Automated Near–Real-time Clinical Performance Feedback for Anesthesiology Residents

One Piece of the Milestones Puzzle

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ABSTRACT

Background: Anesthesiology residencies are developing trainee assessment tools to evaluate 25 milestones that map to the six core competencies. The effort will be facilitated by development of automated methods to capture, assess, and report trainee performance to program directors, the Accreditation Council for Graduate Medical Education and the trainees themselves.

Methods: The authors leveraged a perioperative information management system to develop an automated, near–real-time performance capture and feedback tool that provides objective data on clinical performance and requires minimal administrative effort. Before development, the authors surveyed trainees about satisfaction with clinical performance feedback and about preferences for future feedback.

Results: Resident performance on 24,154 completed cases has been incorporated into the authors' automated dashboard, and trainees now have access to their own performance data. Eighty percent (48 of 60) of the residents responded to the feedback survey. Overall, residents "agreed/strongly agreed" that they desire frequent updates on their clinical performance on defined quality metrics and that they desired to see how they compared with the residency as a whole. Before deployment of the new tool, they "disagreed" that they were receiving feedback in a timely manner. Survey results were used to guide the format of the feedback tool that has been implemented.

Conclusion: The authors demonstrate the implementation of a system that provides near–real-time feedback concerning resident performance on an extensible series of quality metrics, and which is responsive to requests arising from resident feedback about desired reporting mechanisms. **(ANESTHESIOLOGY 2014; 120:172-84)**

IN July 2014 all anesthesiology residency programs will enter the Next Accreditation System of the Accreditation Council for Graduate Medical Education (ACGME). A major aspect of the Next Accreditation System involves the creation of roughly 30 milestones for each specialty that will map to different areas within the construct of the six core competencies: patient care, medical knowledge, systems-based practice (SBP), professionalism, interpersonal and communication skills, as well as practice-based learning and improvement (PBLI).[1] The milestones have been described by leaders of the ACGME as "specialty-specific achievements that residents are expected to demonstrate at established intervals as they progress through training."[1] In anesthesiology, these intervals are currently conceived as progressing through five stages ranging from the performance expected at the end of the clinical base year (Entry Level) to the performance level expected after a period of independent practice (Advanced Level).*

What We Already Know about This Topic

- In July 2014, American residency programs will be required to assess trainee progress on milestones in six core competency areas
- An automated approach to measuring progress in achieving these milestones would facilitate this process by providing timely feedback

What This Article Tells Us That Is New

- An automated, near–real-time feedback system was generated from a perioperative information management system and refined using resident feedback

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* From Draft Anesthesiology Milestones circulated to all anesthesiology program directors (Ver 2012.11.11). Available at: http://anesthesia.stonybrook.edu/anesfiles/AnesthesiologyMilestones_Version2012.11.11.pdf. Accessed October 16, 2013.

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The education community recognizes both the opportunities and challenges that will be present in the implementation of the Milestones Project and the Next Accreditation System.

Finding the appropriate means by which to assess and report on anesthesiology resident performance on all the milestones and core competencies as required in the ACGME Anesthesiology Core Program Requirements may prove daunting.† For instance, there are 60 residents in our residency program. There are currently 25 milestones proposed for anesthesiology, with five possible levels of performance for each milestone. Each resident is expected to be thoroughly assessed across this entire performance spectrum every 6 months, resulting in 1,500 data points for each evaluation cycle reported to the ACGME, along with a report of personal performance provided to each resident.* Finding methods that can moderate the administrative workload on the program directors, clinical competency committees, and residents while still providing highly reliable data will be of great benefit.

Previous studies have reported on similar work in the development of an automated case log system.[2,3] However, to our knowledge there are no descriptions of an automated, near–real-time performance feedback tool that provides residents and program directors with data on objective clinical performance concerning the quality of patient care that residents deliver. The increasing adoption of electronic record keeping in the perioperative period opens the possibility of developing real-time or near–real-time process monitoring and feedback systems. Similar systems have been developed in the past to comply with the Joint Commission mandate for ongoing professional practice evaluation and to improve perioperative processes.[4–10]

In this report we will describe the development of a near–real-time performance feedback system using data collected as part of routine care *via* an existing perioperative information management system. The system described has two main functionalities. First, it allows program directors to assess a number of the milestones under the SBP and PBLI core competencies.* Second, it provides residents with near–real-time performance feedback concerning a wide array of clinical performance metrics. Both functions require minimal clerical or administrative efforts from trainees or training programs. This report will progress in three parts: (1) describe the creation of this system through an iterative process involving resident feedback, (2) detail quantitative baseline data that can be used for future standard setting, and (3) describe the specifics of how data obtained through this system can be used as part of the milestones assessment.

† Anesthesiology Program Requirements. Available at: http://www.acgme.org/acgmeweb/Portals/0/PFAssets/ProgramRequirements/040_anesthesiology_f07012011.pdf. Accessed October 16, 2013.

Materials and Methods

Our study was reviewed and approved by the Vanderbilt University School of Medicine Institutional Review Board (Nashville, Tennessee).

Creation of Automated Data Collection and Reporting Tool

We began by creating logic to score each completed anesthesia case stored in our perioperative information management system and for which a trainee provided care. Each case was scored on a series of quality metrics, which are shown in table 1 and are based on national standards, practice guidelines, or locally derived, evidence-based protocols for process and outcome measures.[11–16] All cases were evaluated, although some cases were not eligible for scoring across all five of the metrics. For each case, if any one of the gradable items was scored as a failure the overall case was scored as a failure. On a given case if a metric did not apply (*i.e.*, central line precaution metric in a case where no central line was inserted), that particular metric was omitted from the scoring for the case. This logic was then programmed into a structured query language script and added to our daily data processing jobs that pull data from our perioperative information management system into our perioperative data warehouse. Our daily jobs are set up to run at midnight to capture and process all cases from the previous day.

After the cases and their associated scores were brought into the perioperative data warehouse, we used Tableau (Version 7.0; Tableau Software, Seattle, WA) to create a series of data visualizations. The first visualization was a view designed for the Program Director and Clinical Competency Committee in order to show the performance of all residents on each metric, plotted over time (fig. 1). The second visualization was a view designed for individual trainees. This is a password-protected Web site that displays the individual performance for the resident viewing his or her data as compared with aggregate data for his or her residency class and for the complete residency cohort, all of which is plotted over time (fig. 2). Both the program director and the individual trainee visualizations contain an embedded window that displays a list of cases where failures have been flagged with a hyperlink to view the electronic anesthesia care record for that case. Row-level filtering was applied at the user level to ensure that each trainee was only able to view their own records. Because the perioperative data warehouse is updated nightly, the visualizations automatically provide new case data each night shortly after midnight.

Resident Input for Refining Feedback Tool

As part of the process of refining this feedback tool, an anonymous online survey was sent to all 60 residents in our training program using Research Electronic Data Capture (REDCap) to elicit their opinions about clinical performance feedback (appendix).[17] We omitted questions about

Table 1. Process and Outcomes Measures Used for Clinical Performance Feedback

Metric	Requirements	Additional Notes
Antibiotic administration (process measure)	An antibiotic must be documented before but within 60 min of incision time (120 min if the drug is vancomycin) *or* it must be noted in the patient's chart that the patient did not require an antibiotic for the surgical procedure	Only the *first* resident on a case is scored in situations where a transfer of care occurs
Glucose monitoring (process measure)	For patients receiving intraoperative insulin: Each time insulin is administered, blood glucose must be documented 30–90 min after insulin is given For diabetic patients (not receiving insulin in the OR): Blood glucose must be documented between anesthesia start and 150 min into the case	For insulin cases, only cases lasting longer than 90 min are scored For diabetic cases, only cases lasting longer than 150 min are scored
Central line insertion (process measure)	Hand hygiene before placement must be documented, else scored as a failure; Full body drape must be documented, else scored as a failure; All barrier equipment worn must be documented, else scored as a failure; Chlorhexidine used for site prep must be documented, else scored as a failure; Ultrasound use documented for internal jugular lines, else scored as a failure	Emergent cases excluded; only the *first* resident on a case is scored in situations where a transfer of care occurs
Pain management (outcome measure)	First documented pain score in PACU must be ≤7 if it is an Adult Numerical, Child Numerical, N-PASS, or FLACC scale. First documented pain score in PACU must be ≤6 if the scale was FPS-R	Only the *last* resident on a case is scored in situations where a transfer of care occurs
Temperature management (outcome measure)	If no temperature is documented in Gaschart or PACU ≥36.0 during the time period of 30 min before Out of Room and 15 min after PACU In Time AND the temperature from Emergence is ≤36.0 then it is scored a failure	Only the *last* resident on a case is scored in situations where a transfer of care occurs; cardiopulmonary bypass cases and induced hypothermia cases excluded

FLACC = Face, Legs, Activity, Cry, and Consolability Scale; FPS-R = Faces Pain Scale—Revised; N-PASS = Neonatal Pain, Agitation, and Sedation Scale; OR = operating room; PACU = postanesthesia care unit.

respondent demographics in order to keep the responses as anonymous as possible. This was done because we wanted credible feedback about an area where the residents could potentially report dissatisfaction, as comments about ways to improve this system in order to make it meaningful to the end user are crucial to its success.

Resident Orientation

A short user guide and explanatory e-mail were developed and delivered to each trainee in order to give an orientation to the Web-based feedback tool, which is provided as Supplemental Digital Content 1, http://links.lww.com/ALN/B9, entitled Resident Performance Dashboard User Manual and Logic.

Results

Survey Results

Eighty percent (48 of 60) of the residents completed the survey. Table 2 displays the summary data from the first portion of the resident survey, which included nine questions sampling four themes:

1. Satisfaction with the frequency/timeliness of feedback before development of this application
2. Satisfaction with the amount of feedback before system development
3. Desire to receive performance data with comparison to peers and faculty
4. Knowledge of current departmental quality metrics.

On average, the 48 survey respondents agreed/strongly agreed that they desire frequent updates on their personal clinical performance in defined quality metrics (*e.g.*, pain score upon entry to postanesthesia care unit, postoperative nausea and vomiting rate) and that they desired to know how they compared with the residency as a whole and with faculty. Additionally, although residents were "neutral" concerning the timeliness of feedback and amount of feedback from faculty evaluators, they on average disagreed that they received feedback in the right amount or in a timely manner concerning practice performance data.

Figure 3 displays the results concerning the residents' report of how often they systematically review their clinical performance now and how often they would like to do so. Of note, 91% responded that they would like to receive a systematic review of practice performance data every 1 to 4 weeks. The survey also included several questions concerning the practice performance areas in which the residents believe that they could improve (table 3). Ninety percent (43 of 48) of residents responded that they could improve in at least one, and often multiple, areas. However, 10.4% (5 of 48) of respondents believed that they were compliant (*i.e.*, highly effective) in all the six areas listed. Table 4 lists qualitative thematic data from a question at the end of the survey to which residents could give free text answers about other performance metrics about which they would like to receive feedback. Finally, all respondents except one noted that they would like to receive this feedback in some electronic form, either by e-mail, Web site, or smartphone application (table 5).

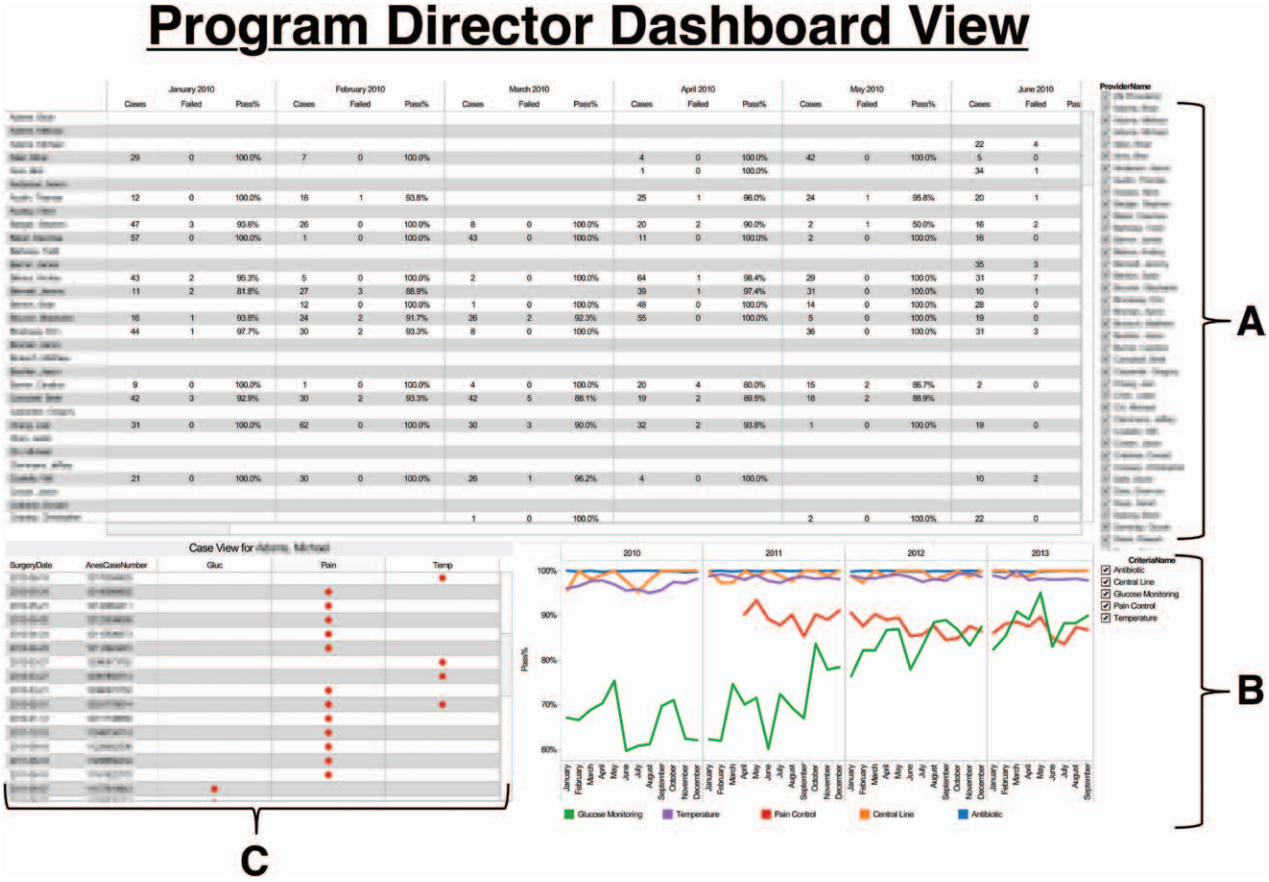

Fig. 1. This figure displays the program director dashboard view which is accessed through a password-protected website. The different panels comprising this dashboard show: (*A*) tabular numerical listings of individual resident scores plotted by case pass/failure rate by month, with "pass/fail" as a binary score taking into account passing on all five metrics or not; (*B*) color-coded graphical representation of performance of all residents on each individual metric over time; and (*C*) listings of individual cases in which occurred, with each row representing one case and the metric(s) failed in that case being depicted by the *red dots*. In this portion of the dashboard, a read-only version of the anesthesia record for a case in question can be accessed from our Anesthesia Information Management System by clicking on the case (one row represents one case). Additionally, in *A* in the figure, resident performance can be sorted by column in ascending or descending order, giving the program director immediate access to the residents who are top performers and those who are low performers on defined quality metrics. Thus, the program director can quickly assess individual resident performance and global programmatic performance from this one dashboard.

The results of the resident survey were used to guide the final format of the feedback tool and the comparators displayed in the data fields. The specific Web site format that had been in development was refined and comparisons to each resident's overall class and the entire residency were added.

Performance Results

We successfully created and launched the automated case evaluation tool and the automated Web visualizations for both the Program Director/Education Office staff and individual trainees as shown in figures 1 and 2. Creation and validation of the case evaluation metrics was completed in less than 4 weeks, and development of the visualizations took approximately 60 h of developer time. Data on 24,154 completed anesthetics from the period February 1, 2010 to March 31, 2013 have been provided to our 60 trainees. Table 6 shows a breakdown of the frequency with which a given metric applied to a case performed by a resident. Antibiotic compliance applied to the greatest percentage of cases and central line insertion precautions applied to the fewest. The large fraction of cases not eligible for scoring on the pain metric comprised patients who were admitted directly to the intensive care unit after surgery, bypassing the postanesthesia care unit, or cases where a nurse anesthetist assumed care at the end of the case. Overall performance by residency class is shown in figure 4 and individual resident performance for the current clinical anesthesia (CA)-3 class is shown in figure 5. Examination of figures 4 and 5 indicates little if any improvement of resident performance on these clinical tasks across the arc of their training. Performance appears to peak in the second CA year. Figure 6 shows the performance of the entire residency on each individual metric over time.

Table 2. Resident Opinion Concerning the Current Use of Electronic Health Record Data

Survey Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I am familiar with the quality performance measures used by the Department and I understand the components assessed in each metric (*e.g.*, normothermia, CVL insertion practice, *etc*.)	5	21	13	9	0
I think that our electronic medical record is appropriately utilized to give me data about my clinical performance	6	11	16	14	1
I am satisfied with the amount of feedback that I get about my clinical performance from faculty	1	15	13	17	2
I receive timely feedback about my clinical performance from faculty	2	17	13	14	2
I am satisfied with the amount of feedback that I get about my clinical performance from practice performance data (*e.g.*, PONV, pain scores in PACU, on time first starts, *etc.*)	1	4	13	17	13
I receive timely feedback about my clinical performance from practice performance data (*e.g.*, PONV, pain scores in PACU, on time first starts, *etc*.)	1	5	10	17	15
I would like to receive frequent updates about my clinical practice according to defined performance metrics (*e.g.*, PONV, pain scores in PACU, on time first starts, *etc*.)	19	24	3	2	0
I would like to receive frequent updates about my clinical practice according to defined performance metrics with comparison with mean performance in my residency class and the residency as a whole	22	21	4	1	0
I would like to receive frequent updates about my clinical practice according to defined performance metrics with comparison with mean performance of faculty	16	26	5	1	0

CVL = central venous line; PACU = postanesthesia care unit; PONV = postoperative nausea and vomiting.

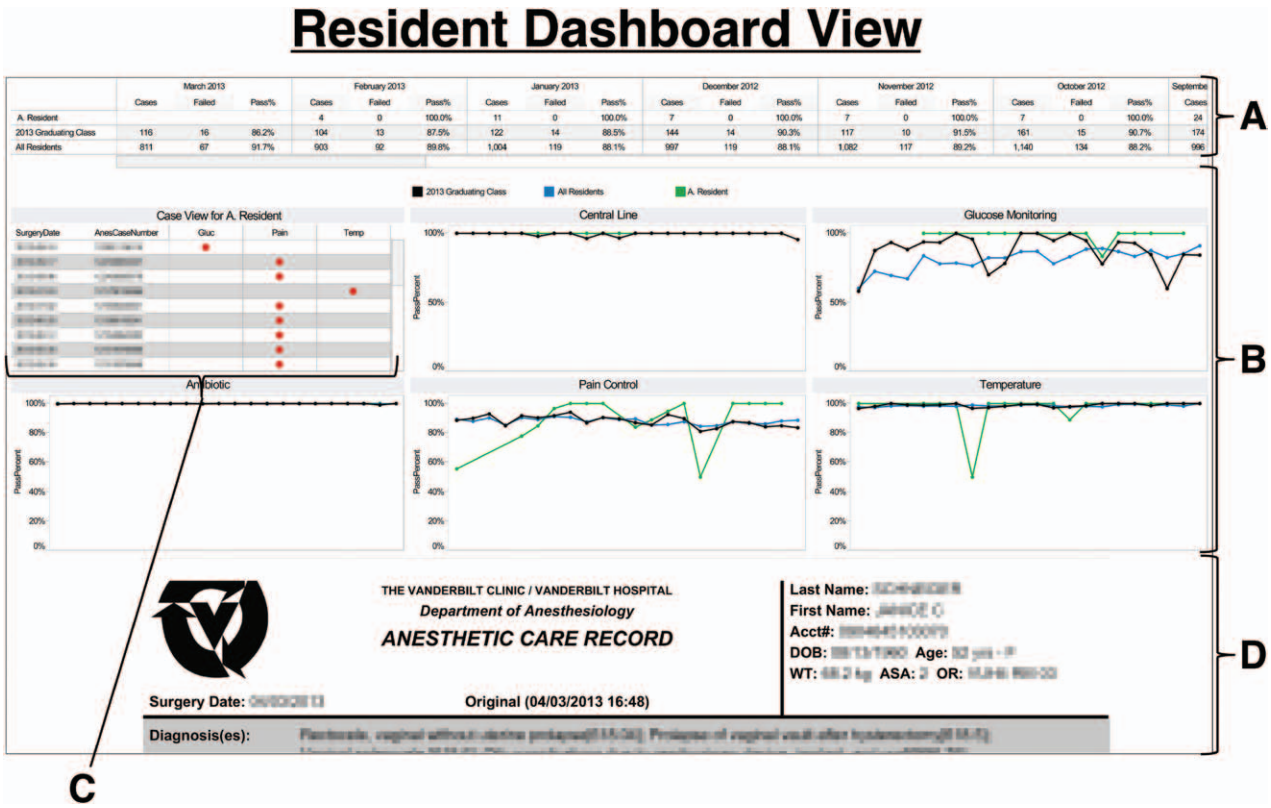

Fig. 2. This figure displays the resident dashboard view which is accessed through a password-protected website. The different panels comprising this dashboard show: (*A*) a tabular view of the performance of a single resident in comparison with clinical anesthesia (CA) training level and entire program by month, with "pass/fail" as a binary score taking into account passing on all five metrics or not; case pass/fail rate; (*B*) a graphical representation of the performance of a single resident in comparison with CA level and entire program by individual metrics by month; (*C*) individual case listings showing where resident performance failures occurred; and (*D*) the PDF form of the case record in our Anesthesia Information Management System can be accessed by clicking on one of the cases listed in *C*.

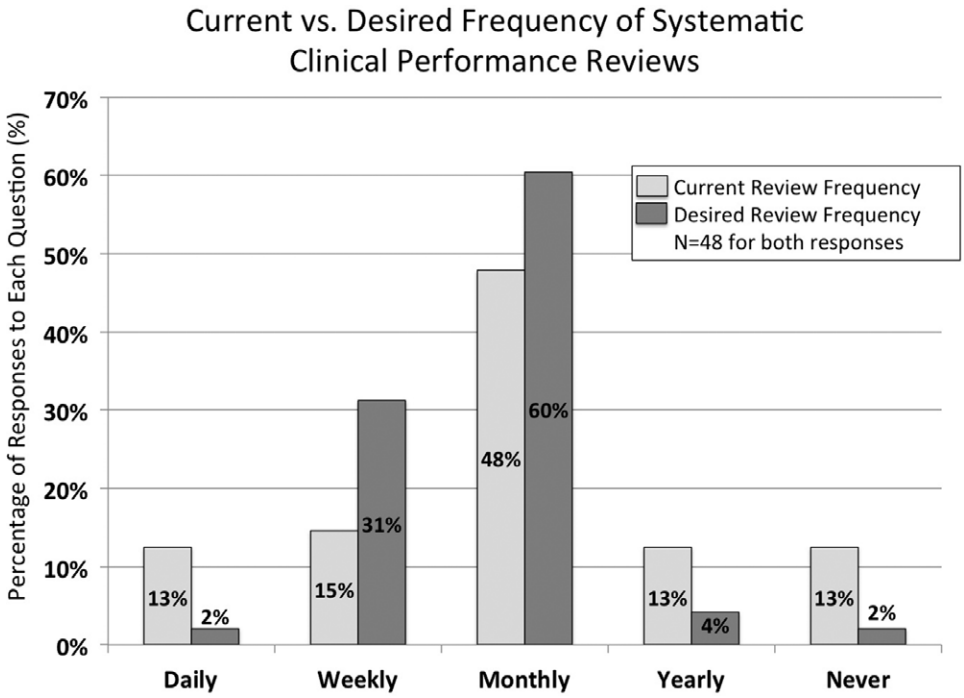

Fig. 3. This figure depicts the resident responses to questions on an anonymous survey administered during the developmental phase of the feedback tool. The questions asked about the resident's current and desired frequency of systematic clinical performance reviews. Results are demonstrated as the percentage of respondents' answering in the categories offered. Of note, more than 25% of residents said that they currently perform any systematic review of their performance at a frequency of once per year or less, whereas 91% stated that they would like a systematic review every 1 to 4 weeks. N = 48 for both questions.

Discussion

We have created an automated system for near–real-time clinical performance feedback to anesthesia residents using a perioperative information management system. The minimal marginal cost of developing this system was a long-term benefit of the substantial previous investment in our dedicated anesthesia information technology development effort.[18] The clinical performance metrics described in this report are process and near–operating room outcome measures that are readily available and related to the quality of care delivered. They provide feedback about this care as an ongoing formative assessment of anesthesiology residents. The system is extensible to other forms of documentation and machine-captured data and for use in Ongoing Professional Performance Evaluation for nonresident clinicians, as has been demonstrated in previous reports by our group.[7,9]

Table 3. Self-assessment of Areas in Which Residents Believe that Performance Can Improve

In Which of the Following Areas Could Your Performance Improve?		In What Area Do You Think That You Need the *Most Improvement*?	
Performance Area	N	Performance Area	N
Antibiotics	7	Antibiotics	4
Normothermia	18	Normothermia	8
PONV prevention	23	PONV prevention	13
Case documentation	18	Case documentation	11
Postoperative pain prevention	22	Postopoperative pain prevention	11
OR efficiency	24	OR efficiency	21
Compliant in all areas	5	Compliant in all areas	5

OR = operating room; PONV = postoperative nausea and vomiting.

Since its implementation, this resident performance evaluation system has required minimal ongoing effort. It provides continuous benefits to our training program and resident trainees with respect to assessment and professional development in the domains of SBP and PBLI. The strengths of this system are (1) its ability to provide objective, detailed data about routine clinical performance and (2) its ability to scale in both the level at which the metrics are evaluated and the number of metrics evaluated, both of which are in line with the ACGME Milestones Project goals.

Concerning the first cited strength, the system described is able to give the program director, the clinical competency committee, and the resident objective, detailed feedback about routine personal clinical performance. Many specialties, including anesthesiology, use case-logging systems to track clinical experience, and these logs are used as a surrogate for performance in routine care.[2,3,19] But, case logs do not contain evaluative information regarding clinical performance. Simulation has come to play a major role in technical and nontechnical skill evaluations as another means of performance assessment.[20] However, much

Table 4. Additional Metrics on Which Residents Desire Feedback

Metrics Desired by Residents Other Than Those Listed in Survey*
Respiratory events, unplanned ICU admissions, postoperative pneumothorax, postoperative delirium/CVA
PONV, postoperative pain, patient satisfaction with anesthetic
Postoperative AKI, postoperative MI, postoperative transfer to the ICU, or postoperative reintubation
Providing balanced feedback will be important. For instance, if the only feedback we get involves postoperative pain scores, the only pressure we will have is to increase analgesic medication administration, most frequently narcotics, with an associated increase in side effects. To balance this it would be helpful to also receive feedback related to overshooting, such as number of patients requiring narcan, noninvasive positive pressure ventilation, reintubation, *etc.* Although these events will be rare, it would provide checks and balances on overmedication.
Technical skills, preparation and organization, patient pain scores, complications
Postoperative pain; eye pain; awareness
Fluid management
Prevention of postoperative pain, patient satisfaction with anesthetic care (outpatients that I cannot go see the next day)
The above metrics + patient satisfaction, sore throat/hoarseness
I would like data on case turnover time and patient outcomes (prevention of PONV, *etc*.)
Time from In Room to surgical incision, from procedure stop to Out of Room
Turnaround OR time. Time from case completion to Out of Room, time to ready for PACU discharge
Prevention of PONV, postoperative pain, and OR efficiency. As residents we often have to rush off to the next case after leaving a patient in the PACU. This is usually only after one set of stable vital signs and before the patient is fully awake. We rarely (I have never) received feedback regarding postoperative pain or PONV. These calls go to the attendings from the PACU nurses.
Hypoxic events postoperative
Clinically appropriate changes in management for a patient (fluid resuscitation, *etc*.) would be nice.

* Comments reported exactly as written by residents.

AKI = acute kidney injury; CVA = cerebrovascular accident; ICU = intensive care unit; MI = myocardial ischemia; OR = operating room; PACU = postanesthesia care unit; PONV = postoperative nausea and vomiting.

anesthesia simulation training in the nontechnical domain involves participants or teams of participants responding to emergency scenarios that are 5 to 15 min in duration. Conversely, it is not feasible to run simulation sessions for hours on end to investigate how residents deliver care in more routine circumstances. What is needed is an ongoing assessment of the quality of the actual clinical performance of residents during the 60 to 80 h/week that they spend delivering anesthesia care in operating rooms. Faculty evaluations of residents have traditionally been used to do this, and a recent report has better quantified how to systematically use faculty evaluation data.[21] But faculty evaluations of residents can be biased about practice performance due to several factors, including the personality type of the resident being evaluated.[22]

In contrast, an automated system that extracts performance data directly from the electronic medical record (EMR) can add copious objective, detailed, near–real-time data as a part of the ongoing formative assessment of the resident. This system would supplement, not replace, these other assessment modalities as one part of navigating the milestones. For instance, although many of the patient care milestones can be accomplished through faculty evaluations, case logs, and simulation, the requirements for the PBLI and SBP core competencies include milestones such as "incorporation of quality improvement and patient-safety initiatives into personal practice" (PBLI1), "analysis of practice to identify areas in need of improvement" (PBLI2), and having a "systems-based approach to patient care" (SBP1).* Although these milestones could be assessed in a number of ways, a system that requires little administrative support and supplies residents with individualized, objective feedback about their clinical performance concerning published quality metrics provides residents with feedback about the areas in their practice in which they need to incorporate quality improvement and patient-safety initiatives. Personalized, objective self-assessment feedback promotes quality improvement on routine practices within internal medicine, such as the longitudinal management of diabetes and prevention of cardiovascular disease, and this advantage could cross over to anesthesiology training.[23–25]

In relation to the second cited strength—the ability to scale in terms of depth and scope—our system is designed

Table 5. Resident Preference for Format of Performance Feedback

How Would You Like to Receive This Feedback?	
E-mail	35
Web site	11
Mobile application	19
Paper	1

Table 6. Description of Cases Eligible for Scoring by Metric

Metric	Total Eligible Cases Scored
Antibiotics	23,709 (98.2%)
Pain control	13,166 (54.5%)
Temperature	11,239 (46.5%)
Glucose monitoring	2,135 (8.8%)
Central line	1,726 (7.1%)
Any metric	24,154 (100%)

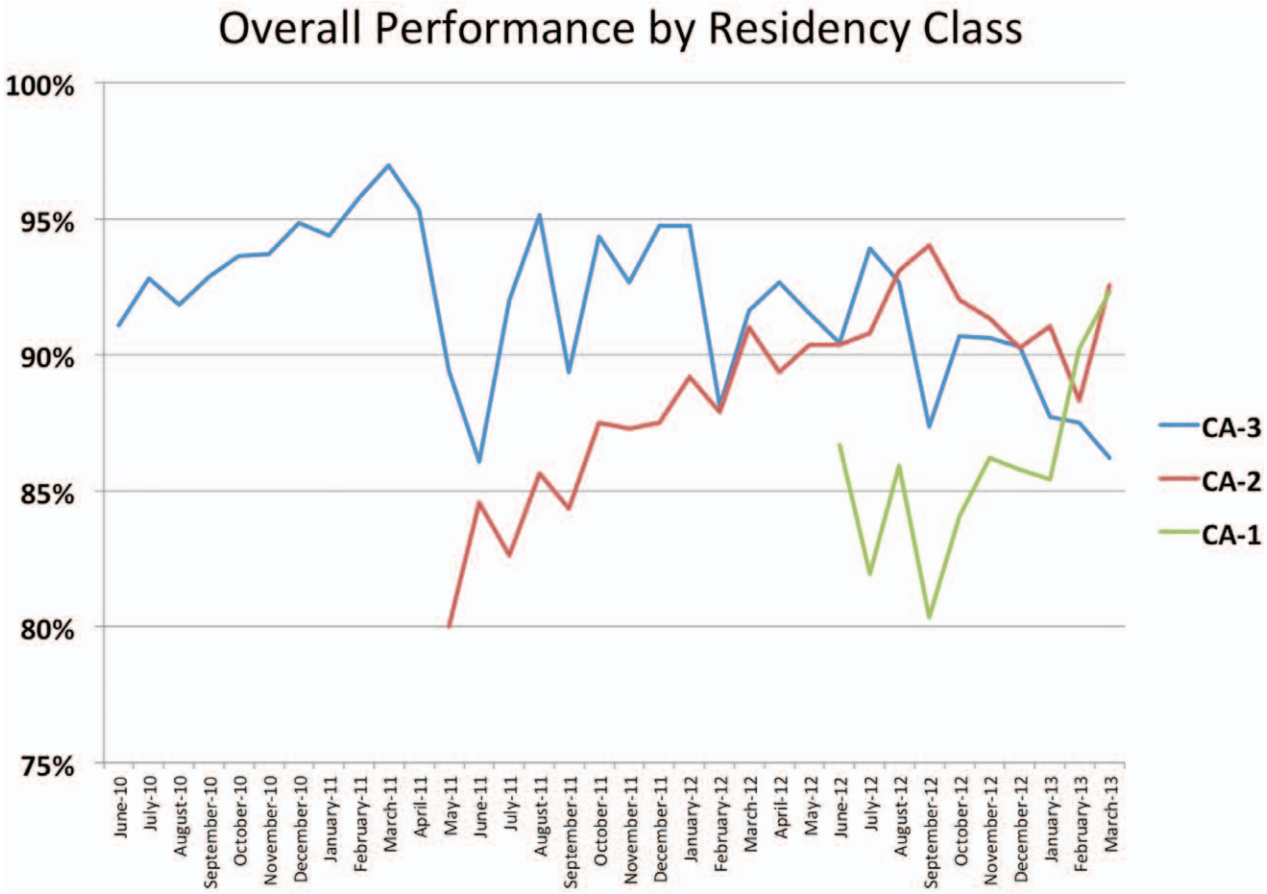

Fig. 4. This figure illustrates the overall case pass rate of each of our current residency classes by month over the past 36 months. Of note, there is no demonstrable improvement over time, as would be expected with longer periods of training, and as is expected to be demonstrated in the Milestones Project. CA = clinical anesthesia.

to be scalable for future growth. Any process or outcome measure that can be given a categorical (*e.g.*, pass/fail, yes/no, present/not present) logic for analysis could be added to this system. Additionally, the pass/fail cutoff for a number of metrics could be changed according to training level, which aligns with the Next Accreditation System and milestones concept. For instance, we currently use an entry-to-postanesthesia care unit pain score of greater than 7 as a cutoff for failure of this metric. This may be appropriate for a CA-1 resident (junior level) to demonstrate competency, but it may represent failure for a CA-3 resident (senior level). Longitudinal feedback with increasing expectations may be valuable for anesthesiology trainees. A recent systemic review of the impact of assessment and feedback on clinician performance found that feedback can positively impact physicians' clinical performance when it is provided in a systematic fashion by an authoritative and credible source over several years.[26]

Several limitations of this report should be noted. First, we have not completed an analysis of the effect of this performance feedback system on the actual performance of the residents as they progress through our residency program. In fact, although our data demonstrate that performance does not improve with training year, which runs counter to the very purpose of the milestones, we believe that this finding may be due to several factors not related to resident development. These may include the high baseline pass rate on some metrics (*e.g.*, antibiotics) and recent operational changes for others (*e.g.*, glucose monitoring) and lack of familiarity with the quality metrics being measured as noted in the resident survey response (table 2). For example, in 2011 we implemented clinical decision support to promote appropriate intraoperative glucose monitoring, and this likely confounds the longitudinal analysis of the CA-3 class performance. However, we believe that sharing the process of development with others is of value in order to show what can be operationalized over a short period of time when a baseline departmental investment in the anesthesia and perioperative information management system and in the personnel to create such tools has been made.[6,7,9,18,27–29] Second, it appears that the individual resident performance variance increases over time. Although we did not have a formal measure of this, a possible explanation of this is that residents are likely to encounter higher acuity patients and cases in which all of the performance metrics apply as they progress through their residency. Although the system is able to

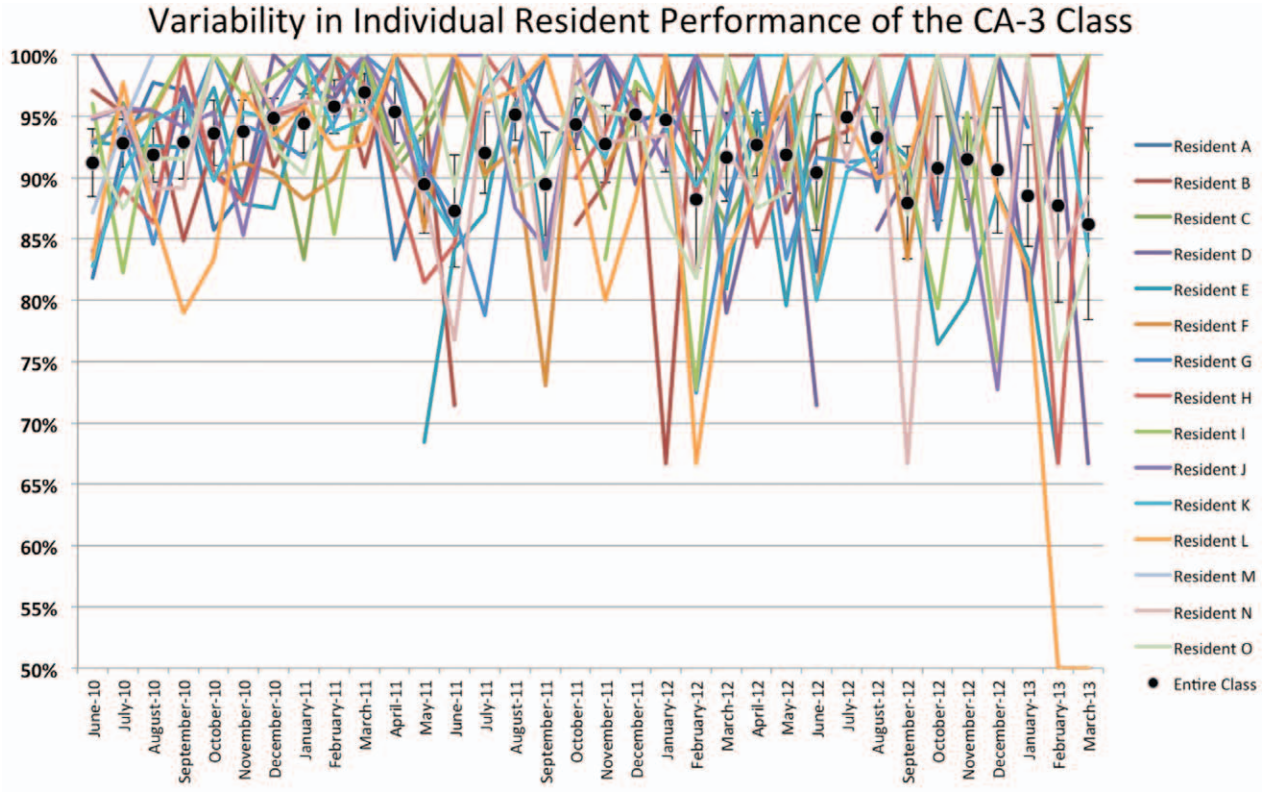

Fig. 5. This figure represents marked variability in the percentage case pass rate of individual residents of the current clinical anesthesia (CA)-3 class by month over their entire anesthesia residency, which starts with a month of anesthesia in June at the end of intern year. There is no discernible pattern of improvement in performance for any resident over time when practicing in a system where feedback on quality metrics was not provided.

report performance over time on a series of metrics, this is not an independent measure of a resident's performance because trainees are supported by both their supervising attendings and systems-level functions (*e.g.*, pop-up reminders to administer antibiotics). Although we cannot fully rule out a faculty-to-resident interaction, it is likely mitigated to some degree by the random daily assignments made among our 120 faculty physicians who supervise residents. Third, we have not investigated the validity and reliability of our composite performance metric, which is heavily influenced by the antibiotic metric as this is the item most commonly present (table 6). Although there is no definitive standard in this domain, previous research has shown that composite scoring systems aggregated from evidence-based measures address these difficulties.[24,25,30] Finally, even though the residents stated that they would like to see their data compared with data on faculty performance, this has not been added as there are a number of confounders that are being discussed (*i.e.*, faculty scores being heavily affected by resident and certified registered nurse anesthetist performance that the faculty themselves supervise).

Further future directions will involve a number of developments. First, evaluation of the effect of this feedback system on longitudinal performance will be undertaken. Because the project is still in the development phase and the number of metrics to be included is expanding, we are currently using the tool only to provide formative feedback. It does, however, fulfill the ACGME requirement to give residents feedback on their personal clinical effectiveness as queried each year in the annual ACGME survey. Second, fair performance standards need to be evaluated and set concerning quality care.[30] On the five metrics measured thus far, what is the minimum percentage pass rate required to demonstrate competency, and is this the same at all years of training and beyond? Several studies have examined this problem in simulation settings, and these rigorous methods now must be applied to clinical performance.[31–33] Third, further process measures will be added to the core list we have in place, such as the use of multimodal analgesia in opioid-dependent patients or avoidance or treatment of the triple-low state.[34,35] In addition to the milestones already discussed above, we plan to expand the use of automatic data capture from the EMR to aid in the assessment of a wide range of the milestones (Patient Care-2, 3, 4, 7; Professionalism-1; PBLI-3). Although the thorough assessment of resident performance and progress should continue to be tracked through multiple sources of input, we believe that use of objective, near–real-time data from the EMR can be leveraged to provide feedback on 12 of the 25 proposed milestones (table 7). Finally, this system could be modified to track additional objective perioperative outcome measures, such as increased level of

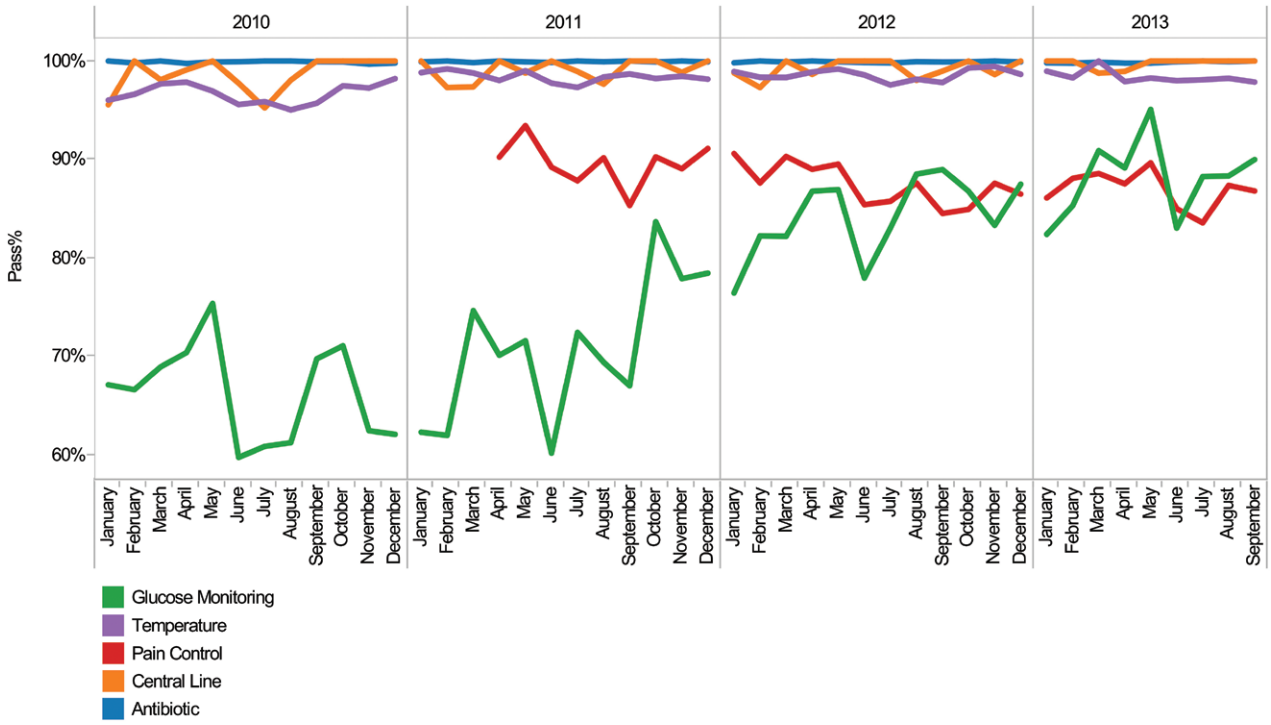

Fig. 6. This figure represents the overall programmatic performance on each of the five quality metrics over the study period and that most of the case failures are accounted for by the glucose monitoring and pain metrics. There is an observed improvement in glucose monitoring and temperature management over time, and the variability in central line documentation shows a reduction. Much of the improvement in glucose monitoring is likely due to decision support reminders embedded in our anesthesia information management system. Pain management does not appear to improve; however, our data show that on average >90% of patients arrive to the postanesthesia care unit with a pain score <7.

Table 7. ACGME Milestones Mapped to Potential Assessment Methods

Milestone	Possible Assessment Method(s)						
PC	1	Fac	Sim			360	
	2	Fac	Sim	EMR			
	3	Fac		EMR		360	
	4	Fac	Sim	EMR			
	5	Fac	Sim				
	6	Fac	Sim				
	7	Fac	Sim	EMR		360	
	8	Fac	Sim	EMR			
	9	Fac	Sim	EMR			
	10	Fac		EMR		360	
MK	1				ITE		
Prof	1	Fac	Sim	EMR		360	
	2	Fac	Sim				
	3	Fac				360	
	4	Fac				360	
	5	Fac	Sim			360	
ICS	1	Fac	Sim			360	
	2	Fac	Sim			360	
	3	Fac	Sim			360	
PBLI	1			EMR			QI Proj
	2			EMR			
	3	Fac		EMR	ITE		
	4	Fac	Sim			360	
SBP	1	Fac		EMR			
	2	Fac					

ACGME = Accreditation Council for Graduate Medical Education; EMR = electronic medical record; Fac = faculty evaluations; ICS = interpersonal and communication skills; ITE = in-training exams, *e.g.*, ABA ITE; MK = medical knowledge; PBLI = practice-based learning and improvement; PC = patient care; Prof = professionalism; QI proj = QI Project; SBP = systems-based practice; Sim = simulation; 360 = patients, nurses, *etc*.

troponin, need for reintubation, acute kidney injury, efficacy of regional blocks, and delirium, all of which can be captured from data in our EMR and all of which were requested by our residents in the survey that we administered (table 4).

In summary, we described the design and implementation of an automated resident performance system that provides near–real-time feedback to the program and to anesthesia residents from our perioperative information management system. The process and outcome metrics described in this report are related to the quality of care delivered. This system requires minimal administrative effort to maintain, and generates automated reports along with an online dashboard. Although this project has just begun and multiple future investigations concerning its validity, reliability, and scope must be completed to evaluate its effectiveness, this use of the EMR should function as one valuable piece in the milestones puzzle.

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Competing Interests

The authors declare no competing interests.

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Appendix. Resident Survey

Question*	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I am familiar with the quality performance measures used by my department and I understand the components assessed in each metric (*e.g.*, normothermia, CVL insertion practice, *etc*.)					
I think that our electronic medical record is appropriately utilized to give me data about my clinical performance					
I am satisfied with the *amount* of feedback that I get about my clinical performance from faculty					
I receive *timely* feedback about my clinical performance from faculty					
I am satisfied with the *amount* of feedback that I get about my clinical performance from practice performance data (*e.g.*, PONV, pain scores in PACU, on time first starts, *etc*.)					
I receive *timely* feedback about my clinical performance from practice performance data (*e.g.*, PONV, pain scores in PACU, on time first starts, *etc*.)					
I would like to receive frequent updates about my clinical practice according to defined performance metrics (*e.g.*, PONV, pain scores in PACU, on time first starts, *etc*.)					
I would like to receive frequent updates about my clinical practice according to defined performance metrics *with comparison to mean performance in my residency class and the residency as a whole*					
I would like to receive frequent updates about my clinical practice according to defined performance metrics *with comparison to mean performance of faculty*					
How often do you systematically review your clinical performance?	Every case	Daily	Weekly	Monthly	Yearly / Never
How often would you like to receive a systematic review of your clinical performance?	Every case	Daily	Weekly	Monthly	Yearly / Never
How would you like to receive this feedback? *[able to select multiple answers]*	Automated e-mail		Web site login	Smartphone App	Paper copy
In which of the following areas could your performance improve? [able to select multiple answers]	-Antibiotic administration -Maintenance of normothermia -Prevention of PONV		-Case documentation -OR efficiency -Prevention of postoperative pain		
In what area(s) do you think that you need the most improvement? [able to select multiple answers]	-Antibiotic administration -Maintenance of normothermia -Prevention of PONV		-Case documentation -OR efficiency -Prevention of postoperative pain		
Please describe performance metrics about which you would like to receive frequent feedback?	*[free text box]*				
Can you think of a specific case in the last month where your performance could have improved? (Please give details if you are willing. All responses are anonymous.)	*Yes No* *[free text box]*				

* This survey was transformed into Research Electronic Data Capture (RedCAP) for Web-based dissemination to the residents.

CVL = central venous line; OR = operating room; PACU = postanesthesia care unit; PONV = postoperative nausea and vomiting.