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Characteristics of Emergency Pages Using a Computer-Based Anesthesiology Paging System in Children and Adults Undergoing Procedures at a Tertiary Care Medical Center

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Abstract

Background—In our large academic supervisory practice attending anesthesiologists concomitantly care for multiple patients. To manage communications within the procedural environment, we use a proprietary electronic computer-based anesthesiology visual paging system. This system can send an emergency page which instantly alerts the attending anesthesiologist and other available personnel that immediate help is needed. We analyzed the characteristics of intraoperative emergency pages in children and adults.

Methods—We identified all emergency page activations between January 1, 2005 and July 31, 2010 in our main operating rooms. Electronic medical records were reviewed for rates and characteristics of pages such as primary etiology, performed interventions, and outcomes.

Results—During the study period, 258,135 anesthetics were performed ($n = 32,103$ children, <18 years) and 370 emergency pages ($n = 309$ adults, $n = 61$ children) were recorded (1.4 per 1,000 cases; 95% CI, 1.3–1.6). Infants had the highest rates (9.4 per 1,000; 95% CI, 5.7–14.4) of emergency page activations ($P < 0.001$ compared to each other age group). In adults, the most frequent causes were hemodynamic (55%), and in children respiratory and airway (60.7%).

Conclusion—Emergency pages were rare in patients older than 2 years. Infants were more likely than children 1–2 yr to have emergency page activation, despite both groups being cared for by pediatric fellowship trained anesthesiologists.

Introduction

A sudden life-threatening event during anesthesia requires a prompt response, and in certain situations multiple providers need to help manage an acutely deteriorating patient. In clinical practices, common communication modalities include alphanumeric paging or overhead paging.^{1,2} While such modes are available at Mayo Clinic, our practice universally uses a proprietary computer-based anesthesiology paging system (CAPS) previously described.³ Activation of CAPS quickly provides a visual alert throughout the operating suites that the attending anesthesiologist is needed or, in the event of an emergency, provides visual and audible alerts that all available personnel should report immediately to the specified location. Intraoperative emergency pages should be viewed as the equivalent of “emergency response team” activations.⁴

Previous reports of intraoperative complications have noted that adverse events were more frequent in infants and children.^{5,6} These early studies found that up to 82% of the intraoperative incidents in children were due to preventable errors.⁷ Keenan et al.^{8,9} suggested that when pediatric trained anesthesiologists care for children the rate of serious adverse events may be reduced. At Mayo Clinic, fellowship trained anesthesiologists care for all our complex pediatric patients including all children younger than 2 years. The aim of our descriptive study is to report the frequency, indications, and major outcomes of intraoperative emergency pages among children and adults undergoing procedures in a

contemporary anesthesia practice. We hypothesized that the frequency of emergency pages would still be higher in infants (children < 1 year of age) compared to older children and adults despite the engagement of pediatric anesthesiologists in their care.

Methods

The approval for review of medical records without the need for written consent was obtained from the Mayo Clinic IRB.

Paging System and Patient Identification

Activation of CAPS is managed through commands on keypad controllers mounted at all anesthesia care locations (Figure 1A) and information is displayed on interconnecting LED screens conspicuously mounted throughout the procedural environment (Figure 1B). Specifics of this activation have been described³ and are briefly summarized in the legend of Figure 1. Response to the emergency page is prompt and, in addition to the attending anesthesiologist, all other available staff and auxiliary personnel respond because it is extremely difficult to narrow the scope of the alert. Since January 1, 2005, all pages made with the CAPS are stored in a Microsoft SQL Server (Microsoft Corp, Redmond, Washington) database. We identified all patients whose intraoperative course resulted in an emergency page from January 1, 2005 to July 31, 2010, at the two hospitals associated with Mayo Clinic in Rochester, Minnesota (Saint Marys and Methodist). Emergency pages that occurred in postanesthesia recovery units or diagnostic suites were excluded from analyses because patient identity could not be accurately determined.

Data Abstraction

All data were abstracted from the electronic medical records and entered manually into the web-based Research Electronic Data Capture (REDCap^R) system (Version 3.6.7, Vanderbilt University, Nashville, Tennessee).¹⁰ Data abstracted included demographics, ASA Physical Status score, specific comorbidities, intraoperative and postoperative events and major outcomes. Comorbid conditions were defined according to criteria previously used for outcome studies at Mayo Clinic¹¹ and include cardiovascular, peripheral vascular, and respiratory diseases; diabetes mellitus; and neurologic conditions (e.g., stroke, developmental delay). The anesthetic record was reviewed for type of anesthesia (combination regional and general anesthetics were considered general anesthetics) and type of in-room anesthesia provider (certified registered nurse anesthetist [CRNA], student registered nurse anesthetist [SRNA], or anesthesia resident physician). At our institution, in-room providers administer anesthesia under direction of an attending anesthesiologist who is present during induction, emergence, and critical portions of the anesthetic. The supervision ratio ranges from 1:2 as a first set of cases in the morning, to 1:3 or 1:4 later in the day.

Indications for the emergency page were identified from notations in the medical records, or by changes in vital signs, and medications, interventions or blood products administered. The probable primary cause was determined by consensus of the 2 senior authors (T.N.W., J.S.) attributed to 1 of 4 main categories: 1) *hemodynamic* which includes 3 subcategories: a) *hypotension* (decrease of systolic blood pressure not explained by a dysrhythmia), b) *dysrhythmias* (including those associated with cardiac arrest not related to hypoxemia or hypotension), c) *hypertension*; 2) *airway-related events* (e.g., inability to intubate, mask ventilate, accidental extubation), or *respiratory-related events* (e.g., hypoxemia, bronchospasm, aspiration, or laryngospasm); 3) *miscellaneous causes* (e.g., seizures, anaphylaxis, or inadequate anesthesia); and 4) *unknown etiology*. Inadequate anesthesia was defined from notation in the anesthetic record or the administration of additional inhaled or IV anesthetics. Timing of pages was recorded as: induction (within 10 minutes of tracheal

intubation), maintenance, or emergence (after surgical closure and within 10 minutes after tracheal extubation). Response time to emergency page was quantified by calculating the difference in time from its activation to the time it was turned off.

Interventions in response to the emergency pages were recorded and were classified as respiratory, major cardiovascular (cardiopulmonary resuscitation, cardioversion, unplanned cardiopulmonary bypass), administration of potent cardiovascular medications, changes in anesthetic or surgical management, transfusion of blood products, and miscellaneous interventions. Cardiac arrest was considered only if the chest compressions and/or cardioversion for a nonperfusing dysrhythmia were performed. Intraoperative and 30-day mortality rates were recorded.

Statistical Analyses

The frequency of emergency pages (*per* 1,000 anesthetics) was calculated overall and also according to age categories based on subjectively determined, but clinically relevant, cut points (age less than 1[infants], 1–2, 3–10, 11–17, 18–29, 30–49, 50–64, 65–74, and > 74 years). This information is presented using point estimates and exact binomial 95% confidence intervals (CIs). Unless otherwise specified, data are summarized using mean $\pm$ SD or median (25th, 75th, 95th percentiles) for continuous variables and proportions for categorical variables. Patient and procedure characteristics, treatments, and outcomes were compared between adults and children using the Wilcoxon rank sum test for continuous variables and Fisher exact test for categorical variables. Two-tailed P values $\leq$ 0.05 were considered statistically significant. Analyses were performed using SAS statistical software (Version 9.2, SAS Institute, Inc, Cary, North Carolina).

Results

During the study time frame, 258,135 procedures were performed under the care of anesthesia teams in our main operating suites, and of those, 32,103 (12.4%) were children (<18 years). A total of 370 emergency pages were recorded at an overall rate of 1.4 *per* 1,000 cases (95% CI, 1.3–1.6). Of these emergency pages, 309 were for adults (1.4 *per* 1,000; 95% CI, 1.2–1.5) and 61 for children (1.9 *per* 1,000; 95% CI, 1.5–2.4). Figure 2 shows the frequency of emergency pages according to age. Infants had the highest rate (9.4 *per* 1,000; 95% CI, 5.7–14.4; $P < 0.001$ compared to each other age category).

Demographics, comorbidities, surgical characteristics, and characteristics of the emergency paging activation are summarized separately for adults and children in Tables 1 and 2. Figure 3 shows the main etiological categories for emergency page activation. The causes differed between adults and children. In adults, the most frequent causes were hemodynamic (55.0%), followed by airway or respiratory-related events (33.0%); while in children, airway or respiratory-related events occurred most often (60.7%). The specific circumstances surrounding airway-related events are provided in Table 3. Interventions in response to emergency pages are shown in Table 4. Cardiac arrests before or during emergency page and overall mortality are summarized in Table 5.

Discussion

We confirmed that intraoperative emergency pages, mostly due to respiratory causes, are more common in infants than in children 1–2 years old, despite both groups being cared for by pediatric trained anesthesiologists. This may be attributed to higher propensity for sudden development of bronchospasm, laryngospasm, and/or oxyhemoglobin desaturation in infants.^{12,13} Furthermore, more than any other emergency, a sudden respiratory event may occur regardless of coexisting comorbidities, which is suggested by our finding that 88.3%

of all our infants with respiratory emergencies were ASA physical status 2. In the second year of life, and later through childhood and adulthood, the rate of intraoperative emergency pages remained consistently low (Figure 2). The majority of emergency pages in adults was associated with cardiovascular causes, which typically develop more gradually; therefore, the anesthesiologist could be paged nonemergently, and this may explain why the rate of emergency pages was found not to increase in the elderly.

Approximately 85% of in-room providers at Mayo Clinic are CRNAs and they activated 51% of the emergency pages; while trainees, residents physicians and SRNAs cover 6% and 9% cases, respectively. Hence, it appears that trainees had a disproportionately higher rate of emergency page activations. This may suggest that trainees activate an emergency page for lower acuity problems or may have a lower threshold for requesting emergency assistance. Unfortunately, since our analysis dataset does not have detailed information (e.g., provider training level) for all procedures performed during this study period, we could not assess whether level of training is a risk for emergency page activation.

It has been shown that there is an association between supervision ratio and the number of lapses during the first-case starts.¹⁴ However, in our practice first round cases are assigned to attending anesthesiologists at a 1:2 ratio, and the first-case starts are in practice staggered. In addition, emergency pages in our practice were uniformly distributed throughout the morning until early afternoon, a time during which our operating rooms are at full working capacity (10–14% of all pages occurred at each hour between 08:00 to 14:00) and attending anesthesiologist coverage during these hours generally increases to 1:3 or 1:4. This suggests that the emergency pages are associated more with the number of cases performed rather than the attending anesthesiologist supervision ratio.

Furthermore, most pages occurred during anesthesia maintenance when the attending anesthesiologist is least likely to be present in the room. Alternatively, when the attending anesthesiologist is present, at induction or emergence, it may be less likely for the page to be activated. Finally, faster response to emergency page for adults during standard versus nonstandard working hours may reflect the fact that more attending anesthesiologists are available to respond during standard working hours. The similar response times to pediatric emergency pages between standard work times and nonstandard times may reflect that off-hour pediatric emergency cases, in contrast to adults, are typically covered in 1:1 ratio, with the pediatric anesthesiologist present nearby.

Limitations of the Study

Our study does not precisely report the rates of intraoperative complications, because emergency page activation cannot uniformly be equated to every patient complication. For example, emergency pages can be triggered erroneously, for nonemergent situations, or reasons unrelated to patient care (e.g., 1 emergency page activation recently occurred because a syncopal episode in a pregnant nurse). These nonpatient-related activations may account for some of the emergency pages with no supporting documentation in the medical records. At the same time, the rate of emergency pages likely represents an underestimate of intraoperative adverse events because the attending anesthesiologist may have been either present during the event or was paged in a less urgent fashion (green or orange light). However, in serious situations (i.e., cardiac arrest), even if present in the room, anesthesiologists may activate the emergency page to summon additional resources; therefore, our report of intraoperative cardiac arrests provides a reasonable estimate. Furthermore, for our study we obtained overall denominators only according to age and for this reason, we cannot estimate or compare the frequency of emergency pages under various conditions (for example, by day of week, by time of day, or according to staff supervision ratio, or incidence in regard to the type of in-room provider at the time of emergency page).

Since our practice has a long tradition that only pediatric fellowship trained anesthesiologists care for more complex cases and the youngest children, we cannot assess the role of specialty trained anesthesiologists on the rate of emergency pages. Finally, CAPS is a proprietary paging system; therefore, our experience may not be generalizable to other settings with different communication systems.

In conclusion, the frequency of emergency pages remains highest in infants despite being cared for by pediatric anesthesiologists. The rate of emergency pages remains at low levels after the first year of life and throughout adulthood. Intraoperative events resulting in an emergency page in infants were more likely related to respiratory complications and less due to comorbid conditions.

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Figure 1.

Components of computer-based anesthesiology paging system (CAPS). Activation of CAPS is managed through commands on keypad controllers (Panel A) which are mounted at all anesthesia care locations. Keypad controllers interface with LED display screens (Panel B) conspicuously mounted throughout the procedural environment. The keypad is activated by a push of a single button to visually display which personnel (e.g., attending anesthesiologist (PHYSICIAN), certified registered nurse anesthetist (CRNA), anesthesia technician (AN TECH), pathologist (PATH), autotransfusion personnel (AUTOTX), monitoring technician (MON TECH), or laboratory personnel (LAB) are needed at specific location. Besides emergency page (bright red flashing display accompanied with an audible alarm as shown on the picture), CAPS can send nonurgent visual page (green light), and urgent (orange light). Panel B depicts an emergent page in red flashing lights. The abbreviation “C209 A” indicates that the anesthesiologist and other available personnel are needed emergently in the operating room 209 which is located in the C section of the operating suite.

Figure 2.

Frequency of emergency pages in the main operating rooms according to age of patients. Values plotted are the point estimate with bars extending to the upper and lower bounds of the 95% CI. The overall emergency page activation rate was 1.4 per 1,000 cases (95% CI, 1.3–1.6). Abbreviation: EmP = Emergency page. Pairwise comparisons between age groups were performed using the chi-square test. In order to account for multiple comparisons (36 pairwise comparisons), $P = 0.001$ was used to denote statistical significance. From these pairwise comparisons, infants were found to have a significantly higher rate of emergency paging compared to each other age group (all $P < 0.001$).

Figure 3.
Main causes for emergency pages.

Table 1

Demographic and Surgical Characteristics in Patients Who had an Emergency Page

Characteristics	Child N=61	Adult N=309	P-value*
Age (years), median [25 th , 75 th]	61 [46–71]	1 [0–9]	
Male sex	32 (52.5)	183 (59.2)	0.394
ASA Physical Status			<0.001
1	20 (32.8)	14 (4.5)	
2	19 (31.1)	111 (35.9)	
3	18 (29.5)	145 (46.9)	
4	3 (4.9)	36 (11.7)	
5	1 (1.6)	3 (1.0)	
Comorbidities			
Hypertension	2 (3.3)	174 (56.3)	<0.001
Cardiovascular disease	12 (19.7)	116 (37.5)	0.008
Respiratory disease	13 (21.3)	97 (31.4)	0.127
Neurologic conditions	19 (31.1) [†]	44 (14.2)	0.003
Diabetes	0 (0.0)	64 (20.7)	<0.001
Operation Type			<0.001
General	10 (16.4)	70 (22.7)	
Thoracic	1 (1.6)	23 (7.4)	
Vascular	1 (1.6)	30 (9.7)	
Orthopedic	10 (16.4)	60 (19.4)	
Neurosurgery	5 (8.2)	16 (5.2)	
Transplant	0 (0.0)	6 (1.9)	
Urology/Gynecology	10 (16.4)	51 (16.5)	
Otorhinolaryngology	11 (18.0)	31 (10.0)	
Obstetrics	0 (0.0)	1 (0.3)	
Plastics	5 (8.2)	6 (1.9)	
Diagnostic procedure	7 (11.5)	3 (1.0)	
Cardiac	1 (1.6)	12 (3.9)	
Emergency Operation	4 (6.6)	28 (9.1)	0.627

Data are presented N (%) with the exception of age which is median [25th, 75th].

* Fisher's exact test.

[†] In 16 children the neurological condition was developmental delay.

Abbreviations: ASA, American Society of Anesthesiologists.

Table 2**Anesthetic Characteristics and Causes for Emergent Page Events**

Characteristic	Child N=61	Adult N=309	P value
Event Documentation			0.590
Cause and intervention documented	48 (78.7)	257 (83.2)	
Cause documented but intervention not documented	4 (6.6)	14 (4.5)	
Intervention documented but cause not documented	0 (0.0)	4 (1.3)	
No documentation of cause or intervention	9 (14.8)	34 (11.0)	
Anesthesia Type			1.000
General anesthesia	59 (96.7)	297 (96.1)	
Neuraxial anesthesia only	0 (0.0)	2 (0.6)	
Monitored anesthesia care/regional anesthesia	2 (3.3)	10 (3.2)	
Anesthesia Stage at Event Occurrence			0.480
Awake [£]	0 (0.0)	4 (1.3)	
Induction	17 (27.9)	63 (20.4)	
Maintenance	29 (47.5)	172 (55.7)	
Emergence	15 (24.6)	70 (22.7)	
Time of Event Occurrence			0.687
Standard working hours (Mon-Fri 8:00 AM to 5:00 PM)	54 (88.5)	265 (85.7)	
Night/weekends	7 (11.5)	44 (14.3)	
Time to Response (seconds), median (25th, 75th, 95th)[†]	21 [14, 29, 42]	26 [17, 34, 58]	0.008
In-room Anesthesia Provider			0.586
Nurse anesthetist	35 (57.4)	155 (50.2)	
Student nurse anesthetist	11 (18.0)	71 (23.0)	
Resident physician	15 (24.6)	83 (26.9)	
Primary Cause for Emergency Page Activation			<0.001 [‡]
Hemodynamic Causes	8 (13.1)	170 (55.0)	
Dysrhythmia	4	129	
Hypotension	4	39	
Hypertension	0	2	
Airway or Respiratory Causes	37 (60.7)	102 (33.0)	
Airway-related events	10	36	
Respiratory-related events	27	66	
Miscellaneous Causes	12 (19.7)	14 (4.5)	
Inadequate anesthesia	9	4	
Seizure	1	4	
Presumed anaphylaxis	2	2	
Acute mental status change	0	2	
Embolism	0	1	
Suspect malignant hyperthermia	0	1	
Unknown Cause[§]	4 (6.6)	23 (7.4)	

Data are presented N (%) with the exception of time to response which is median [25th, 75th, and 95th percentile].

* Fisher's exact test except comparison of time response which was performed using Wilcoxon rank sum test.

£ During placement of a regional anesthetic block or invasive vascular line insertion.

† Among adults, response time was shorter during standard working hours (24 [17, 34, 57] seconds) compared to nights and weekends, (32 [22, 43, 87]), P=0.002. Among children the time to response did not differ for pages that occurred during standard working hours (21.5 [15, 28, 42]) compared to nights and weekends (16 [12, 30, 40]), P=0.803.

‡ Analysis compares groups across main cause categories: hemodynamic vs. respiratory vs. miscellaneous vs. unknown.

§ Indication for emergency page activation could not be determined because of lack of documentation and no obvious perturbations of vital signs or documented interventions.

Table 3**Emergency Page Associated With Airway-Related Emergencies****PEDIATRIC PATIENTS****Induction**

- Difficult mask ventilation (n=2)
- Difficult intubation (n=1)
- Difficulty ventilating through laryngeal mask airway (n=1)
- Inadvertent tracheal extubation (n=1)

Maintenance

- Inadvertent tracheal extubation (n=3)

Emergence

- Difficult mask ventilation after oral surgery (n=2)

ADULT PATIENTS**Induction**

- Difficult mask ventilation (n=5)
- Difficult tracheal intubation (n=14)

Maintenance

- Inadvertent tracheal extubation (n=2)
- Apnea during monitored anesthesia care requiring tracheal intubation (n=1)
- Disconnection of endotracheal tube from anesthesia circuit (n=1)
- Airway lost during tracheotomy (n=3)
- Difficult ventilation through laryngeal mask airway (n=2)
- Inability to reintubate trachea during exchange of endotracheal tube (n=2)

Emergence

- Hypoxic episode after tracheal extubation requiring reintubation or tracheostomy (n=5)
- Difficult tracheal reintubation (n=1)

Abbreviation: n= number

Table 4**Interventions Performed During Emergency Page**

Characteristic	Child N=61	Adult N=309	P-value *
Respiratory Interventions	33 (54.1)	91 (29.4)	<0.001
Bronchodilator nebulizer	4	7	
Tracheal reintubation	10	24	
Secured airway	13	37	
Mask ventilation	9	19	
Suction	0	3	
Ventilatory settings adjusted	4	7	
Chest tube placed	0	2	
Major Cardiovascular Interventions	6 (9.8)	79 (25.6)	0.011
Chest compressions	6	70	
Cardioversion	1	26	
Unplanned cardiopulmonary bypass	0	1	
Change in Management	9 (14.8)	44 (14.2)	1.00
Regional/MAC converted to general anesthesia	0	5	
Deepened anesthesia	6	11	
Change in surgical technique	0	2	
Case discontinued	3	29	
Vasoactive Management	15 (24.6)	162 (52.4)	<0.001
Vasopressors [†]	7	114	
Other cardiovascular medications	11	113	
Other Interventions	2 (3.3)	8 (2.6)	0.673
Sodium bicarbonate	1	8	
Naloxone	0	2	
Intralipid (local anesthetic toxicity)	0	2	
Dantrolene + cooling	0	1	
Diphenhydramine	1	1	
Flooded surgical field with saline for VAE	1	0	
Equipment repaired	0	1	
Observe only	0	1	
Blood Products Administered	2 (3.3)	26 (8.4)	0.285
Blood transfusion	2	24	
Other blood products	1	14	
Intervention not Documented	11 (18.0)	38 (12.3)	0.221

Data are presented N (%). The sum of individual interventions may be higher than the number of patients in the main intervention categories because some individuals received multiple interventions.

* Fisher exact test.

[†]Vasopressors included ephedrine, phenylephrine, epinephrine, norepinephrine, vasopressin, dopamine, milrinone, calcium chloride.

[‡]Other cardiovascular drugs included use of anticholinergics (atropine or glycopyrrolate), beta-adrenergic blocker (including labetalol), other antihypertensive drugs (e.g., hydralazine), and antiarrhythmic drugs (e.g., amiodarone).

Abbreviations: VAE, venous air embolism, MAC, monitored anesthesia care.

Table 5

Cardiac Arrest and Mortality in Adult and Pediatric Patients who had an Emergent Page

Event	Child N=61	Adult N=309
Cardiac Arrest	6 (9.8)	76 (24.6)
Asystole	3	43
Ventricular fibrillation	2	24
Pulseless electrical activity	1	9
Intraoperative Death *	0 (0)	13 (4.2)
Mortality, 30-Day †	2 (3.3)	21 (6.8)

Data are presented as N (%).

* All intraoperative deaths occurred in patients undergoing major surgery.

† Patients who died postoperatively all underwent major surgery except 1 adult patient whose support was withdrawn after suffering anoxic brain injury following a cardiac arrest during arytenoid surgery. Nine patients who were alive at hospital discharge but had missing 30-day follow-up were assumed to be alive at 30 days.