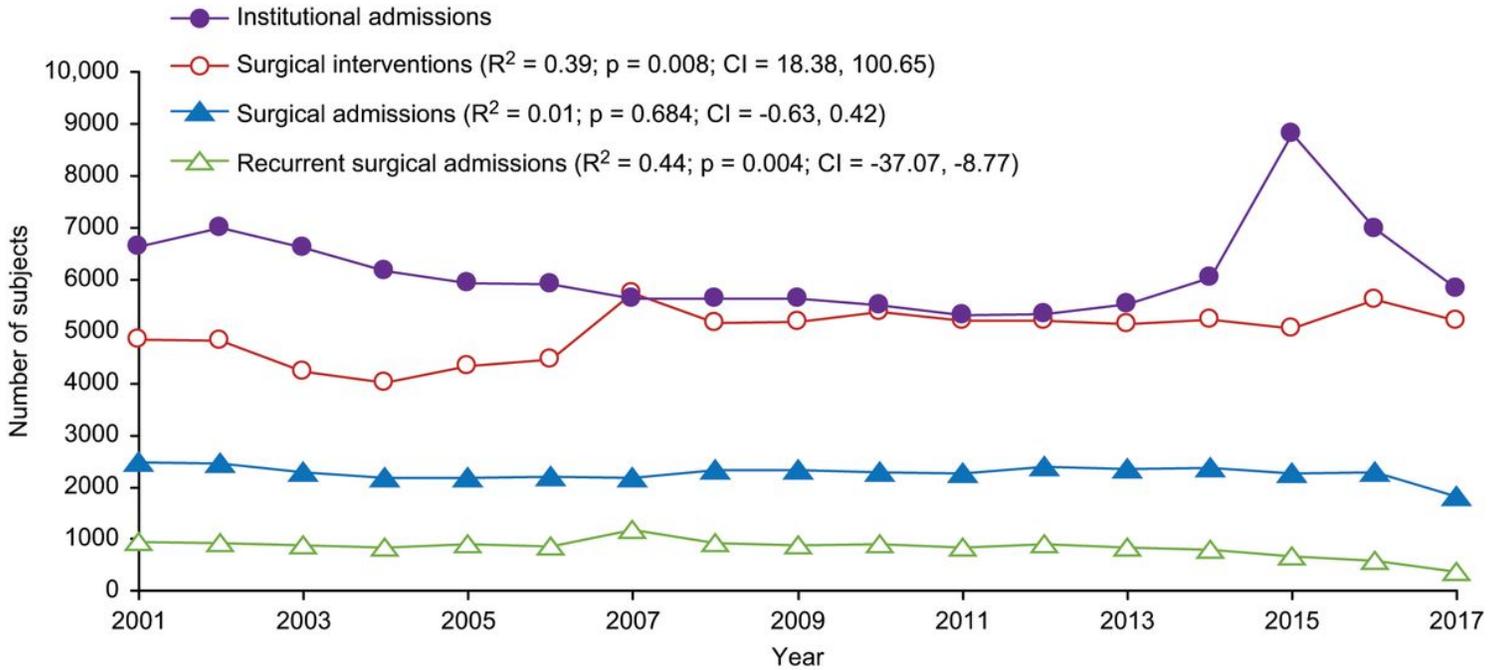


Figure 1

2001-2017 Institutional admissions. National Institute of Paediatrics (Instituto Nacional de Pediatría, INP)
 Figure footnote: Surgical admission: Institutional admission involving one surgical intervention; recurrent surgical admission: surgical admission involving 2 or more interventions, Surgical interventions: procedures performed in the INP central operating room

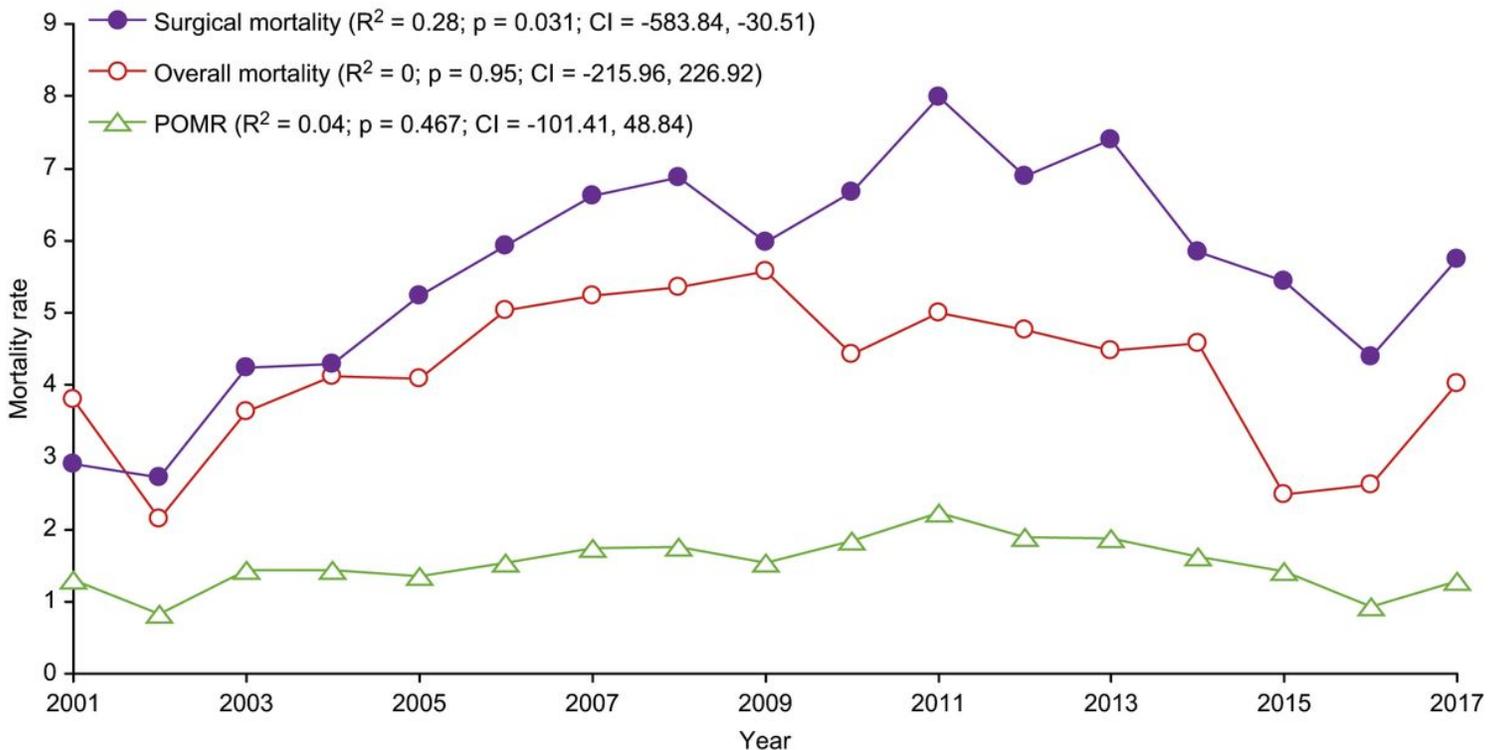


Figure 2

2001-2017 Institutional mortality. National Institute of Paediatrics (Instituto Nacional de Pediatría, INP)
Figure footnote: Surgical mortality: deaths/surgical admissions, Overall mortality: deaths/institutional admissions, POMR: deaths during the hospital preoperative stay or first 30 days posoperatively

Supplementary Files

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- [Database.xlsx](#)