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SPECIAL ARTICLE

Development and implementation of local pediatric anesthesia performance metrics at a Canadian children's hospital: a technical report

Élaboration et mise en œuvre de mesures de productivité de l'anesthésie pédiatrique localement dans un hôpital canadien pour enfants : un rapport technique

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Abstract

Purpose *In this project, we sought to develop and implement pediatric anesthesia metrics into electronic health records (EHR) in a hospital setting to improve quality and safety of patient care. While there has been an upsurge in metric-driven health care, specific metrics catering to pediatric anesthesia remain lacking despite widespread use of EHR. The rapid proliferation and implementation of EHR presents opportunities to develop and implement metrics appropriate to local patient care, in this case pediatric anesthesia, with the strategic goal of enhancing quality and safety of patient care, while also delivering transparency in reporting of such metrics.*

Clinical features *Using a quasi-nominal consensus group design, we collected requirements from attending anesthesiologists using Agile methodology. Forty-five metrics addressing quality of care (e.g., induction experience, anesthesia delivery, unanticipated events, and postanesthetic care unit stay) and provider performance (e.g., bundle-compliance, collaboration, skills assurance) were developed. Implementation involved integration into the EHR followed by transition from PDF-based feedback to interactive Power BI (Microsoft Corporation, Redmond, WA, USA) dashboards.*

Conclusion *We introduced and implemented customized pediatric anesthesia metrics within an academic pediatric hospital; however, this framework is easily adaptable across multiple clinical specialties and institutions. In harnessing data-collecting and reporting properties of EHR, the metrics we describe provide insights that facilitate real-time monitoring and foster a culture of continuous learning in line with strategic goals of high-reliability organizations.*

Résumé

Objectif *Dans le cadre de ce projet, nous avons cherché à développer et à mettre en œuvre des mesures d'anesthésie pédiatrique dans les dossiers de santé électroniques (DSE) en milieu hospitalier afin d'améliorer la qualité et la sécurité des soins aux patient·es. Bien qu'il y ait eu une recrudescence des soins de santé guidés par les procédures d'évaluation, les mesures spécifiques à l'anesthésie pédiatrique restent insuffisantes malgré l'utilisation généralisée du DSE. La prolifération et la mise en œuvre rapides des DSE offrent des possibilités d'élaborer et de mettre en œuvre des paramètres appropriés aux soins*

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locaux aux patient·es, dans ce cas-ci en anesthésie pédiatrique, dans le but stratégique d'améliorer la qualité et la sécurité des soins tout en assurant la transparence des communications concernant ces paramètres.

Caractéristiques cliniques *À l'aide d'un modèle de groupe consensuel quasi nominal, nous avons recueilli les exigences des anesthésiologistes traitant·es à l'aide de la méthodologie Agile. Quarante-cinq paramètres portant sur la qualité des soins (p. ex., l'expérience d'induction, l'administration de l'anesthésie, les événements imprévus et le séjour en salle de réveil) et la productivité des prestataires (p. ex., l'observance des forfaits, la collaboration, l'assurance des compétences) ont été élaborés. La mise en œuvre a impliqué l'intégration dans le DSE, suivie de la transition des commentaires en format PDF vers les tableaux de bord interactifs Power BI (Microsoft Corporation, Redmond, WA, États-Unis).*

Conclusion *Nous avons introduit et mis en œuvre des mesures personnalisées de l'anesthésie pédiatrique au sein d'un hôpital pédiatrique universitaire. Cependant, ce cadre est facilement adaptable à de multiples spécialités cliniques et institutions. Parce qu'elles exploitent les propriétés de collecte de données et de communications du DSE, les mesures que nous décrivons fournissent des informations qui facilitent la surveillance en temps réel et favorisent une culture d'apprentissage continu conforme aux objectifs stratégiques des organisations à haute fiabilité.*

Keywords anesthesia · informatics · perioperative · quality improvement

A metric is a quantifiable measure used to track, compare, and assess performance or a process. Metrics are tracked to record and analyze progress toward a set goal or key performance indicator (KPI). In business, a KPI may be a revenue target or sales quota. In health care, an example of a KPI would be compliance with perioperative bundles such as for pediatric strabismus surgical repair, and within this bundle, compliance with each recommended task addresses a unique metric.[1] Metrics are employed in health care to measure, report, and ultimately improve the safety and quality of patient care.[2] Performance and quality metrics provide valuable insight into the effectiveness of various processes, interventions, and implementations because they provide a quantifiable means for evaluating the quality of care hospital-wide and within specific units and departments.[3] In pediatric anesthesia, patient safety and quality of care metrics are yet to be widely adopted, resulting in lost opportunities to introduce focused interventions as a means to improve the quality of patient care.[4]

The underuse of metrics in pediatric anesthesia to date is partly explained by the general nature of existing metrics, which often fail to capture the unique requirements and nuances of pediatric anesthesia care. In many cases, such metrics are developed with a one-size-fits-all approach, often from adult perioperative medicine, which may confer some degree of standardization but do not offer the level of specificity needed for specialized pediatric anesthesia outcomes. The current widespread implementation of electronic health records (EHR) presents an opportunity for clinical departments, hospitals, and health authorities to implement quality metrics that are automatically collected and reported to health care workers with advantages of rapid review and reporting turnaround.[5,6]

To address such potential gains, we developed a set of metrics specifically tailored to current and near-future patient outcomes pertaining to the delivery of patient care by the Department of Anesthesia & Pain Medicine at the Hospital for Sick Children (SickKids; Toronto, ON, Canada). This technical report documents the process of developing such metrics, provides clear definitions, describes specific use cases, and presents preliminary data on their implementation and effectiveness.

Methods

This study used a modified nominal group technique (NGT) to incorporate a wide range of perspectives and expertise into the development process. The NGT typically involves direct, in-person discussions and immediate results, focusing on stakeholder perspectives through a process of idea generation and consensus. In contrast to the classical NGT that uses in-person meetings only, we employed various methods including in-person meetings, virtual meetings, e-mails, and phone calls. For this reason, we refer to this methodology as modified NGT.[7] This work was performed at the Department of Anesthesia and Pain Medicine at SickKids. Development of the metrics was part of a software implementation and did not require ethical approval as per the Government of Canada's Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (2018).[8]

Metrics working group for defining metrics

We approached this work by creating two working groups, which worked sequentially rather than in parallel. The first group was brought together a year before EHR implementation at a time when the hospital encouraged numerous "breakout groups" separate to the institutional

hierarchy responsible for high-level planning. Our department created a quality improvement (QI) metrics working group led by the department chief, director of QI (C. M. D.) and Informatics Lead (C. M.). The working group comprised leadership from various subspecialty teams within our department and included representatives for acute pain, chronic pain, cardiovascular anesthesia, spinal/scoliosis anesthesia, postanesthesia care unit (PACU), transfusion and blood conservation, satellite and off-site, intensive care units (ICUs), medication safety, and trauma and resuscitation. Through iterative e-mail communications and in-person meetings, we encouraged all members to submit metrics that contributed to the quality of care delivered, assurance of best practices (as led by existing enhanced recovery after surgery protocols, previous QI project outcomes, care bundles within the National Surgical Quality Improvement Program, and Solutions for Patient Safety Network). Over the course of six months, this list was refined and tabulated to reflect areas of overlap (e.g., many members each requesting pain data from the PACU). This list is submitted as Electronic Supplementary Material (ESM) eAppendix. The second technical working group comprised the three leads from the working group plus analysts, experts, and programming staff from Epic (Epic Systems Corporation, Verona, WI, USA), who worked alongside hospital staff to deliver as much functionality as possible beyond day-to-day clinical activities by time of Go-Live. Multiple meetings were held throughout this six-month period to transform metric requests into Epic reports that could be collated and disseminated to members of the anesthesia department. Where possible, single metrics were brought together to create "compound metrics" that reflected compliance with suggested care alongside outcomes of care provided. Representation of all such metric data are beyond the scope of this report; however, the success of this approach was previously published in quality improvement projects describing strabismus surgery in our department.[1]

The completed metric set was integrated into the Epic EHR during its hospital-wide implementation in June 2018. Epic is a complex health information system composed of integrated modules, including one for anesthesia care. Its advanced level of integration ensures that patient information from any health encounter is accessible to any provider viewing that patient's record. This facilitates the creation of metrics using information from any part of the patient's record in Epic. For anesthesiologists, it enables the generation of metrics spanning the entire continuum of a patient's perioperative/perianesthesia journey, with the start and end points defined by the specific metric of interest.[5,6] In addition, the working group also identified metrics for the following two categories: quality metrics (quality of induction experience, anesthesia delivery, unanticipated events, and PACU stay) and provider performance (compliance, collaboration, and skills assurance).

Agile methodology for developing metrics

We used Agile methodology to iteratively develop and validate the metrics within Epic. The Agile development methodology, frequently employed in software development, promotes a tight-knit collaboration between the end-user and the software developer. It encourages review and feedback at every stage, including development, testing, and deployment. This approach has been linked with high levels of satisfaction among end-users and has been used successfully in developing pediatric anesthesia content.[9–12] Over a period of nine months, we initially met with Epic analysts weekly to identify relevant EHR data-points, to validate and clean data using automated processes, and to apply algorithmic rules to compute various metrics. Figure 1 shows how we employed both NGT and Agile methodology for each metric defined. When the QI metrics working group finalized metrics for development, these were passed onto

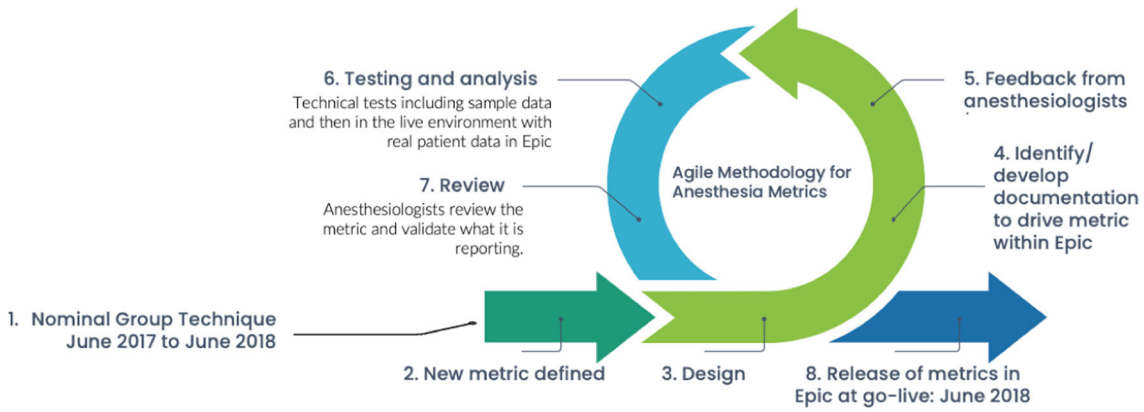

Fig. 1 Timeline and methodology for development of quality metrics

Table 1 Quality metrics collected

Metric	Definition	Function required	Alignment with strategic goals and priorities
Quality of induction experience (5)			
Type of premedication	Midazolam, lorazepam, ketamine, dexmedetomidine, fentanyl, morphine, hydromorphone, propofol (can be more than 1). Route can be PO/SL/IN/IM/IV.	Identify and capture medications documented as administered	Patient-centred care: documenting what works, consistency of care
PPIA	Parent present at induction?	Yes/no	Patient-centred care: documenting what works, consistency of care
IV catheter on arrival?	IV catheter present on arrival?	Yes/no	Patient-centred care: documenting what works, consistency of care
Type of induction	Inhaled, IV, steal	Yes/no	Patient-centred care: documenting what works, consistency of care
Number of attempts for venous access	1, 2, 3, 4, 5, multiple	Yes/no	Patient-centred care: documenting what works, consistency of care, link to hospital-acquired condition peripheral IV injuries bundle
Anesthesia delivery (3)			
Technology employed	Ultrasound, videolaryngoscopy	Yes/no	Patient-centred care: documenting what works, consistency of care. Data for future budget and equipment purchase purposes. Prevention of safety events.
Vascular access	Documentation of instance of arterial catheter and/or central venous catheter insertion	Yes/no plus accompanying report	Documentation, skills and competency assurance, record of procedure in case of future safety concerns
Regional block performed?	Documentation of performance of regional, neuraxial, nerve, field blocks. List expands to accommodate evolution/development of new blocks in future practice	Yes/no plus accompanying report	Documentation, skills and competency assurance, record of procedure in case of future safety concerns, data that can be shared with external databases (e.g., PRAN)
Unanticipated events (button presses) (9)			
Change in postoperative disposition?	Escalation of expected postoperative disposition from discharge home, ward admission, constant observation bed, overnight ICU to hospital bed, PICU, NICU, or CCCU	Yes/no	Tracking of unanticipated events and their impact on hospital resources
If "yes", where?	OR, PACU, IGT, preoperatively	Identify option from definition list	Identify and track trends, root-cause analysis for serious events, data gathering to suggest future safety interventions
Lowest SpO_2 during episode	What was the lowest SpO_2 documented during the unanticipated event?	% number (0–100)	Identify and track trends, root-cause analysis for serious events, data gathering to suggest future safety interventions
Lowest HR during episode	What was the lowest HR documented during the unanticipated event?	A number (0–200)	Identify and track trends, root-cause analysis for serious events, data gathering to suggest future safety interventions
Medications administered	All medications as contained in hospital resuscitation sheet	Identify which, if any, of those medications were documented as administered	Identify and track trends, root-cause analysis for serious events, data gathering to suggest future safety interventions
Cardiopulmonary resuscitation	Chest compressions documented in event-description records.	Yes/no	Identify and track trends, root-cause analysis for serious events, data gathering to suggest future safety interventions, external benchmarking

Table 1 continued

Metric	Definition	Function required	Alignment with strategic goals and priorities
Phase of anesthesia	Induction, maintenance, emergence, recovery	Identify option from four listed	Identify and track trends, root-cause analysis for serious events, data gathering to suggest future safety interventions relative to location (OR/PACU) and staffing cover
Airway in use at time of incident	None, FM, NP, SGA, ETT, trach	Identify one of options presented in the definition	Identify and track trends, root-cause analysis for serious events, data gathering to suggest future safety interventions relative to case acuity and clinical decision support
Free comments			
Unanticipated admits (3)			
Where has the patient been admitted?	Escalation of expected postoperative disposition from discharge home, ward admission, constant observation bed, overnight ICU to hospital bed, PICU, NICU, or CCCU	Yes/no	Tracking of unanticipated events and their impact on hospital resources
Time spent in PACU	Time (in minutes, hours) from patient arrival to PACU until patient discharge from PACU	A number (minutes, hours)	Resource planning, efficiency, impact of other factors such as pain, PONV, discharge orders, etc. on ability to maintain space in PACU and facilitate full surgical capacity
Impact on length of stay	Time (in hours, days)	A number (hours, days)	Resource planning, efficiency, impact of other factors such as pain, PONV, discharge orders, etc. on ability to maintain patient flow-through and facilitate full surgical capacity
PACU stay (9)			
First SpO_2 post arrival	First documented SpO_2 on arrival to PACU	A number. Identify specifically when $< 90\%$	Tracking safety data, link to unanticipated events (especially those documented at emergence or occurring in PACU)
First temperature	First documented temperature on arrival to PACU	A number. Identify specifically when $< 36.5\ ^{\circ}C$ and $< 36\ ^{\circ}C$	Tracking safety data, link to NSQIP and NICU data on hypothermia and surgical site infections
Heart rate on admission	First documented HR on arrival to PACU	A number	Tracking safety data, link to unanticipated events
NIBP on admission	First documented BP on arrival to PACU	A number	Tracking safety data, link to unanticipated events
First pain score	First documented pain score on arrival to PACU	A number, depending on pain scale identified by PACU nurse—take score and convert to equivalence of 1 to 10. Also report as < 3 = mild, 4–6 = moderate, > 6 = severe.	Record and trend patterns of pain management in OR, identify procedures associated with greater pain, link to regional reports for effectiveness of blocks (e.g., better than epidural or not?), Hospital Score Card identifies pain as the fifth vital sign
Number of pain scores $> 3/10$	Number of documented pain scores $> 3/10$ during patient's PACU stay	A number, depending on pain scale identified by PACU nurse—take score and convert to equivalence of 1 to 10. Number > 3 = moderate to severe pain.	Record and trend patterns of pain assessment and management in PACU, identify procedures associated with greater pain, link to regional reports for effectiveness of blocks (e.g., better than epidural or not?), Hospital Score Card identifies pain as the fifth vital sign, link to reports of naloxone administration in OR or PACU

Table 1 continued

Metric	Definition	Function required	Alignment with strategic goals and priorities
Number of pain scores > 6/10	Number of documented pain scores > 6/10 during patient's PACU stay	A number, depending on pain scale identified by PACU nurse—take score and convert to equivalence of 1 to 10. Number > 6 = severe pain.	Record and trend patterns of pain assessment and management in PACU, identify procedures associated with greater pain, link to regional reports for effectiveness of blocks (e.g., better than epidural or not?), Hospital Score Card identifies pain as the fifth vital sign, link to reports of naloxone administration in OR or PACU
Total number of pain scores recorded	Number of documented pain scores	A number, which is then used as denominator for number of times moderate or severe pain as recorded to calculate and report the proportion (%) of pain scores recorded in PACU as moderate or severe	Record and trend patterns of pain assessment and management in PACU, identify procedures associated with greater pain, analyze quality of pain management and drug choice in PACU, link to PONV score for iatrogenic opioid related PONV, data gathering to suggest future interventions
Bedside PEWS	Bedside Pediatric Early Warning Score, a number. Record at PACU admission and PACU discharge.	A number. Trending upward or downward at time of intended discharge?	Documentation of patient fitness for discharge, can be analyzed retrospectively if clinical concerns in 24 hr post discharge from PACU

BP = blood pressure; CCCU = cardiac critical care unit; ETT = endotracheal tube; FM = face mask; HR = heart rate; ICU = intensive care unit; IGT = image-guided therapy; IM = intramuscular; IN = intranasal; IV = intravenous; NIBP = noninvasive blood pressure; NICU = neonatal intensive care unit; NP = nasal prongs; NSQIP = National Surgical Quality Improvement Project; OR = operating room; PACU = postanesthesia care unit; PEWS = Pediatric Early Warning Score; PICU = pediatric intensive care unit; PO = *per os* (oral); PONV = postoperative nausea and vomiting; PPIA = parental presence at induction; PRAN = Pediatric Regional Anesthesia Network; SGA = supraglottic airway; SL = sublingual; SpO_2 = peripheral oxygen saturation; trach = tracheostomy

the technical working group for development using the Agile methodology. This period was followed by a hiatus of some months while Epic analysts built the metrics. We recommenced our meetings in the last month before implementation to rereview the build. This was followed by scrutiny of early data to confirm veracity prior to provision of metrics to staff anesthesiologists. Data on metrics were validated at multiple stages, with metrics identified as requiring additional work undergoing further review and amendment. All metrics were made available as detailed reports within the Epic Anesthesia Registry to encourage standardization of care delivered and to decrease heterogeneity of practice when unpredictable or undesirable patient outcomes were identified. In recognizing the growing importance of data visualization to make complex data understandable and actionable, timely data release was transitioned to Epic-based reports and a Power BI dashboard. Power BI (Microsoft Corporation, Redmond, WA, USA) is an interactive data visualization software product developed with a primary focus on business intelligence.

Results

We developed 45 metrics in total for quality and provider feedback within our department and institution. Table 1 displays QI metrics developed with definitions, calculations, and the supporting cases for their development.

In addition to QI metrics, provider performance metrics were reported as a demonstration of technical clinical and technical skill competence as well as compliance with departmental and organizational KPIs (Table 2). In addressing quality of care provision, we created reports that analyzed group and (anonymized) individual contributions to individual metrics (e.g., pain scores in the PACU) that also link to compliance with the perioperative bundle developed for pediatric strabismus repair.[1] Our work in the strabismus population has been previously published; however, for the purposes of this report, Fig. 2 shows that prior to implementation of Epic, we struggled to maintain bundle compliance above a mean of 60%. This compliance rate achieved marginal gains in

Table 2 Provider metrics collected

Metric	Definition	Function required	Alignment with goals & priorities
Compliance and collaborative reports (8)			
07:35 Huddle attendance	Time of preoperative team huddle	A time. Either on time (before 07:35) or late or not documented (not done).	Compliance with expected standards of care, commitment to safety, efficiency and resource guidance
08:00 Start	Time of bringing first patient of the day into OR	A time. Either on time (before 08:00) or late or not documented (not done).	Compliance with expected standards of care, commitment to safety, efficiency and resource guidance
Antibiotic administration	Is this an operation listed as requiring antibiotics? Were antibiotics given within 1 hr of incision? Prepopulated list of operations: if antibiotic is indicated was it given and given at right time?	Yes/no	Compliance with expected standards of care, commitment to safety, link to surgical-site infection bundle data and external reporting to NSQIP and SPS
Surgical site infection bundle	Several items of standardized care intended to deliver best practices and best outcomes concerning surgical site infections	For each identified item, was it done or not? Yes/no? What % compliance with overall bundle is observed?	Compliance with expected standards of care, commitment to safety, target low-compliance items for further examination and possible intervention, link to surgical-site infection bundle data and external reporting to NSQIP and SPS. Demonstrate ongoing engagement of anesthesia and perioperative services with hospital strategies and patient-reported outcomes.
Strabismus bundle	Several items of standardized care intended to deliver best practices and best outcomes concerning strabismus surgery		Change care, compliance with expected standards of care, commitment to safety, target low-compliance items for further examination and possible intervention, link to PACU reports such as pain, PONV, LOS. Publication of QI projects.
Tonsillectomy bundle	Several items of standardized care intended to deliver best practices and best outcomes concerning tonsillectomy ± adenoidectomy		Change care, compliance with expected standards of care, commitment to safety, target low-compliance items for further examination and possible intervention, link to PACU reports such as pain, PONV, LOS. Publication of QI projects.
CLABSI bundle	Several items of standardized care intended to deliver best practices and best outcomes concerning central-line insertion		Compliance with expected standards of care, commitment to safety, target low-compliance items for further examination and possible intervention, link to hospital CLABSI bundle data and external reporting to NSQIP and SPS. Demonstrate ongoing engagement of anesthesia and perioperative services with hospital strategies and patient-reported outcomes.
Future hospital acquired conditions bundles	Yet unknown bundles assembled to address future hospital-acquired conditions of concern		Compliance with expected standards of care, commitment to safety, target low-compliance items for further examination and possible intervention, link to hospital bundle data and external reporting to NSQIP and SPS, show ongoing engagement of anesthesia and perioperative services with hospital strategies and patient-reported outcomes

Table 2 continued

Metric	Definition	Function required	Alignment with goals & priorities
Skills assurance for staff (8)			
Intubations	Placing an ETT	Total year/person, time since last procedure	Competency-based learning and teaching, skills and competence assurance, documentation of expertise
Venous access	Placing an IV catheter		
Arterial line	Placing an arterial catheter		
Central venous line placement	Placing a central venous catheter		
Caudal epidural	Placing a caudal epidural		
Lumbar epidural	Placing a lumbar epidural		
Thoracic epidural	Placing a thoracic epidural		
Specific regional blocks	Performing a regional block		

CLABSI = central line-associated blood stream infection; ETT = endotracheal tube; IV = intravenous; LOS = length of stay; NSQIP = National Surgical Quality Improvement Project; PACU = postanesthesia care unit; PONV = postoperative nausea and vomiting; SPS = Solutions for Patient Safety Network

PACU pain scores; however, upon implementation of the care bundle within Epic and compounding compliance-rates to outcomes in dashboard form (Fig. 3), compliance improved significantly as shown in Fig. 2 by the improvements in both compliance and PACU pain visible and sustained from Summer 2020 on.

Key performance indicator (KPI) outcomes are presented relative to group and individual compliance within recommended bundles of care as applicable. Key performance indicators might be an internal departmental priority, such as postoperative pain, or institutional safety priorities for hospital-acquired conditions, such as surgical-site infection. Physician access to data describing the number of central venous catheterizations or placement of thoracic epidural catheters is also a viable resource for scheduling certain rooms and cases to maintain equitable access to appropriate procedures to maintain clinical technical skills.

Dashboards

We also developed a Department of Anesthesia Power BI dashboard summarizing early priority key metrics. While a more exhaustive list of metrics and reports is presented in Table 1, our initial choice of "roll-out" metrics for dashboard reporting was based on two important factors. The first factor was which of the metrics from the department's prior "paper-based" QI program lent themselves to early, rapid transformation to electronic collection and reporting. These decisions were based on choosing metrics that reported day-to-day clinical data points fundamental to any anesthesia information management system (e.g., oxygen saturations, temperature, pain, drug administration, postoperative disposition). The second factor was which metrics best represented the safety of care provided (e.g., incidence of cardiopulmonary resuscitation, severe laryngospasm requiring urgent escalation in care), quality of care provided (e.g., pain on arrival to PACU), professional behaviour (incidence of nonreconciled controlled substance documentation, bundle compliance), and impact of clinical outcomes (unanticipated admission to ICU). Table 3 shows the key metrics included in our department's preliminary dashboards.

Figure 4 shows the homepage for our prototype dashboard in Power BI. This provides important data describing departmental productivity and safety of care through visual representations of metrics against time. Figure 5 shows a dashboard for some of our statistical process control charts (SPC). These report monthly rates of emergency calls in the operating rooms and unplanned ICU admissions across a 30-month period. Statistical process control charts also show the results of projects and interventions designed to improve the rates of such outcomes. In the fall of 2020, the unplanned ICU admission chart showed monthly data points above upper control limits which suggested special-cause variation, i.e., variations to a system or process that were not previously observed, and which disrupt predictable favourable functioning of that system. Review of the cases reported, in addition to identification of similar peaks in perioperative respiratory adverse events, suggested increased airway hyperreactivity in patients following upper respiratory tract infections. Accordingly, a strict four-week symptom-free period prior to elective anesthesia was implemented (six weeks for patients with positive SARS-CoV-2 results), which resulted in a return to "normal baseline activity" for the subsequent ten months.

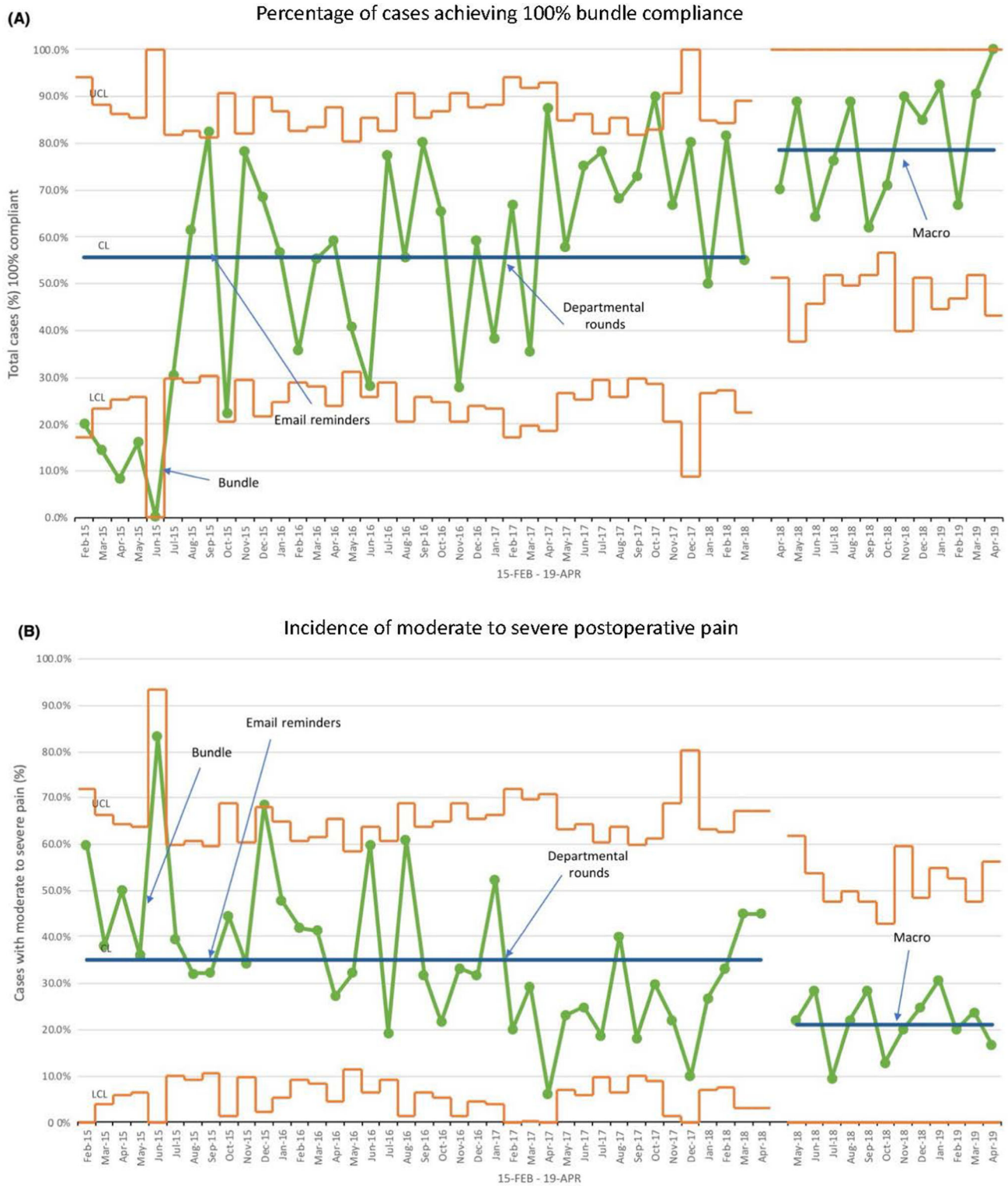

Fig. 2 Bundle compliance and postoperative pain scores in strabismus surgical repairs. (A) Percentage of strabismus surgeries achieving full bundle compliance; (B) incidence of moderate to severe pain post strabismus repair.

Blue line = centre line; orange lines = upper and lower control limits

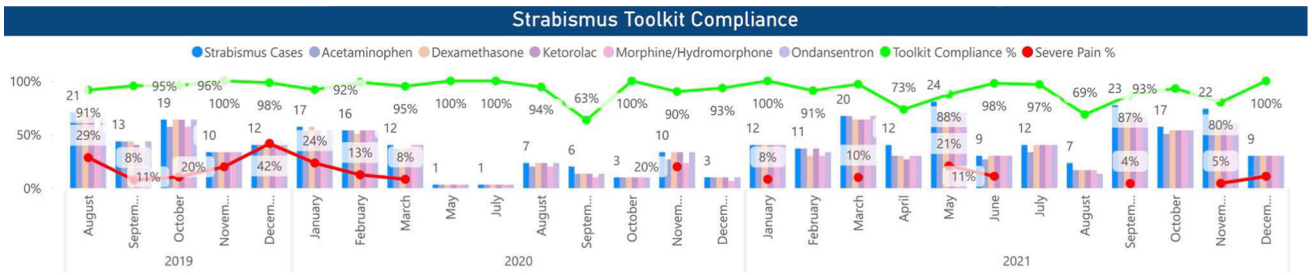

Fig. 3 Power BI dashboard for strabismus quality metrics. This Power BI (Microsoft Corporation, Redmond, WA, USA) dashboard reports intraoperative compliance with individual units, total bundle compliance, number of cases, and incidence of moderate to severe postoperative pain.

Table 3 Key metrics included in preliminary Power BI dashboards

Metric	Denominator	Add-on information
Total GAs administered	Time (month, year, week)	
ASA Physical Status		
Complications	Per 1,000 GAs	Text descriptions
Internal codes	Per 1,000 GAs	Text descriptions, SPC chart
CPR	Per 1,000 GAs	Text descriptions
Cancellations	Per 1,000 GAs	
Days since last serious safety event		
Unexpected admissions to ICU	Per 1,000 GAs % of total GAs per month	SPC chart
Serious laryngospasm*	Per 1,000 GAs	
Opioid stewardship	% of unreconciled controlled-substance ampoules withdrawn from automated dispensing cabinet per month	By location By level of training†
PONV	% of total GAs in chosen timeframe	By ASA
First SpO_2 in PACU	% of total GAs $< 95\%$, $< 90\%$ in chosen time frame	By individual provider
First temperature in PACU	% of total GAs $< 36.5\ ^{\circ}C$, $< 36.0\ ^{\circ}C$ in chosen time frame	By surgical speciality
Pain in PACU	% of total GAs in chosen timeframe in moderate pain, severe pain on arrival to PACU	
Pain in PACU	% of total pain scores in PACU describing moderate or severe pain	
Strabismus compliance	% of total bundle compliance across all strabismus cases in chosen time frame	By ASA Physical Status By individual provider
Strabismus compliance (individual bundle items)	% of compliance with each bundle item across all strabismus cases in chosen time frame	
Strabismus compliance (pain)	% incidence of moderate and severe pain in PACU for all strabismus cases in chosen time frame	Linked to PACU pain metric By ASA Physical Status
Strabismus compliance (PONV)	% incidence of PONV in PACU for all strabismus cases in chosen time frame	By individual provider
Glossary		Terms, definitions, clarifications for dashboard items and metrics

*Defined as laryngospasm requiring overhead call for help in the operating rooms

†Level of training, staff/attending, fellow, resident, anesthesia assistants

ASA = American Society of Anesthesiologists; CPR = cardiopulmonary resuscitation; GA = general anesthesia; ICU = intensive care unit; PACU = postanesthesia care unit; PONV = postoperative nausea and vomiting; SPC = statistical process control chart

Fig. 4 Sample data used in dashboard prototype development

ASA = American Society of Anesthesiologists Physical Status; CPR = cardiopulmonary resuscitation; ERaS = enhanced recovery after surgery; GA = general anesthesia; ICU = intensive care unit; PACU = postanesthesia care unit; SSE = serious safety event

Discussion

This technical report describes the development of quality metrics in pediatric anesthesia and their implementation into our institution's anesthesia care quality program. Defining and implementing standardized pediatric anesthesia quality metrics begins and ends with the patient but must be relevant to the individual clinician, clinical department, and institution to reflect expectations of care and uphold institutional values and strategic priorities. As EHR user interfaces continue to evolve, new opportunities arise to capture and present metrics in innovative and insightful ways through graphically rich, interactive, user-friendly dashboards. These advancements not only facilitate the process of performance reflection but also empower health care providers by rendering complex data more digestible and therefore actionable. In our department, the transition from PDF-based feedback to Power BI dashboards, and the ongoing integration into Epic dashboards, exemplifies such evolution in action.

Most institutions have introduced tools such as failure mode and effect analysis, lean methodology and Six Sigma within their quality divisions. Such measures report significant cost reductions and improvements in patient outcomes.[13] The specialty of anesthesiology continues to take innovative strides in the evolution and development of health care metrics tailored to patient care. Joseph *et al*. detailed their web-based custom perioperative dashboard, OR Watch, which is used primarily for operational management.[14] Hensley *et al*. described a highly evolved, interactive series of dashboards designed to enhance quality in cardiac anesthesia at Johns Hopkins Hospital.[15] They reported the performance of metrics evaluating transfusion practices, intraoperative opioid use, intraoperative dexmedetomidine use, lactate values, time to extubation, and many more. These in turn fed into KPIs such as length of stay, percent survival, time spent in rehabilitation facilities, and discharge home, which in turn fed global and smart aims of improving the overall quality of cardiac anesthesia care to facilitate both the quality of the patient experience, and patient survival. While there are ongoing national and international collaborations such as the Pediatric Regional Anesthesia Network and Pediatric National Surgical Improvement Program, we are currently

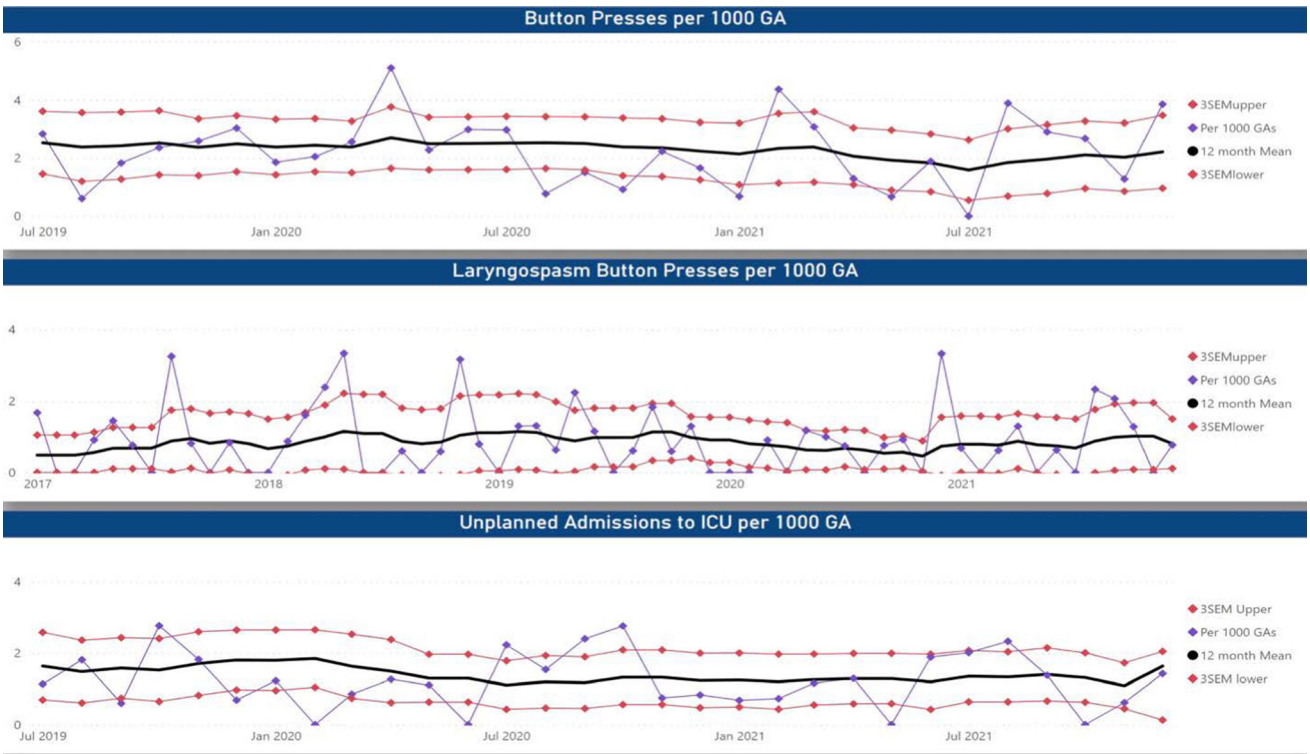

Fig. 5 Statistical process control charts. The top chart displays urgent calls for help in the operating room, the middle chart displays urgent calls for help in the operating room because of laryngospasm, and the bottom chart displays monthly unplanned ICU admissions. All data points are per 1,000 GAs.

GA = general anesthetic; ICU = intensive care unit; SEM = standard error of the mean

unaware of reports that describe local metric and dashboard development for use within EHR in pediatric anesthesiology. While we are yet to integrate the metrics and dashboards we describe to the extent employed by Johns Hopkins cardiac anesthesia, we nevertheless describe a similar ethos of vertical integration of individual patient-centred metrics as delivered in the operating room (e.g., pain management, central line insertion), as experienced during recovery (e.g., pain, postoperative nausea and vomiting, temperature), as impacting upon hospital resources (e.g., unexpected overnight admission, unanticipated ICU admission within 24 hr of anesthesia stop), and as contributing to overall hospital KPIs and reports (e.g., surgical site infections, central line-associated blood stream infection). Like Johns Hopkins, we also emphasize on the importance of rapid turnover, interactive, graphic-based data reporting as a source of self-reflection, continued learning, competence assurance, and focusing of quality improvement initiatives and projects during times of limited resources both financial and personnel-related.

Compound metrics provide a comprehensive perspective on the quality of care delivered and experienced during surgical procedures and hospital medicine admissions. Since our work with the pediatric strabismus population, we implemented a similar process of bundled care to our pediatric tonsillectomy population. Compliance rates greater than 85% with this bundle delivered a 36% decrease in the incidence of moderate to severe pain in the PACU, a 55% decrease in rescue opioid administrations, and a 44% decrease in emergence delirium, all without increasing PACU length of stay, hospital length of stay, postoperative hemorrhage, or readmission rates after discharge (unpublished data). There has been a notable move toward team-based perioperative care, and compound quality metrics provide helpful data when requesting extra resources and funding.[16,17] Such data can also be used to direct community-based approaches as we emerge from lockdown restrictions and address surgical waitlist times. Our institution has the capability to collaborate with other Epic users. Recent collaborations include multisite work on COVID-19 implications for pediatric anesthesia, impact of public health protocols on school teachers and students, and international appendectomy outcomes during the pandemic.[18–20]

The work described in this technical report was successful because of the environment in which it was carried out. SickKids is a member of the Solutions for

Patient Safety Network, a data-sharing network that comprises 180-plus children's hospitals across North America. Institutional performance on KPIs such as central-line associated blood stream infections, surgical site infections, falls, unplanned extubations, etc., is reported to the network. Individual hospitals subsequently see their own performance relative to group data in raw form and SPC formats. From this, future goals are created, and network-created bundles of care can be adopted and implemented. One observes one's progress over time and such macrodata can be shared at a department and individual level to match such seemingly simple metrics as timely antibiotic delivery in the operating room to local and network surgical-site infection rates. SickKids committed personnel and resources to this program and to Caring Safely, a patient safety initiative expressly focused on eliminating preventable patient harm. After our institutional EHR launch, the first two to three months of data collection were time-consuming while our departmental Safety & Quality Lead (C. M. D.) worked through many "bugs" in the system with Epic experts to refine the functioning of reports. At its peak, this work consumed 16–20 hr a month but with increasing familiarity and optimization of reports, it fell to approximately four hours per month, which entailed spot data checks and audits, and data-transfer from Epic to Power BI.

While this technical report provides insights into the development and implementation of tailored pediatric anesthesia metrics within our local institution, there are some limitations. This study was conducted within a single institution and the developed metrics and outcomes may not be directly applicable or transferrable to other institutions with different patient demographics, clinical practices, or EHR systems. Nevertheless, the paucity of pediatric-relevant data and quality metrics "out of the box" during our EHR implementation suggests our institution is the first to develop quality metrics to this degree of fidelity that speak to both patient and provider alike. New metrics will continue to be defined as new data sources are created by innovative surgeries and like-minded collaborators. Further studies across multiple institutions will ultimately be needed to show full potential of the metrics presented in this report; however, the work described here serves as a solid foundation for any clinical department or institution embarking on developing their own metrics and dashboards.

In conclusion, we describe the process of developing, customizing, and implementing 45 pediatric anesthesia metrics addressing quality and provider feedback within a quaternary academic pediatric institution. These metrics were developed and integrated into our hospital's EHR to facilitate real-time monitoring and reporting. The framework, methodologies, and results of this study can be translated for use in other clinical specialties and other institutions.

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