Pediatric Anesthesia Morbidity and Mortality in the Perioperative Period

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One of the most frequent questions asked of a pediatric anesthesiologist is "What are the risks of anesthesia for my child?" Unfortunately, few studies have examined the consequences of general anesthesia in children. We used data from a large pediatric anesthesia follow-up program at Winnipeg Children's Hospital (1982–1987) to determine rates of perioperative adverse events among children of different ages. A check-off form was completed by a pediatric anesthesiologist for each case (n = 29,220) and a designated follow-up reviewer examined all anesthesia forms and hospital charts to ascertain adverse effects for children less than 1 mo, 1–12 mo, 1–5 yr, 6–10 yr, and 11–16 yr of age in the intraoperative, recovery room, and postoperative periods. The majority of the children were healthy, and 70% had no preoperative medical conditions. Infants less than 1 mo old were more likely to be undergoing major cardiac or vascular procedures, whereas the older children had mainly orthopedic or otolaryngologic procedures. Infants less than 1 mo old had the highest rate of adverse events both intraoperatively and in the recovery room. The main problem in this age group was related to the respiratory and cardiovascular systems. In children over 5 yr of age, postoperative nausea and vomiting was very frequent, with about one-third of the children experiencing this problem. When all events were considered (both major and minor), there was a risk of an adverse event in 35% of the pediatric cases. This contrasts with 17% for adults. This morbidity survey helps to focus on areas of intervention and for further study.

Key Words: ANESTHESIA, PEDIATRIC. COMPLICATIONS, PEDIATRIC.

One of the most frequent questions parents ask of a pediatric anesthesiologist is "What are the risks of anesthesia for my child?" Unfortunately, few studies have examined the consequences of general anesthesia in children. A study from France (1,2) reviewed 40,240 anesthetics administered to children younger than 15 yr of age. There were 27 major complications within 24 h of the administration of the anesthetic (seven per 10,000 anesthetics) (2). However, the study did not elaborate on the morbidity and mortality associated with children of different age groups—for example, neonates. Although the study extended into the recovery period, patient management problems on the ward were not identified. This appears to be the only major morbidity survey of pediatric anesthesia in recent years.

The emergence of quality assurance programs across North America has necessitated the identification of rates and etiologies of patient-related problems. This information is used to improve patient care by the modification of clinical practice; it acts as the justification for resource allocations, and it suggests future research projects. Therefore, there is clearly a need for more information about the implications of anesthetic care in the pediatric population in order to direct and improve future practice.

We were fortunate in having access to the databank from a large anesthesia follow-up program at the Winnipeg Children's Hospital. Data had been collected from mid-1982 to 1987 inclusive (n = 29,220 anesthetics), and we used this information to deter-

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mine the rates of perioperative adverse events occurring in children of different ages.

Methods

The Pediatric Anesthesia Follow-up Program at Winnipeg Children's Hospital is similar to that reported previously for adults and obstetrical cases (3,4). Each child was cared for by a board-certified pediatric anesthesiologist, who filled out a special anesthetic check-off record. This record included information about selected coexisting medical conditions, age of the child, whether the child had a preoperative tour of the hospital, how the airway was managed intraoperatively, and which anesthetic drugs and monitors were used. The anesthesiologist assessed each child preoperatively, categorizing each according to the American Society of Anesthesiologists' physical status classification (5). During the course of anesthesia and surgery, any intraoperative events requiring action by the anesthesiologist were recorded on the same form. Selected adverse events that may have occurred during the immediate recovery period were added to the record by the recovery room nursing staff.

Within 72 h of the procedure, a designated anesthesia follow-up nurse or respiratory therapist reviewed all inpatient anesthesia records for accuracy and completeness and recorded any events the anesthesiologist may have failed to document. All available hospital charts were also reviewed, and any postoperative events were added to the follow-up record. For inpatients, wherever possible, an interview was carried out with the child or parents to learn of any problems and to assess the level of satisfaction or dissatisfaction with the anesthetic experience. The results of the interviews were then added to the record. The complete form was returned to the attending anesthesiologist for review before data processing. As the anesthesiologists' billing card was incorporated into the follow-up record thereby necessitating filling out billing and follow-up information simultaneously, compliance with the program was excellent.

Consistent definitions of the study variables (see Appendix) were used during the 6-yr period, with the exception of two additional variables, added in 1984, relating to airway management. An experienced anesthesia technician familiar with the care of children reviewed 140 random records from the database, comparing the information on the computer files with that of the hospital charts. The information was found to be coded reliably with the exception of the duration of anesthesia. The data on perioperative events were accurately recorded and thus considered valid for the purpose of this study.

We were first interested in a description of the children and what operations and anesthetic drugs were used. We then determined the rate of adverse events occurring in the perioperative period, namely, (a) during the operative procedure (intraoperative events), (b) immediately postoperatively (recovery room events), and (c) within 3 days of operation (early postoperative events). We expressed the rate of these adverse events per 10,000 anesthetics, with the children divided into five age ranges (under 1 mo, 1–12 mo, 1–5 yr, 6–10 yr, and 11–16 yr). To see if there were time differences in complications, certain analyses were grouped into three time periods: 1982–83, 1984–85, and 1986–87. A χ^2 statistic was used to test for the statistical significance of differences in rates of adverse events across age groups. (Refer to the Appendix for more details on the statistical analysis.) Finally, we compared the overall results for the children with that from our previous study of adults (3) to see if the types and rates of adverse events were similar.

Results

Characteristics of the children in the study are seen in Table 1. The children included neonates to adolescents, with most children in the 1–5-yr age group. The vast majority of the cases were judged to be healthy both in terms of physical status (95% being I or II) and coexisting medical conditions (74% having none). Generally, these children were admitted for elective surgery and increasingly slated as outpatients (45% of cases).

The site of the surgical procedure by age group of the children is found in Table 2. A wide range of procedures were performed at the hospital including intracranial, cardiac, and major vascular. However, the majority of operations were relatively routine "eye, ear, nose, and throat" and musculoskeletal. Neonates had the highest age-specific rates for intracranial, intraabdominal, or major vascular/cardiac procedures.

Details on the anesthetic monitors, drugs used, and duration of anesthesia are found in Table 3. Most of the procedures lasted 15–60 min but 14.3% took more than 2 h. Virtually all children had electrocardiogram, blood pressure, and esophageal stethoscope monitoring as routine procedures; other monitors were modified to particular circumstances. Nitrous oxide was used in 96% of the cases, and

Table 1. Characteristics of Cases

Characteristic	n	%
Age		
<1 mo	361	1.2
1–12 mo	2,544	8.7
1–5 yr	13,484	46.2
6–10 yr	7,184	24.6
11+ yr	5,647	19.3
Physical status score		
I	22,409	76.7
II	5,297	18.1
III	1,237	4.2
IV	205	0.7
V	36	0.1
Elective/emergency status		
Elective	25,940	88.7
Emergency	3,280	11.2
Admission status		
Inpatients	16,137	55.2
Day surgery	13,083	44.8
Time period		
1982–1983	7,280	24.9
1984–1985	10,604	36.2
1986–1987	11,283	38.6
Coexisting medical conditions		
None	21,473	73.6
Upper respiratory	1,724	5.9
Lower respiratory	1,328	4.6
Cardiovascular	831	2.9
Musculoskeletal	1,348	4.6
Metabolic	584	2.0
Renal	340	1.2
On chronic medication	779	2.7
Other conditions	4,427	15.2

halothane was by far the most widely used volatile agent (91%). Use of relaxants for prolonged paralysis was infrequent (9%), although more than half the patients were briefly paralyzed for intubation. We also rarely used diazepam, ketamine, and rectally administered or narcotic agents.

Intraoperative events by age of the child are seen in Table 4. There were considerable differences across the five age groups. Neonates had the highest rate of adverse events, with the most frequent problem being "other respiratory" (laryngospasm, apnea, or bronchospasm). Overall, infants 1–12 mo of age had the fewest intraoperative events when compared with all groups. Among children 1–5 and 6–10 yr of age, the most frequent problems were arrhythmias. The incidence of vomiting and arrhythmia was greater in the older children, whereas difficulties relating to the respiratory system were more frequent in children under 1 yr of age. Mortality rates were the highest in the neonatal group.

Recovery room events are summarized in Table 5. Again, the highest rate of adverse events was seen in the neonatal group. Problems relating to the respiratory system were the most frequent, but there were also frequent concerns about temperature changes in these children. In infants 1–12 mo of age, the rate of complications was very low, the most frequent being associated with the respiratory system. Older children (1–5 yr) also had a high incidence of respiratory problems. The adolescent age group had high rates of vomiting as well as respiratory disorders. Again, as for intraoperative events, cardiac arrest was most often seen in the neonatal group.

Table 6 outlines the early postoperative events among children whose charts were reviewed by the nurse (n = 22,760, 78% of all anesthetics). About 62% of the neonates had no adverse postoperative events, compared with 81% for infants 1–12 mo and 59% for older children. Among the neonates, the most common problems were respiratory (2519 per 10,000) and cardiovascular (630 per 10,000), whereas in infants 1–12 mo of age, vomiting and problems involving the respiratory system and temperature regulation were common.

A somewhat different picture is seen in older children. The incidence of nausea and vomiting was high for those aged 1–5 yr (20%) and increased in the oldest children to about one in three children. The older children also experienced more sore throats, headaches, and muscle pains, although perhaps these data are misleading, as younger children are unable to express these symptoms. As expected, croup was most frequent in children aged 1–5 yr. Despite the frequency with which these postoperative problems (albeit many minor in nature) occurred, there was very little parental dissatisfaction with the anesthetic experience (about four per 10,000 anesthetics).

As a summary we tabulated in two ways the proportion of cases in which there was at least one perioperative event: first as a function of age group, and second as a function of the year when the procedure was performed. Table 7 gives the final tabulation by age group of the children. Overall, the youngest group (neonates) were the most likely to experience an event intraoperatively or in the recovery room. They were less likely to experience a minor event postoperatively than were the older children but much more likely to undergo a major postoperative event. The rate of having any perioperative event was lowest for infants aged 1–12 mo and highest for children more than 6 yr of age. However, the oldest children were much more likely to experience minor postoperative events considered to be inconveniences but not life-threatening.

For the time-trend summary, about 9% of the cases had at least one event intraoperatively; this trend fell

Table 2. Surgical Site by Age of Child (Percentage of Cases)

	Age					
	<1 mo (*n* = 361)	1–12 mo (*n* = 2,544)	1–5 yr (*n* = 13,484)	6–10 yr (*n* = 7,184)	11+ yr (*n* = 5,647)	Total (*n* = 29,220)
Intracranial	3.32	2.52	0.53	0.72	0.74	0.83
EENT	6.65	18.20	52.80	52.34	29.02	44.51
Other head and neck	4.43	8.06	13.36	6.44	6.50	9.76
Intrathoracic nonvascular	6.37	0.67	0.13	0.40	0.66	0.42
Major vascular/cardiac	12.74	1.73	0.59	0.54	0.34	0.78
Intraabdominal	42.11	17.61	3.84	5.58	9.63	7.06
Trunk	5.54	15.80	4.96	4.20	3.67	5.48
Spine	1.66	0.28	0.10	0.28	1.65	0.48
Perineal	4.99	11.36	6.73	5.23	4.66	6.34
Extremities	1.11	11.95	10.38	19.04	35.97	17.48
Endoscopy	8.31	6.13	3.90	4.06	5.68	4.53
Other	2.77	5.70	2.67	1.14	1.49	2.33

EENT, eye, ear, nose, and throat.

Table 3. Anesthetic Drugs, Monitors, and Duration

	n	%
Monitors		
Electrocardiogram	29,052	99.4
Blood pressure cuff	28,871	98.8
Precordial/esophageal stethoscope	28,462	97.4
Temperature	13,045	44.6
Nerve stimulator	1,809	6.2
Intraarterial	599	2.0
Urinary catheter	499	1.7
Central venous pressure	438	1.5
Drugs		
Nitrous oxide	27,964	95.7
Barbiturate	6,984	23.9
Muscle relaxant/intubation	14,902	52.1
Muscle relaxant/paralysis	2,630	9.0
Diazepam	88	0.3
Ketamine	321	1.1
Rectal	58	0.2
Local anesthetic	1,782	6.1
Narcotic	2,805	9.6
Halothane	26,619	91.1
Enflurane	789	2.7
Methoxyflurane	88	0.3
Isoflurane	1,753	6.0
Standby	935	3.2
Other drugs	935	3.2
Duration of anesthesia		
<15 min	798	2.7
15–60 min	14,511	49.7
1–2 h	9,744	33.4
>2 h	4,167	14.3

slightly from 1982 to 1987 (Table 8). For recovery-room events, the proportions were very stable over time, at about 13% of cases. Early postoperative events were divided into major and minor, the former being life-threatening or with potential lasting morbidity and the latter more in the nature of inconvenience. About 21% of the children experienced a minor problem and this decreased from 27.3% in 1982–1983 to 20.9% in 1986–1987. With respect to major postoperative events, about 4% of the children had at least one significant event. Overall, about 40% of the children experienced at least one problem, whether in the intraoperative, recovery-room, or the later postoperative period. This contrasts with the findings in adults who had about the same rate of occurrence of intraoperative events, but much lower recovery and postoperative problems. Overall 18% of the adults had at least one perioperative problem.

Discussion

The Pediatric Anesthesia Follow-up Program database is subject to certain limitations in its ability to assess perioperative events, as discussed in our previous reports (3,4). In our follow-up program, no attempt is made to distinguish adverse events that may be attributable to the surgical procedure rather than to the anesthetic. However, the main focus of the program is to examine consequences of the surgical process that have a high likelihood of an anesthetic contribution. The time frame of the follow-up (72 h) also makes it unlikely that many surgical problems would yet become manifest. The major concerns include the grouping of several outcome variables (for example, "other respiratory" rather than individual events such as laryngospasm or bronchospasm). In addition, the inclusion of an event is subject to interpretation by the individual completing the form, suggesting that what might be considered to be a significant problem by one anesthesiologist may not be considered important by another individ-

Table 4. Intraoperative Events by Age of Child, 1982–1987 (Rate per 10,000 Anesthetics)

	Age											
	<1 mo (n = 361)		1–12 mo (n = 2,544)		1–5 yr (n = 13,484)		6–10 yr (n = 7,184)		11+ yr (n = 5,647)		Total (n = 29,220)	
	n	Rate	n	Rate	n	Rate	n	Rate	n	Rate	n	Rate
None	308	8,532	2,368	9,308	12,585	9,333	6,381	8,882	5,126	9,077	26,736	9,150
Vomiting	1	28	12	47	76	56[a]	71	99	77	136[a]	237	81
Arrhythmia	6	166	22	86	527	391	670	933	317	561	1,542	528[b]
Blood pressure	14	388[a]	14	55	30	22[a]	14	19	26	46	99	34
Temperature	3	83	6	24	18	13	6	8	9	16	42	14
Cardiac arrest	1	28	3	12	4	3	3	4	3	5	14	5
Airway obstruction	8	222	51	200[a]	133	99	62	86	51	90	305	105
Other respiratory	26	720[a]	81	318[a]	159	118	59	82[a]	56	99	381	130
Drug incident	0		5	20	27	20	20	28	20	35	72	25
Surgical	1	28	8	31	53	39	31	43	22	39	115	39
Death	3	83[a]	2	8	4	3	1	1	1	2	11	4

[a]$P < 0.01$, exact tail probability calculation based on Poisson distribution.
[b]$P < 0.01$, χ^2 test for association.

Table 5. Recovery Room Events by Age of Child, 1982–1987 (Rate per 10,000 Anesthetics)

	Age											
	<1 mo (n = 361)		1–12 mo (n = 2,544)		1–5 yr (n = 13,484)		6–10 yr (n = 7,184)		11+ yr (n = 5,647)		Total (n = 29,220)	
	n	Rate	n	Rate	n	Rate	n	Rate	n	Rate	n	Rate
None	301	8,338	2,376	9,340	11,971	8,878	6,201	8,632	4,848	8,585	25,696	8,794
Laryngospasm	1	28	11	43	252	187	127	177	93	165	484	166[a]
Vomiting	0		21	83	552	410	614	855	528	935	1,715	587[a]
Cardiac arrest	2	55[b]	1	4	3	2	1	1	0		7	2
Arrhythmia	0		3	12	11	8	11	15	5	9	30	10
Blood pressure	50	1,385[b]	3	12	13	10[b]	11	15[b]	18	32	95	17
Temperature	17	471[b]	35	138	77	57[b]	62	86	90	159[b]	281	96
Airway obstruction	1	28	41	161	599	444	187	260	104	184	932	319[a]
Other respiratory	42	1,163[b]	63	248[b]	142	105	56	78[b]	58	103	361	124
Drug incident	0		5	20	26	19	14	19	17	30	62	21
Surgical	1	28	16	63	177	131	120	167	43	76	357	122

[a]$P < 0.01$, χ^2 test for association.
[b]$P < 0.01$, exact tail probability calculation based on Poisson distribution.

ual. However, as the follow-up reviewer examines all records and the majority of hospital charts, it is unlikely that any major events would have been missed. There is still the possibility that the more minor adverse events may have been underreported.

During the creation of the form in the mid-1970s, the most important perioperative events were included in the check-off format based on what was then considered to be the major concerns for children undergoing anesthesia. Thus the form may not reflect more current knowledge about pediatric anesthesia nor the recent introduction of monitors or therapeutic agents. In addition, the change in follow-up personnel during the study period is of concern, particularly when recording events with a large subjective component such as parental dissatisfaction. However, the consistency in the rates over the 6-yr period makes it unlikely that there was a major problem with interobserver reliability.

Children less than 1 mo old appeared to have the greatest risk of perioperative adverse events, particularly major problems such as cardiac arrest and other cardiovascular or renal events. Perioperative death rates were also higher for these children. However, in view of the small number of children in this age group coming to operation, the influence of one or two adverse events on such occurrence rates can be dramatic. These infants were also much more likely to undergo major surgical procedures (i.e., cardiovascular or intraabdominal) and were more likely to be assessed preoperatively as PS 3 to PS 5 than the older children. In addition, these infants were routinely nursed in the Intensive Care Nursery where the greater level of observation in the imme-

Table 6. Early Postoperative Events by Age of Child (Rate per 10,000 Charts Reviewed)

	Age											
	<1 mo (n = 270)		1–12 mo (n = 2,045)		1–5 yr (n = 10,158)		6–10 yr (n = 5,693)		11+ yr (n = 4,594)		Total (n = 22,760)	
	n	Rate	n	Rate	n	Rate	n	Rate	n	Rate	n	Rate
None	167	6,185	1,656	8,098	7,341	7,227	3,392	5,958	2,690	5,855	15,247	6,699
Nausea/vomiting	13	481	100	489	2,042	2,011	1,949	3,424	1,474	3,209	5,579	2,451[a]
Other respiratory	68	2,519	121	592	196	196	81	142	82	178	548	241[a]
Temperature	20	741	77	377	226	222	111	195	97	211	531	233[a]
Surgical	1	37	53	259	183	180	122	214	70	152	429	188[a]
Other problem	3	111	51	249[b]	172	169	78	137	73	159	377	166
Croup	2	74	22	108	135	133[b]	27	47[b]	13	28[b]	199	87
Cardiovascular	17	630[b]	24	117[b]	30	30[b]	28	49	20	44	119	52
Positional	1	37	4	20	28	28	23	40	26	57	82	36
Renal	6	222[b]	6	29	23	23	14	25	24	52	73	32
Eye	1	37	6	29	25	25	4	7[b]	13	28	49	22
Arterial line	4	148[b]	10	49[b]	12	12	6	11	9	20	41	18
Behavior disorder	1	37	6	29	18	18	5	9	5	11	35	15
Thrombophlebitis	5	185[b]	4	20	5	5	4	7	9	20	27	12
Seizures	1	37	3	15	6	6	7	12	0		17	7
Parental dissatisfaction	0		1	5	3	3	1	2	3	7	8	4
Death	4	148[b]	1	5	2	2	1	2	2	4	10	4
Hepatic	0		0		0		0		0		0	0
Nerve palsy	0		0		0		0		0		0	0
Sore throat	[c]		[c]		44	43	99	174	145	316	289	141[d]
Headache	[c]		[c]		42	41	66	116	134	292	242	118[d]
Muscular pain	[c]		[c]		33	32	36	63	59	128	128	56[d]
Dental	[c]		1	5	4	4	8	14	4	9	17	8
Awareness	[c]		[c]		2	2	7	12	3	7	12	5

[a] $P < 0.01$, χ^2 test for association, 2 × 5 contingency table.
[b] $P < 0.01$, exact tail probability calculation based on Poisson distribution.
[c] Children under the age of 1 yr could not describe these symptoms.
[d] $P < 0.01$, χ^2 test for association, 2 × 3 contingency table.

Table 7. Perioperative Events, Summary by Age Group (Percent Total Anesthetics)

	<1 mo (n = 361)	1–12 mo (n = 2,544)	1–5 yr (n = 13,484)	6–10 yr (n = 7,184)	11+ yr (n = 5,647)
Any intraoperative event	14.96	7.31	7.10	12.22	9.69
Any recovery-room event	16.61	7.23	12.20	14.88	15.23
Any postoperative					
Minor event[a]	13.57	10.30	20.32	31.49	32.44
Major event[b]	23.82	7.51	3.26	3.37	3.33
Any event[c]					
Among patients seen	48.89	25.92	37.50	50.52	51.33
Among all patients	41.55	23.47	33.16	45.04	45.78

[a] Includes nausea and vomiting, sore throat, muscle pain, headache, dental, positional, extremities, eye, croup, temperature, behavior problem, thrombophlebitis, arterial line problem, awareness, and "other."
[b] Includes "other respiratory," cardiovascular, nerve palsy, hepatic, renal, seizures, surgical complications, and death.
[c] Percentage of total anesthetics in which there was at least one event in either the intraoperative, recovery-room, or later postoperative period.

diate postoperative period may result in an enhanced detection of perioperative events. As a result of this study, we have reviewed our management of neonates. Specifically, we identified significant problems with hypothermia and cardiovascular instability during transportation of ill neonates weighing less than 1000 g from the intensive care nursery, which is located on a different floor, to the operating rooms. Currently, we administer general anesthesia in the nursery for the most critically ill neonates rather than expose them to the risks of transport. Because of the higher incidence of major events in neonates, we have extensively reviewed our monitoring requirements for neonates. Our major conclusion is that there is an increasing need for equipment suppliers to design anesthesia monitors and ventilators specifi-

Table 8. Perioperative Events Summary Over Time (% Total Anesthetics)

	Children (%)			Adults[a] (%)
	1982–83	1984–85	1986–87	1979–83
Any intraoperative	9.52	9.00	8.58	10.6
Any recovery room	12.91	13.24	13.03	5.9
Any postoperative				
Minor[b]	27.38	26.21	20.86	9.4
Major[c]	3.82	4.39	3.55	0.5
Any event[d]				
Among cases seen	44.58	42.95	40.82	31.6
Among all cases	40.23	38.61	35.35	17.8

[a]Reference 3.
[b]Includes nausea and vomiting, sore throat, muscle pain, headache, dental, positional, extremities, eye, croup, temperature, behavior problem, thrombophlebitis, arterial line problem, awareness, and "other."
[c]Includes "other respiratory," cardiovascular, nerve palsy, hepatic, renal, seizures, surgical, and death.
[d]Percentage of total anesthetics in which there was at least one event in either the intraoperative, recovery-room, or later postoperative period.

cally for the intraoperative management of very small neonates.

With regard to intraoperative events, there was little difference between the rate of adverse events for the pediatric age group as compared with the rates for adults (3). In the adult group, the overall rate of any intraoperative complication was 10.6 per 10,000 and in children was about nine per 10,000. In the recovery room, the profile of adverse events experienced by the children differed considerably from that of the adults: children were less likely to experience problems with arrhythmias or hypotension, but were more likely to have problems related to the respiratory system. Overall the rate of recovery room complications was 5.9 per 10,000 for adults and 13 per 10,000 for children. These results formed the administrative rationale for the purchase of additional monitoring equipment such as oximetry and noninvasive blood pressure machines for the recovery room.

Among the older children, there was a considerable problem with postoperative nausea and vomiting, with nearly one-third of the children experiencing this problem. This is in contrast to only 5% of adults with the same complaint (3). As with the adult patients, nausea and vomiting were the most frequent postoperative problems in this study. However, the low rate of administration of intraoperative narcotics in the pediatric population (as compared with the adults we studied) suggests an etiology distinct from the anesthetic drugs, perhaps including the surgical procedure itself, anxiety, fear, or postoperative pain. In an effort to reduce postoperative nausea, we have significantly increased our use of supplemental regional anesthesia among other measures.

As noted above, there are no large series with which to compare the present results with the exception of that of Tiret et al. from France (2). However, comparisons between the two series are difficult because of differences in patient populations, surgical profiles (e.g., eye, ear, nose, and throat procedures constituted 30.9% of the French series compared with 44.5% in ours), duration of follow-up (the French study included only events occurring within 24 h of the procedure, whereas our study extended to 72 h postoperatively), and definitions of outcomes. One comparison that can be made is that of the rate of cardiac arrest: in the French study, the rate of cardiac arrest for infants under 1 yr of age was 19 per 10,000 anesthetics, which compares favorably with the present study rate of 24 per 10,000. An interesting point was that in the French study, there were no major events in children undergoing cardiac procedures.

In evaluating the findings of this survey, we can see that children's experience with anesthesia is quite different from that of adults. Not only are the types of problems dissimilar, but the timing of the disorders extend well into the postoperative period. Whereas the profile of problems is probably not that surprising, the magnitude of the occurrence rates is noteworthy. This study has certainly prompted us to be more vigilant in assessing the respiratory system in children.

We were pleased that there was a stability or, in the case of postoperative events, a decline in the rate of problems over time. The number of deaths was too small to show time trends, but the decrease in morbidity is encouraging. We found that this audit was particularly helpful in assessing the quality of care at our institution, and it has led to modifications in patient care. By defining the problems, prophylactic measures such as alternative methods of pain control, respiratory management, and antinausea therapy can be implemented and evaluated. Although observations such as these cannot be generalized to other hospitals, they do point out the merit of monitoring perioperative events in directing future therapeutic decisions.

In summary, we have carried out a survey of 6 yr of experience with pediatric anesthesia at our hospital. This paper highlights the differences between children and adults especially in three areas: the high morbidity rate among neonates, the importance of respiratory disorders in younger children, and the high frequency of postoperative nausea and vomiting in older children. These areas require attention in designating areas for future investigation and intervention.

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Appendix

A. Definition of Variables Used in the Follow-up Study

Coexisting medical conditions: Upper respiratory—upper respiratory illness or difficult airway; Lower respiratory—includes asthma, cystic fibrosis; Metabolic—includes diabetes and thyroid disorders; Receiving chronic medications—includes bronchodilators and anticonvulsants; Other conditions—includes neurologic and hematologic disorders.

Intraoperative events: Arrhythmia—includes supraventricular, ventricular, or heart block; Blood pressure—hypotension where blood pressure fell at least 30% from preoperative value; Temperature—hypothermia; Other respiratory—includes laryngospasm and bronchospasm; Drug incident—anaphylactoid reactions or other drug reactions; Surgical—mainly excessive bleeding.

Recovery-room events: Same definitions as for intraoperative.

Postoperative events: Muscular pain—generalized (fasiculation) muscle pain; Dental—broken or chipped teeth; Positional—pain, bruising, or pressure sores in localized area possibly due to malpositioning during the procedure; Eye—corneal abrasion, conjunctivitis; Other respiratory—atelectasis, pulmonary edema, pneumonia; Temperature—elevated temperature greater than 38°C; Cardiovascular—hypotension, hypertension, arrhythmia, tachycardia, bradycardia; Hepatic—jaundice; Renal—oliguria; Arterial line—excessive bruising, no pulse; Awareness—recall of events in the operating room; Surgical—excessive bleeding, return to operating room.

B. Statistical Methods

As the number of infants less than 1 mo old was small (n = 361), a χ^2 test was not suitable for determining differences across age groups for many of the variables occurring at low rates. Therefore, to test for statistically significant equalities among the remaining variables in rates of outcomes across the five age groups, we compared the rate for each adverse event for a specific age group with that of the rate for all ages. This was done by comparing the observed number of events with the expected number of events (standardized morbidity ratio [SMR]). The age-specific expected number of events was determined by multiplying the number of children in each age strata by the observed rate of occurrence of each event in the total sample. The statistical significance of the SMR was assessed by calculating the exact tail probability of the Poisson distribution for observing more (for SMR > 1) or less (for SMR < 1) events than expected. To account for multiple statistical comparisons P values <0.01 were considered to be indicative of statistical significance.

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