

Appendix 2:

Reference 1

Methods: Authors conducted an e-mail survey of Anesthesiologists in the US in 2010.

Results: “Five thousand anesthesiologists were solicited; 615 (12.3%) responses were received.

Twenty-four percent of respondents had installed an AIMS, while 13% were either installing a system now or had selected one, and an additional 13% were actively searching. Larger anesthesiology groups with large case loads, urban settings, and government affiliated or academic institutions were more likely to have adopted AIMS.

Initial cost was the most frequently cited AIMS barrier. The most commonly cited benefit was more accurate clinical documentation (79%), while unanticipated need for ongoing information technology support (49%) and difficult integration of AIMS with an existing EMR (61%) were the most commonly cited problems.”

[Trentman TL, Mueller JT, Ruskin KJ, Noble BN, Doyle CA. Adoption of anesthesia information management systems by US anesthesiologists. J Clin Monit Comput 2011;25:129–35.]

Reference 2

Joint Commission Report.

[Kohn L, Corrigan JM, Donaldson MS. To Err is Human: Building a Safer Health System.

Report from the Committee on Quality of Health Care in America. Washington DC: The

Joint Commission journal on quality improvement, 1999:227–34.]

Reference 3

Excerpt: “The Department of Health and Human Services (DHHS) released two proposed regulations affecting HIT (www.healthit.hhs.gov). The first, a notice of proposed rule-making (NPRM), describes how hospitals, physicians, and other health care professionals can qualify for billions of dollars of extra Medicare and Medicaid payments through the meaningful use of electronic health records (EHRs). The second, an interim final regulation, describes the standards and certification criteria that those EHRs must meet for their users to collect the payments. In addition, between August and December 2009, my office — the DHHS Office of the National Coordinator for Health Information Technology (ONC) — announced nearly \$2 billion worth of new programs to help providers become meaningful users of EHRs and to lay the groundwork for an advanced electronic health information system. All these actions were authorized by the Health Information Technology for Economic and Clinical Health (HITECH) Act, which was part of the American Recovery and Reinvestment Act of 2009, also known as the stimulus bill.”

[Blumenthal D. Launching HiteCH. N Engl J Med 2010;362:382–5.]

Reference 4

Excerpt: “The Anesthesia Patient Safety Foundation initiative on perioperative data management took a major step forward when, at the American Society of Anesthesiologists Annual Meeting in New Orleans in October 2001, the APSF Board of Directors unanimously approved the following motion:

‘The APSF endorses and advocates the use of automated record keeping in the perioperative period and the subsequent retrieval and analysis of the data to improve patient safety.’ ”

[APSF Board of Directors. APSF Endorses Use of Automated Record Keepers. Anesthesia Patient Safety Foundation Newsletter 2001;16:49.]

Reference 5

Methods: “We conducted a retrospective cross-sectional study to determine the association between physician specialty and the prevalence of EHR adoption, and a retrospective serial cross-sectional study to determine the association of physician specialty and the rate of EHR adoption over time. We used the 2005–2009 National Ambulatory Medical Care Survey. We considered fourteen specialties, and four definitions of EHR adoption.”

Specialties included were defined by the National Center for Health Statistics (NCHS): Family medicine/general practice, internal medicine, pediatrics, general surgery, obstetrics and gynecology, orthopedic surgery, cardiovascular diseases, dermatology, urology, psychiatry, neurology, ophthalmology, otolaryngology, and other specialties.

Results: “Physician specialty was significantly associated with EHR adoption, regardless of the EHR definition, after adjusting for covariates. Psychiatrists, dermatologists, pediatricians, ophthalmologists, and general surgeons were significantly less likely to adopt EHRs, compared to the reference group of family medicine / general practitioners. After adjustment for covariates, these specialties were 44 – 94% less likely to adopt EHRs than the reference group. EHR adoption increased in all specialties, by approximately 40% per year. The rate of EHR adoption over time did not significantly vary by specialty.”

[Grinspan ZM, Banerjee S, Kaushal R, Kern LM. Physician specialty and variations in adoption of electronic health records. *Applied Clinical Informatics* 2013;4:225–40.]

Reference 6

Methods: “During March–September 2009, the American Hospital Association surveyed all acute care hospitals about their health IT activities as of March 1, 2009. A paper copy of the survey was sent to each hospital’s chief executive officer, who asked the person most knowledgeable about the hospital’s health IT efforts to complete it.”

Results: “The American Hospital Association surveyed 4,493 acute care, nonfederal hospitals, of which 3,101 responded—giving a response rate of 69 percent... Overall, we saw modest gains in electronic health record adoption between 2008 and 2009. The proportion of hospitals rising to the highest criterion of a comprehensive record, according to the expert panel’s definition, nearly doubled, from 1.5 percent to 2.7 percent (Exhibit 1). Similarly,

there was a moderate gain in the proportion of hospitals that met all of the criteria for a basic record, from 7.2 percent to 9.2 percent. In total, 11.9 percent of U.S. hospitals had either a basic or a comprehensive electronic health record in 2009.”

[Jha AK, DesRoches CM, Kralovec PD, Joshi MS. A Progress Report On Electronic Health Records In U.S. Hospitals. *Health Affairs* 2010;29:1951–7.]

Reference 7

Beck, J., Benson, D., Coleman, J., Hoepfner, M., Johnson, M., Maglott, D., ... Tatusova, T. (Eds.). (2013). PubMed: The Bibliographic Database. In *The NCBI Handbook, 2nd edition*. (2nd editio). Bethesda: National Center for Biotechnology Information. Retrieved from: <http://www.ncbi.nlm.nih.gov/books/NBK143764/?report=reader>.

Reference 8

Federal document.

[Sebelius K. Health Information Technology: Standards, Implementation Specifications, and Certification Criteria for Electronic Health Record Technology, 2014 Edition; Revisions to the Permanent Certification Program for Health Information Technology. *Federal Register* 2012;77:54163–292.]

Reference 9

Methods: “We retrospectively studied electronic anesthesia records of ambulatory and day-of-surgery admission surgical cases in which one of our usual prophylactic antibiotics was administered from June 2004 through December 2005, an interval that includes cases both before and after the February 2005 implementation of the new reminder. Compliance was defined as documented antibiotic administration within 60 min before the surgical procedure starting time. Noncompliant cases were divided into those in which dosing was too early or too late.”

Results: “Compliance for 4987 cases before and 9478 cases after the reminder was implemented increased from 82.4% to 89.1% ($P < 0.01$). This increase was found both for attending anesthesiologists assisted by a resident or nurse anesthetist (82.9% before vs 89.1% after, $P < 0.01$) and for attending anesthesiologists working alone (80.1% before vs 89.3% after, $P < 0.01$). The improvement in compliance was associated with a decrease in the incidence of antibiotics administered too late (i.e., after surgical incision) (15.2% before vs 8.1% after, $P < 0.01$), but with no significant change in the incidence of antibiotics administered too early (i.e., more than 60 min before skin incision) (2.4% before vs 2.8% after, $P = 0.07$).”

[Wax DB, Beilin Y, Levin M, Chadha N, Krol M, Reich DL. The Effect of an Interactive Visual Reminder in an Anesthesia Information Management System on Timeliness of Prophylactic Antibiotic Administration. *Anesth Analg* 2007;104:1462–6.]

Reference 10

Methods: “We first reviewed 12 mo of electronic anesthesia records to establish a baseline compliance rate for arterial catheter documentation. Residents and Certified Registered Nurse Anesthetists were randomly assigned to a control group and experimental group. When surgical incision and anesthesia end were documented in the electronic record keeper, a reminder routine checked for an invasive arterial blood pressure tracing. If a case used an arterial catheter, but no procedure note was observed, the resident or Certified Registered Nurse Anesthetist assigned to the case was sent an automated alphanumeric pager and e-mail reminder. Providers in the control group received no pager or e-mail message. After 2 mo, all staff received the reminders.”

Results: “A baseline compliance rate of 80% was observed (1963 of 2459 catheters documented). During the 2-mo study period, providers in the control group documented 152 of 202 (75%) arterial catheters, and the experimental group documented 177 of 201 (88%) arterial lines ($P < 0.001$). After all staff began receiving reminders, 309 of 314 arterial lines were documented in a subsequent 2 mo period (98%). Extrapolating this compliance rate to 12 mo of expected arterial catheter placement would result in an annual incremental \$40,500 of professional fee reimbursement.”

[Kheterpal S, Gupta R, Blum JM, Tremper KK, O Reilly M, Kazanjian PE. Electronic Reminders Improve Procedure Documentation Compliance and Professional Fee Reimbursement. *Anesth Analg* 2007;104:592–7.]

Reference 11

Methods: “Computer software was developed that automatically examines electronic anesthetic records and alerts clinicians to documentation errors by alphanumeric page and e-mail. The software’s efficacy was determined retrospectively by comparing billing performance before and after its implementation. Staff satisfaction with the software was assessed by survey.”

Results: “After implementation of this software, the percentage of anesthetic records that could never be billed declined from 1.31% to 0.04%, and the median time to correct documentation errors decreased from 33 days to 3 days. The average time to release an anesthetic record to the billing service decreased from 3.0 ± 0.1 days to 1.1 ± 0.2 days. More than 90% of staff found the system to be helpful and easier to use than the previous manual process for error detection and notification.”

[Spring SF, Sandberg WS, Anupama S, Walsh JL, Driscoll WD, Raines DE. Automated documentation error detection and notification improves anesthesia billing performance. *Anesthesiology* 2007;106:157–63.]

Reference 12

Methods: “Following hospital ethics approval, we analyzed surgical inpatient data for the period between April 2002 and June 2006. First, we assessed the acceptance of the system by quantifying the overall usage of the incident reporting system. We measured the proportion of incident reporting forms filled (forms filled out with or without incidents reported) for all procedures performed on all patients, from the early introduction of the

fully computerized system in 2002 to its latest update in 2006. Unfilled forms were identified as those where none of the incident categories were completed (predefined, free text, or “no incident” category).”

Results: “During the study period 48,983 patients having an interventional procedure under anesthesia were recorded into the system. The majority of patients (67.4%) were 41 years or older. The most frequent types of procedures were performed on the digestive (28.9%) and musculoskeletal system (21.1%). There were 9,306 (19%) emergency procedures and 3,928 (8%) of these were performed after hours.

System users, senior staff anesthesiologists, and trainees completed 41,678 (85.1%) computerized incident forms over the period of observation, from April 2002 to June 2006. Most of these forms (86.3%) reported no incident occurring. In the remaining forms (13.7%) one or several intraoperative incidents per procedure were reported. The proportion of uncompleted forms, following an initial increase, remained relatively constant throughout the period of observation, between 13% to 16.6%.”

[Haller G, Myles PS, Stoelwinder J, Langley M, Anderson H, McNeil J. Integrating Incident Reporting into an Electronic Patient Record System. *J Am Med Inform Assoc* 2007;14:175–81.]

Reference 13

Methods: “The Drug Analysis prints were accessed from (www.mhra.gov.uk/home/idcplg?IdcService=1/4 SS_GET_PAGE&nodeId1/4353) and

downloaded on 26 September 2005 for a selection of drugs that were considered to be wholly or mainly used specifically in association with anaesthetic practice. These were the intravenous induction agents (methohexitone, thiopentone, etomidate, propofol and ketamine), the neuromuscular blocking drugs (suxamethonium, vecuronium, rocuronium, atracurium, cisatracurium, gallamine, tubocurarine and pancuronium) and neostigmine, the inhalational anaesthetic agents (halothane, desflurane, isoflurane, enflurane, methoxyflurane and trichloroethylene) and nitrous oxide, the local anaesthetic agents (lidocaine, lidocaine with epinephrine, lidocaine with phenylephrine, bupivacaine, levobupivacaine, ropivacaine, procaine and prilocaine), and a selection of analgesic agents that included alfentanil, fentanyl, ketorolac, remifentanyl, the opioid antagonist naloxone, and the benzodiazepine midazolam and its antagonist flumazenil.”

Results: “For all drug data accessed, there were 11 199 reactions reported in 6603 patients with 620 (9%) reported fatalities. Of the reactions, 750 (7%) were allergic. There was a mean of 1.7 reactions per patient.”

[Holdcroft A. UK drug analysis prints and anaesthetic adverse drug reactions.

Pharmacoepidemiol Drug Saf. 2007;16:316–28.]

Reference 14

Methods: “In this retrospective investigation at a large academic hospital, we reviewed 11,603 cases (spanning an 8-mo period) comparing records of medications (i.e., narcotics,

benzodiazepines, ketamine, and thiopental) recorded as removed from our automated medication dispensing system with medications recorded as administered in our AIMS.”

Results: “In 15% of cases, we found discrepancies between dispensed versus administered medications. Discrepancies occurred in both the AIMS (8% cases) and the medication dispensing system (10% cases). Although there were many different types of user errors, nearly 75% of them resulted from either an error in the amount of drug waste documented in the medication dispensing system (35%); or an error in documenting the medication in the AIMS (40%).”

[Vigoda MM, Gencorelli FJ, Lubarsky DA. Discrepancies in Medication Entries Between Anesthetic and Pharmacy Records Using Electronic Databases. *Anesth Analg* 2007;105:1061–5.]

Reference 15

Methods: “With IRB approval, we reviewed the AIMS generated case records of 3 patients who, during routine postoperative visits, reported recall of intraoperative events under general anesthesia. The AIMS in use at the time of these events at our institution (Saturn Information System and Recorder version 4.1 software, Draeger Medical Inc, Telford, PA) automatically recorded physiologic data including inspired and expired gas concentrations.”

Results: “The reports of recall were evaluated by a departmental committee and judged to represent instances of awareness during general anesthesia. These conclusions were based on close correlations of actual intraoperative events with the accounts given by the patients.”

[Driscoll WD, Columbia MA, Peterfreund RA. Awareness during general anesthesia: analysis of contributing causes aided by automatic data capture. J Neurosurg Anesthesiol 2007;19:268–72.]

Reference 16

Methods: “Observational studies chronicled the change over 2 yr as non-OR time was allocated by specialty, and nonanesthesia clerks and nurses scheduled anesthesia teams. Experimental studies investigated how tabular and graphical displays affected the scheduling of milestones (e.g., NPO times) and appointments before anesthetics.”

Results: “Anesthetics performed in allocated time increased progressively from 0% to 75%.

Scheduling of anesthetics by nonanesthesia clerks and nurses increased progressively from 0% to 77%. Consistency of patient instructions was improved. The quality of resulting schedules was good. Implementation was not associated with worsening of multiple operational measures of performance such as cancellation rates, turnover times, or complaints. However, schedulers struggled to understand fasting and arrival times of patients, despite using a web site with statistically generated values in tabular formats. Experiments revealed that people ignored their knowledge that anesthetics can start earlier

than scheduled. Participants made good decisions with both tabular and graphical displays when scheduling appointments preceding anesthesia.”

[Dexter F, Xiao Y, Dow AJ, Strader MM, Ho D, Wachtel RE. Coordination of Appointments for Anesthesia Care Outside of Operating Rooms Using an Enterprise-Wide Scheduling System. *Anesth Analg* 2007;105:1701–10.]

Reference 17

Methods: “Anesthesiologists, OR nurses, and housekeepers were given nine simulated scenarios (vignettes) involving multiple ORs to study their decision-making. Participants were randomized to one of four groups, all with an updated paper OR schedule: with/without command display and with/without passive status display.”

Results: “Participants making decisions without command displays performed no better than random chance in terms of increasing the predictability of work hours, reducing over-utilized OR time, and increasing OR efficiency. Status displays had no effect on these end-points, whereas command displays improved the quality of decisions. In the scenarios for which the command displays provided recommendations that adversely affected safety, participants appropriately ignored advice.”

[Dexter F, Willemsen-Dunlap A, Lee JD. Operating Room Managerial Decision-Making on the Day of Surgery With and Without Computer Recommendations and Status Displays. *Anesth Analg* 2007;105:419–29.]

Reference 18

Editorial reviewing methods to quantify delays in PACU admission.

[Dexter F. Measuring the Frequency of Delays in Admission into the PACU. J Perianesth Nurs 2007;22:293–4.]

Reference 19

Editorial reviewing approach to optimize patient flow to PACU using electronic displays.

[Dexter F. Bed Management Displays to Optimize Patient Flow From the OR to the PACU. J Perianesth Nurs 2007;22:218–9.]

Reference 20

Methods: “We reviewed all electronic anesthesia records” (Saturn Information System and Recorder version 4.1 software, Draeger Medical Inc., Telford, PA) “generated during a 1-month period” (January 2005) “at our institution to ascertain completion rates for six clinical documentation elements: allergies, IV access, electrocardiogram rhythm, ease of mask ventilation, laryngoscopic grade of view, and insertion depth of the endotracheal tube.”

Results: “Of 2838 records, 64% had the necessary free text remark in the allergy element. The free text required to complete endotracheal tube depth documentation appeared in 538 of

918 cases in which the patient was tracheally intubated (59%). Free text documentation of the electrocardiogram rhythm diagnosis appeared at least once in 86% of records.

Documentation of mask ventilation characteristics was entered by touch screen from a pick list and was expected in 781 records but appeared in 664 records (85%).

Laryngoscopic grade of view documentation was also selected by touch screen and expected in 883 records but present in 811 cases (92%). Any notation of IV access appeared in 84% of records.”

[Driscoll WD, Columbia MA, Peterfreund RA. An Observational Study of Anesthesia Record Completeness Using an Anesthesia Information Management System. *Anesth Analg* 2007;104:1454–61.]

Reference 21

Methods: “The data were taken from a single hospital staffed by resident and visiting full-time anaesthetists over a 17-month period.” (unspecified study period) “A total of 25 anaesthetists with a wide range of experience administered general anaesthesia during the study period, with data collected from 3790 consecutive general anaesthetics. Data from every anaesthetic was recorded using the Winchart electronic patient record management system (Medtel, Lane Cove, N.S.W.). Patient details, intra-operative notes, drug and fluid administration and continuous output from monitors were recorded, stored in a relational database and accessed using standard Structured Query Language or third party modules.”

Results: “A total of 138 separate adverse events were identified for all operative cases over 17 months, with an overall adverse event incidence of 3.3%. The adverse event incidence during colonoscopy and laryngospasm/hypoxia during desflurane anaesthesia was 6.3% and 1.3% respectively. This decreased to 2.8% ($P < 0.005$) and 0.13% ($P < 0.0001$) respectively for the nine months following feedback and the introduction of guidelines.”

[Grant C, Ludbrook G, Hampson EA, Semenov R, Willis R. Adverse physiological events under anaesthesia and sedation: a pilot audit of electronic patient records. *Anaesth Intensive Care* 2008;36:222–9.]

Reference 22

Methods: “We analyzed electronic medical records of ambulatory patients with CAD (prior myocardial infarction [MI], coronary artery bypass surgery, and angioplasty with or without stenting, angina) presenting for elective noncardiac surgery between 1/2004 and 6/2006 (30 mo) at an inner city hospital.”

Results: “Of 21,039 ambulatory patients seen in the preanesthesia clinic, 6.4% (1346) had CAD.

Patients with CAD: Men were more likely to be taking β -blockers ($P < 0.002$), statins ($P < 0.0001$), aspirin ($P < 0.0001$), and antiplatelet medications ($P < 0.04$), although there was a trend of increased use of aspirin ($P < 0.01$) by women over the course of the study.

Patients with history of prior MI: Men with a prior MI were more likely to be taking β -blockers ($P < 0.0001$) and statins ($P < 0.02$), although there was a trend of increased use of β -blockers ($P < 0.0005$) and aspirin ($P < 0.03$) by women over the course of the study.

Quarterly prevalence rates for outpatient medication use were greatest for β -blockers and least for aspirin. Patients were more likely to be taking a statin, aspirin, or oral antiplatelet medication if they were receiving chronic β -blocker therapy ($P < 0.0001$ for each medication).”

[Vigoda MM, Rodríguez LI, Wu E, Perry K, Duncan R, Birnback DJ, Lubarsky DA. The Use of an Anesthesia Information System to Identify and Trend Gender Disparities in Outpatient Medical Management of Patients with Coronary Artery Disease. *Anesth Analg* 2008;107:185–92.]

Reference 23

Methods: “We used custom software to continuously scan for missing clinical documentation during anesthesia. We used patient allergies as a test case, taking advantage of a unique requirement in our system that allergies be manually entered into the electronic record. If no allergy information was entered within 15 min of the “start of anesthesia care” event, a one-time prompt was sent via pager to the person performing the anesthetic. We tabulated the daily fraction of cases missing allergy data for the 6 mo before activating the alert system. We then obtained the same data for the subsequent 9 mo. We tested for systematic performance changes using statistical process control methodologies.”

Results: “Before initiating the alert system, the fraction of charts without an allergy comment was slightly more than 30%. This decreased to about 8% after initiating the alerts, and was significantly different from baseline within 5 days. Improvement lasted for the duration of

the trial. Paging was suspended on nights, weekends, and holidays, yet weekend documentation performance also improved, indicating that weekday reminders had far-reaching effects.”

[Sandberg WS, Sandberg EH, Seim AR, Anupama S, Ehrenfeld JM, Spring SF, Walsh JL. Real-Time Checking of Electronic Anesthesia Records for Documentation Errors and Automatically Text Messaging Clinicians Improves Quality of Documentation. *Anesth Analg* 2008;106:192–201.]

Reference 24

Methods: “Medical information of all patients undergoing elective surgery in our regional teaching hospital is routinely entered in an anesthesia information management system at the preoperative screening clinic. Our departmental PONV prevention guidelines identifies patients as “high-risk” and thus eligible for PONV prophylaxis based on the presence of at least three of the following risk factors: female gender, history of PONV or motion sickness, nonsmoker status, and anticipated use of postoperative opioids. Using automated reminders, we studied the effect of DS on guidelines adherence using an off–on– off design. In these three study periods, we queried for all consecutive patients visiting the preoperative screening clinic who were eligible for PONV prophylaxis and studied how often it was prescribed correctly.”

Results: “Between November 2005 and June 2006, 1340, 2715, and 1035 patients were included in the control, DS and post-DS periods, respectively. As a result of mandatory data entry

of risk factors, the percentage of high-risk PONV patients increased from 28% in the control period to 32% and 31% in the DS and post-DS periods, respectively. During the control period, 38% of all high-risk patients were prescribed PONV prophylaxis. This increased to 73% during the DS period and decreased to 37% in the post-DS period.”

[Kooij FO, Klok T, Hollmann MW, Kal JE. Decision Support Increases Guideline Adherence for Prescribing Postoperative Nausea and Vomiting Prophylaxis. *Anesth Analg* 2008;106:893–8.]

Reference 25

Methods: This study is based in the United Kingdom. “The NRLS database was examined for all reports relating to anaesthesia from January 2004 to February 2006. Each” National Reporting and Learning System “NRLS report referred to an unintended or unexpected incident that could have or did lead to harm for one or more patients receiving” National Health Service (UK) “NHS funded care. When an incident report is made and a record of it is stored digitally in a safety management system in a Trust, that information is gathered, de-identified and stored in the NRLS.”

Results: “Of 12 606 reports over a 2-year period, 2842 (22.5%) resulted in little harm or a moderate degree of harm, and 269 (2.1%) resulted in severe harm or death, with procedure or treatment problems generating the highest risk. One thousand and thirty-five incidents (8%) related to pre-operative assessment, with harm occurring in 275 (26.6%), and 552 (4.4%) related to epidural anaesthesia, with harm reported in 198 (35.9%). Fifty-eight

occurrences of anaesthetic awareness were also examined. This preliminary analysis is not authoritative enough to warrant widespread changes of practice, but justifies future collaborative approaches to reduce the potential for harm and improve the submission, collection and analysis of incident reports.”

[Catchpole K, Bell MDD, Johnson S. Safety in anaesthesia: a study of 12,606 reported incidents from the UK National Reporting and Learning System. *Anaesthesia* 2008;63:340–6.]

Reference 26

Methods: “From October 1, 2004, to September 15, 2005, all medications administered to patients undergoing cardiac surgery were documented with a BCMA system at a large acute care facility. Drug claims data for 12 targeted anesthetics in diagnosis-related groups (DRGs) 104–111 were analyzed to determine the quantity of drugs charged and the revenue generated. Those data were compared with claims data for a historical case–control group (October 1, 2003, to September 15, 2004, for the same DRGs) for which medication use was documented manually. From October 1, 2005, to October 1, 2006, anesthesiologists for cardiac surgeries either voluntarily used the automated system or completed anesthesia records manually.”

Results: “A total of 870 cardiac surgery cases for which the BCMA system was used were evaluated. There were 961 cardiac surgery cases in the historical control group. The BCMA system increased the quantity of drugs documented per case by 21.7% and drug revenue captured per case by 18.8%. The time needed by operating-room pharmacy staff

to process an anesthesia record for billing decreased by eight minutes per case. After two years, anesthesiologists voluntarily used the new technology on 100% of cardiac surgery patients.”

[Nolen AL, Rodes WD. Bar-code medication administration system for anesthetics: Effects on documentation and billing. *Am J Health Syst Pharm* 2008;65:655–9.]

Reference 27

Review article describing perioperative information management systems and considerations for data evaluation and visualization.

[Nagy PG, Konewko R, Warnock M, Bernstein W, Seagull J, Xiao Y, George I, Park A. Novel, Web-based, information-exploration approach for improving operating room logistics and system processes. *Surg Innov* 2008;15:7–16.]

Reference 28

Methods: “The data from 503 women, having received spinal anesthesia for cesarean sections” between July 1, 2002 and December 31, 2004 “were investigated using online gathered vital signs and specially checked manual entries employing an anesthesia information management system. Blood pressure, heart rate, and oxygen saturation were measured throughout and hypotension was defined as either a drop in mean arterial blood pressure of >20% from baseline value or readings of <90 mmHg systolic arterial blood pressure. Thirty-two variables were studied for association with hypotensive episodes using

univariate analysis and logistic regression employing a forward stepwise algorithm to identify independent variables ($P < 0.05$).”

Results: “Hypotension was found in 284 cases (56.5%). The univariate analysis identified the neonate’s weight, mother’s age, body mass index, and peak sensory block height associated with hypotension. Body mass index, age and sensory block height were detected as independent factors for hypotension (odds-ratio: 1.61 each).”

[Brenck F, Hartmann B, Katzer C, Obaid R, Brüggmann D, Benson M, Röhrig R, Junger A. Hypotension after spinal anesthesia for cesarean section: identification of risk factors using an anesthesia information management system. J Clin Monit Comput 2009;23:85–92.]

Reference 29

Methods: “The 2005–2006 American College of Surgeons– National Surgical Quality Improvement Program participant use data file is a compilation of outcome data from general surgery procedures performed in 121 US medical centers. The primary outcome was AKI within 30 days, defined as an increase in serum creatinine of at least 2 mg/dl or acute renal failure necessitating dialysis. A variety of patient comorbidities and operative characteristics were evaluated as possible predictors of AKI. A logistic regression full model fit was used to create an AKI model and risk index. Thirty-day mortality among patients with and without AKI was compared.”

Results “Of 152,244 operations reviewed, 75,952 met the inclusion criteria, and 762 (1.0%) were complicated by AKI. The authors identified 11 independent preoperative predictors: age 56 yr or older, male sex, emergency surgery, intraperitoneal surgery, diabetes mellitus necessitating oral therapy, diabetes mellitus necessitating insulin therapy, active congestive heart failure, ascites, hypertension, mild preoperative renal insufficiency, and moderate preoperative renal insufficiency. The c statistic for a simplified risk index was 0.80 in the derivation and validation cohorts. Class V patients (six or more risk factors) had a 9% incidence of AKI. Overall, patients experiencing AKI had an eightfold increase in 30-day mortality.”

[Kheterpal S, Tremper KK, Heung M, Rosenberg AL, Englesbe M, Shanks AM, Campbell DA. Development and validation of an acute kidney injury risk index for patients undergoing general surgery: results from a national data set. *Anesthesiology* 2009;110:505–15.]

Reference 30

Methods: “The Giessen study evaluated factors related to the use of positive inotropic drugs (PIDs) in adults undergoing elective cardiac surgery with cardiopulmonary bypass (CPB). The same objective and methods were applied to data of 1672 patients of the Heart Centre Siegburg. In both centres anaesthetic procedures were recorded with the AIMS NarkoData. Existing database queries were adapted according to the Siegburg database configuration for detection of patients having received PIDs during or after weaning from CPB.”

Results: “It was revealed that data from the Siegburg database using the same data model and configuration, were identical to the Giessen database except for a few items only. Thus database queries of the Giessen study could be applied to the new data pool requiring no considerable additional input.”

[Jost A, Junger A, Zickmann B, Hartmann B, Banzhaf A, Quinzio L, Müller M, Wagner RM, Hempelmann G. Potential benefits of Anaesthesia Information Management Systems for multicentre data evaluation: risk calculation of inotropic support in patients undergoing cardiac surgery. *Med Inform Internet Med* 2003;28:7–19.]

Reference 31

Methods: “The aim of this paper is to describe the design, development, training and implementation of a computerized pre-anesthetic evaluation form associated to the evaluation of the user satisfaction with the system.”

Results: “Since the system went live in September 2008 there were 15,121 closed structured forms, 60% for ambulatory procedures and 40% for procedures that required hospital admission. 82% of total closed structured forms had recorded a risk of the procedures of 1-2, according to the American Society of Anesthesiologists classification.”

[Arias A, Benítez S, Canosa D, Borbolla D, Staccia G, Plazzotta F, Casais M, Michelangelo H, Luna D, Bernaldo de Quirós FG. Computerization of a preanesthetic evaluation and user satisfaction evaluation. *Stud Health Technol Inform* 2010;160:1197–201.]

Reference 32

Editorial describing application of a preoperative and postoperative patient tracking system at a single institution.

[Sullivan EE. How to work smarter, not harder: a preoperative tracking system. *J Perianesth Nurs* 2009;24:247–9.]

Reference 33

Methods: “We retrospectively reviewed all recorded surgical cases of 2 large European teaching hospitals from 2005 to 2008, involving 85,312 cases and 92,099 h in total. Surgical times tended to be skewed and bounded by some minimally required time. We compared the fit of the normal distribution with that of 2- and 3-parameter lognormal distributions for case durations of a range of Current Procedural Terminology (CPT)-anesthesia combinations, including possible surgeon effects. For cases with very few observations, we investigated whether supplementing the data information with surgeons’ prior guesses helps to obtain better duration estimates. Finally, we used best fitting duration distributions to simulate the potential efficiency gains in OR scheduling.”

Results: “The 3-parameter lognormal distribution provides the best results for the case durations of CPT-anesthesia (surgeon) combinations, with an acceptable fit for almost 90% of the CPTs when segmented by the factor surgeon. The fit is best for surgical times and somewhat less for total procedure times. Surgeons’ prior guesses are helpful for OR

management to improve duration estimates of CPTs with very few (<10) observations. Compared with the standard way of case scheduling using the mean of the 3-parameter lognormal distribution for case scheduling reduces the mean over reserved OR time per case up to 11.9 (11.8–12.0) min (55.6%) and the mean under reserved OR time per case up to 16.7 (16.5–16.8) min (53.1%). When scheduling cases using the 4-parameter lognormal model the mean over utilized OR time is up to 20.0 (19.7–20.3) min per OR per day lower than for the standard method and 11.6 (11.3–12.0) min per OR per day lower as compared with the biased corrected mean.”

[Stepaniak PS, Heij C, Mannaerts GHH, de Quelerij M, de Vries G. Modeling Procedure and Surgical Times for Current Procedural Terminology-Anesthesia-Surgeon Combinations and Evaluation in Terms of Case-Duration Prediction and Operating Room Efficiency: A Multicenter Study. *Anesth Analg* 2009;109:1232–45.]

Reference 34

Methods: “We derived the conditional Bayesian lower prediction bound of a case’s duration, conditional on the minutes of elapsed OR time. Our derivations make use of the posterior predictive distribution of OR times following an exponential of a scaled Student t distribution that depends on the scheduled OR time and several parameters calculated from historical case duration data. The statistical method was implemented using Structured Query Language (SQL) running on the anesthesia information management system (AIMS) database server. In addition, AIMS workstations were sent instant messages displaying a pop-up dialog box asking for anesthesia providers’ estimates for

remaining times. The dialogs caused negotiated interruptions (i.e., the anesthesia provider could reply immediately, keep the dialog displayed, or defer response). There were no announcements, education, or efforts to promote buy-in.”

Results: “After a case had been in the OR longer than scheduled, the median remaining OR time for the case changes little over time (e.g., 35 min left at 2:30 pm and also at 3:00 pm while the case was still on-going). However, the remaining time differs substantially among surgeons and scheduled procedure(s) (16 min longer [10th percentile], 35 min [50th], and 86 min [90th]). We therefore implemented an automatic method to estimate the times remaining in cases. The system was operational for >119 of each day’s 120 5-min intervals. When instant message dialogs appearing on AIMS workstations were used to elicit estimates of times remaining from anesthesia providers, acknowledgment was on average within 1.2 min (95% confidence interval [CI] 1.1–1.3 min). The 90th percentile of latencies was 6.5 min (CI: 4.4–7.0 min).”

[Dexter F, Epstein RH, Lee JD, Ledolter J. Automatic Updating of Times Remaining in Surgical Cases Using Bayesian Analysis of Historical Case Duration Data and “Instant Messaging” Updates from Anesthesia Providers. *Anesth Analg* 2009;108:929–40.]

Reference 35

Methods: “We used the Anaesthesia Databank Switzerland, built on routinely and prospectively collected data on all anaesthesias in 21 hospitals” including procedures performed

between 2000 and 2004. ” The three outcomes were assessed using multi-level logistic regression models.”

Results: “Among 147,573 anaesthesias, hypotension ranged from 0.6% to 5.2% in participating hospitals, and from 0.3% up to 12% in different surgical specialties. Most (73.4%) were minor single events. Age, ASA status, combined general and regional anaesthesia techniques, duration of surgery and hospitalization were significantly associated with hypotension. Although significantly associated, the emergency status of the surgery had a weaker effect. Hospitals’ odds ratios for hypotension varied between 0.12 and 2.50 ($P < 0.001$), even after adjusting for patient and anaesthesia factors, and for type of surgery. At least one post-operative incident occurred in 9.7% of the procedures, including 0.03% deaths. Intra-operative hypotension was associated with a higher risk of post-operative incidents and death.”

[Taffé P, Sicard N, Pittet V, Pichard S, Burnand B, for the ADS study group. The occurrence of intra-operative hypotension varies between hospitals: observational analysis of more than 147,000 anaesthesia. *Acta Anaesthesiol Scand* 2009;53:995–1005.]

Reference 36

Methods: “Starting with the implementation of an anesthesia information management system (AIMS), we designed and implemented several feedback mechanisms to improve compliance of proper antibiotic delivery and documentation. This included generating e-

mail feedback of missed documentation, distributing monthly summary reports, and generating real-time electronic alerts with a decision support system.”

Results: “In 20,974 surgical cases for the period, June 2008 to January 2010, the interventions of AIMS install, e-mail feedback, summary reports, and real-time alerts changed antibiotic compliance by -1.5%, 2.3%, 4.9%, and 9.3%, respectively, when compared with the baseline value of 90.0% \pm 2.9% when paper anesthesia records were used. Highest antibiotic compliance was achieved when using real-time alerts. With real-time alerts, monthly compliance was >99% for every month between June 2009 and January 2010.”

[Nair BG, Newman S-F, Peterson GN, Wu W-Y, Schwid HA. Feedback Mechanisms Including Real-Time Electronic Alerts to Achieve Near 100% Timely Prophylactic Antibiotic Administration in Surgical Cases. *Anesth Analg* 2010;111:1293–300.]

Reference 37

Methods: “A sample of 70 handwritten records was randomly selected from anaesthesia performed in the month prior to implementation of the Integrated Injectable Drug Administration and Automated Anaesthesia Record System and compared to a similar sample of electronic records generated eight months later. A comprehensive scoring system, based on the Australian and New Zealand College of Anaesthetists’ guideline PS6, was used to compare the completeness of information throughout the entire intraoperative record.” “A record of all anaesthetics performed during March 2005 (618 cases) and November 2005 (718 cases) were obtained retrospectively from an electronic

database. During March, anaesthetics were recorded by hand on a standard preformatted record incorporating extensive checklists and free text entries. The November records were electronic IDAS records printed at the completion of each case and placed in the patients' notes in an identical fashion to the handwritten records.”

Results: “There was no significant difference in the total score for completeness between electronic (78%) and handwritten (83%) records ($P=0.16$). Handwritten records were more complete with respect to weight ($P < 0.0001$), American Society of Anesthesiologists' physical status score ($P < 0.0001$), the size and type of artificial airway used ($P=0.003$) and a record of the surgeons involved ($P=0.0004$). Electronic records were more complete with respect to a record of drug administration including intravenous drugs ($P < 0.0001$), vapour ($P=0.0001$) and nitrous oxide/oxygen ($P < 0.0001$), a record of end-tidal carbon dioxide monitoring ($P=0.006$) and the level of trainee supervision ($P=0.0002$).”

[Wrightson WAG. A comparison of electronic and handwritten anaesthetic records for completeness of information. *Anaesth Intensive Care* 2010;38:1052–8.]

Reference 38

Methods: “Seven” National Health Service, UK, “NHS sites took part in a pilot study over a 3 month period. Five used a second-person and two used bar-code electronic confirmation of drugs given during anaesthesia. A total of 36 consultant anaesthetists and three trainees, 15 operating department practitioners (ODPs), and seven anaesthetic nurses participated. A group of anaesthetists, ODPs, and nurse practitioners (n1/411) from different NHS sites

independently observed both methodologies. In addition, each site was visited and observed by one of the study investigators. At the end of the study period, four focus groups (two with participants from pilot sites and two with observers) were held. The discussions were taped, transcribed, and qualitatively analysed. Data were triangulated using observer's notes and investigator's reflective diaries, and processed using line-by-line coding. The codes were then synthesized into themes."

Results: "Both methods were perceived to contribute to the prevention of drug errors. For the two-person confirmation to be carried out correctly, there should be no distraction or time pressure. The main limitation to the feasibility was that the continuous presence of the second person was not always possible. The process also met with resistance from the staff at some pilot sites. Electronic confirmation was always feasible, as it did not require the presence of a second person. It was found to be intuitive to the anaesthetist's current working practice. However, there were some practical issues related to introduction of new technology and an initial learning curve."

[Evley R, Russell J, Mathew D, Hall R, Gemmell L, Mahajan RP. Confirming the drugs administered during anaesthesia: a feasibility study in the pilot National Health Service sites, UK. *Br J Anaesth* 2010;105:289–96.]

Reference 39

Methods: "We sought to explore the national picture by analysing incidents relating to neuromuscular blockade in anaesthesia from the National Reporting and Learning System

from England and Wales between 2006 and 2008. We searched the database of incidents using SNOMED CTÒ search terms and reading the free text of relevant incidents.”

Results: “There were 231 incidents arising from the use or reversal of neuromuscular blocking agents. The main themes identified were: nonavailability of drugs (45 incidents, 19%), possible unintentional awareness under general anaesthesia (42 incidents, 18%), potential allergic reaction (31 incidents, 13%), problems with reversal of blockade (13 incidents, 6%), storage (13 incidents, 6%) and prolonged apnoea (11 incidents, 5%).”

[Arnot-Smith J, Smith AF. Patient safety incidents involving neuromuscular blockade: analysis of the UK National Reporting and Learning System data from 2006 to 2008. *Anaesthesia* 2010;65:1106–13.]

Reference 40

Methods: “Seventeen thousand four hundred twelve consecutive, elective operations from the general surgical department in an academic hospital were analyzed. The outcome was OR time, and the potential predictive factors were surgeon’s estimate, number of planned procedures, number and experience of surgeons and anesthesiologists, patient’s age and sex, number of previous hospital admissions, body mass index, and eight cardiovascular risk factors. Linear mixed modeling on the logarithm of the total OR time was performed.”

Results: “Characteristics of the operation and the team had the largest predictive performance, whereas patient characteristics had a modest but distinct effect on OR time: operations were shorter for patients older than 60 yr, and higher body mass index was associated with longer OR times. The surgeon’s estimate had an independent and substantial contribution to the prediction, and the final model explained 27% of the residual variation in log (OR time). Using the prediction model instead of the surgeon’s prediction based on historical averages would reduce shorter-than-predicted and longer-than-predicted OR time by 2.8 and 6.6 min per case (a relative reduction of 12 and 25%, respectively), assessed on independent validation data.”

[Eijkemans MJC, van Houdenhoven M, Nguyen T, Boersma E, Steyerberg EW, Kazemier G. Predicting the unpredictable: a new prediction model for operating room times using individual characteristics and the surgeon's estimate. *Anesthesiology* 2010;112:41–9.]

Reference 41

Methods: “OR information system data were obtained for all children (aged 18 years and younger) undergoing a gastroenterology procedure with an anesthesiologist over 21 months. Summaries of data were used for a qualitative, systematic review of prior studies to learn which apply to brief pediatric cases. Patient arrival times were changed to be based on the statistical method relating actual and scheduled start times.”

Results: “Even perfect case-duration prediction would not affect whether a brief case was performed on a certain date and/or in a certain OR. There was no evidence of usefulness

in calculating the probability that one case would last longer than another or in resequencing cases to influence postanesthesia care unit staffing or patient waiting from scheduled start times. The only decision for which the accuracy of case-duration prediction mattered was for the shortest time that preceding cases in the OR may take. Knowledge of the preceding procedures in the OR was not useful for that purpose because there were hundreds of combinations of preceding procedures and some cases cancelled. Instead, patient ready times were chosen based on 5% lower prediction bounds for ratios of actual to scheduled OR times. The approach was useful based on a 30% reduction in patient waiting times from scheduled start times with corresponding expected reductions in average and peak numbers of patients in the holding area.”

[Smallman B, Dexter F. Optimizing the Arrival, Waiting, and NPO Times of Children on the Day of Pediatric Endoscopy Procedures. *Anesth Analg* 2010;110:879–87.]

Reference 42

Methods: “We conducted a systematic review of ACGME requirements and our AIMS record, and made modifications after identifying data element and attribution issues. We studied 2 methods (parsing of free text procedure descriptions and CPT4 procedure code mapping) to automatically determine ACGME case categories and generated AIMS-based case logs and compared these to assignments made by manual inspection of the anesthesia records. We also assessed under and over reporting of cases entered manually by our residents into the ACGME website.”

Results: “The parsing and mapping methods assigned cases to a majority of the ACGME categories with accuracies of 95% and 97%, respectively, as compared with determinations made by 2 residents and 1 attending who manually reviewed all procedure descriptions. Comparison of AIMS-based case logs with reports from the ACGME Resident Case Log System website showed that >50% of residents either underreported or over reported their total case counts by at least 5%.”

[Simpao A, Heitz JW, McNulty SE, Chekemian B, Brenn BR, Epstein RH. The Design and Implementation of an Automated System for Logging Clinical Experiences Using an Anesthesia Information Management System. *Anesth Analg* 2011;112:422–9.]

Reference 43

Methods: “The first electronic reminder was a timer-triggered ‘blinking button’ feature in the Anesthesia Information Management System (AIMS). The second was generated with a real-time decision support system, the Smart Anesthesia Messenger (SAM). The AIMS reminder was applied for the first five months of the study, whereas the SAM reminder was applied for the second five months. A retrospective analysis was performed to evaluate the efficacy of the reminder messages in improving the antibiotic re-dose success rate.

Results: “In a total of 940 cases, the anesthesia team was reminded of the need for antibiotic re-dosing with AIMS, whereas in 922 cases, the SAM system gave the reminder. The AIMS

reminders have achieved a timely re-dose success rate of $62.5\% \pm 1.6\%$, whereas the SAM reminders achieved a significantly higher success rate: “ $93.9\% \pm 3.4\%$ ($p < 0.001$).”

[Nair BG, Newman S-F, Peterson GN, Schwid HA. Automated electronic reminders to improve redosing of antibiotics during surgical cases: comparison of two approaches. *Surg Infect (Larchmt)* 2011;12:57–63.]

Reference 44

Methods: The Surgical Care Improvement Project “SCIP 1 compliance and the corresponding outcome variable (surgical site infection [SSI]) were examined prospectively over 2 consecutive 6-month periods before (A) and after (B)” Point-of-care electronic prompt “POCEPs implementation at a regional health system. Secondary analysis extended the observation to two 12-month periods (A¹ and B¹). A 2-year (C and D) sustainability phase followed.”

Results: “The 19,744 procedures included 9127 and 10,617 procedures before (A) and after (B) POCEPs implementation, respectively. POCEPs increased compliance with SCIP indicators in period B by 31% (95% CI, 30.0%–32.2%) from 62% to 92% ($P < 0.001$) and were associated with a sustainable, contemporaneous decrease in the incidence of SSI from 1.1% to 0.7% ($P = 0.003$; absolute risk reduction, 0.4%; 95% CI, 0.1%–0.7%). Secondary and sustainability analysis revealed that compliance rates remained $>95\%$ with mean SSI rates lower for all periods compared with pre-POCEPs SSI rates (0.8%, 0.7%, and 0.5% vs 1.1%; $P < 0.001$).”

[Schwann NM, Bretz KA, Eid S, Burger T, Fry D, Ackler F, Evans P, Romancheck D, Beck M, Ardire AJ, Lukens H, McLoughlin TM. Point-of-care electronic prompts: an effective means of increasing compliance, demonstrating quality, and improving outcome. *Anesth Analg* 2011;113:869–76.]

Reference 45

Methods: “We aimed to explore the national picture by reviewing patient safety incidents relating to anaesthetic equipment from the National Reporting and Learning System for England and Wales between 2006 and 2008. We searched the database using the system’s own classification and by scrutinising the free text of relevant incidents.”

Results: “There were 1029 relevant incidents. Of these, 410 (39.8%) concerned patient monitoring, most commonly screen failure during anaesthesia, failure of one modality or failure to transfer data automatically from anaesthetic room to operating theatre. Problems relating to ventilators made up 185 (17.9%) of the reports. Sudden failures during anaesthesia accounted for 142 (13.8%) of these, with a further 10 cases (0.9%) where malfunction caused a sustained or increasing positive pressure in the patient’s airway. Leaks made up 99 (9.6%) of incidents and 53 (5.2%) of incidents arose from the use of infusion pumps. Most (89%) of the incidents caused no patient harm; only 30 (2.9%) were judged to have led to moderate or severe harm. Although equipment was often faulty, user error or unfamiliarity also played a part. A large variety of causes led to a relatively small

number of clinical scenarios, that anaesthetists should be ready, both individually and organisationally, to manage even when the cause is not apparent.”

[Cassidy CJ, Smith A, Arnot-Smith J. Critical incident reports concerning anaesthetic equipment: analysis of the UK National Reporting and Learning System (NRLS) data from 2006-2008*. *Anaesthesia* 2011;66:879–88.]

Reference 46

Methods: “We used the capabilities of our anesthesia information management system (AIMS) in conjunction with internally developed, secure, intranet-based, Web application software. The application is implemented with a backend allowing robust data storage, retrieval, data analysis, and reporting capabilities. We customized a feature within the AIMS software to create a hard stop in the documentation workflow before the end of anesthesia care time stamp for every case. The software forces the anesthesia provider to access the separate quality assurance data collection program, which provides a checklist for targeted clinical events and a free text option. After completing the event collection program, the software automatically returns the clinician to the AIMS to finalize the anesthesia record.” “The QA Database application is implemented in Microsoft® ASP.NET with Microsoft SQL Server (Microsoft Corporation, Redmond, WA) as the database backend.” Study included patients between January 2005 and August 2010.

Results: “The number of events captured by the departmental quality assurance office increased by 92% (95% confidence interval [CI] 60.4%–130%) after system implementation. The

major contributor to this increase was the new electronic system. This increase has been sustained over the initial 12 full months after implementation. Under our reporting criteria, the overall rate of clinical events reported by any method was 471 events out of 55,382 cases or 0.85% (95% CI 0.78% to 0.93%). The new system collected 67% of these events (95% confidence interval 63%–71%).”

[Peterfreund RA, Driscoll WD, Walsh JL, Subramanian A, Anupama S, Weaver M, Morris T, Arnholz S, Zheng H, Pierce ET, Spring SF. Evaluation of a Mandatory Quality Assurance Data Capture in Anesthesia: A Secure Electronic System to Capture Quality Assurance Information Linked to an Automated Anesthesia Record. *Anesth Analg* 2011;112:1218–25.]

Reference 47

Review article focusing on AIMS integrated with hospital EHR.

[Springman SR. Integration of the Enterprise Electronic Health Record and Anesthesia Information Management Systems. *Anesthesiol Clin* 2011;29:455–83.]

Reference 48

Review article focused on AIMS vendors in 2011.

[Stonemetz J. Anesthesia Information Management Systems Marketplace and Current Vendors. *Anesthesiol Clin* 2011;29:367–75.]

Reference 49

Methods: “In a recent New Zealand study (ACTRN12608000068369), both manual and automated records were acquired from the same anaesthetics. Manual records were digitized using digital callipers. Selected data (systolic, diastolic, and mean arterial pressure; heart rate; SpO₂; E'CO₂) were replayed in a computerized anaesthetic record-keeping system with which the participants were familiar, to present manual and corresponding automated anaesthetic records. Ten anaesthetists, randomly selected from participants in this study, assessed 24 replayed records (a manual and an automated record from each of 10 anaesthetics, with two of each displayed twice). They indicated where and how they would have intervened if administering these anaesthetics. We compared the number of interventions for each pair of anaesthetics and subjective measures of anaesthetic quality.” Study conducted

Results: “In our selected sample of unstable anaesthetics, the mean (SD) number of interventions per anaesthetic was 4.0 (2.9) vs 5.2 (3.4) for manual and automated records, respectively (P1/40.013). Subjective measures did not differ significantly between record types. Assessors identified 32 artifacts in six manual records (0.32/record assessment) and 105 artifacts in eight automated records (1.05/record assessment), P1/40.14. Replicability was moderate (COV 39.8%).”

[van Schalkwyk JM, Lowes D, Frampton C, Merry AF. Does manual anaesthetic record capture remove clinically important data? *Br J Anaesth* 2011;107:546–52.]

Reference 50

Methods: “We evaluated 212,706 electronic anesthesia records from 3 large academic centers.

We determined the fraction of cases with ≥ 10 -minute BP monitoring gaps at baseline and did a root cause analysis to determine common causes for these lapses. We then designed and implemented automated systems at 2 of the hospitals to notify point-of-care providers immediately after such 10-minute gaps occurred and determined the subsequent impact of this feedback on BP gap incidence, compared with baseline.”

Results: “At Hospital A, the notification system reduced the incidence of cases with at least 1 BP gap ($1.48\% \pm 0.19\%$ SD vs $0.79\% \pm 0.36\%$ SD, $P < 0.0001$). At Hospital B, the gap incidence was not significantly altered when notification was provided after a 10-minute gap had already occurred ($2.72\% \pm 0.60\%$ SD vs $2.45\% \pm 0.48\%$ SD, $P = 0.27$), but the incidence was reduced when such notification was provided after 6 minutes without a BP reading ($2.72\% \pm 0.60\%$ SD vs $1.54\% \pm 0.19\%$ SD, $P < 0.0001$). At Hospital C, where notification was not implemented, the baseline rate of BP gaps was consistent across the preintervention and follow-up periods ($7.03\% \pm 1.27\%$ SD vs $7.13\% \pm 0.11\%$ SD, $P = 0.74$). Although monitors disconnected during position change was the most common identifiable cause of BP gaps, reasons for the missing BP measurements were often not documented. During a week when the electronic charting system was temporarily inoperable, no BP gaps were noted on a convenience sample of 500 paper records from Hospital A (99% upper confidence limit = 0.83%).”

[Ehrenfeld JM, Epstein RH, Bader S, Kheterpal S, Sandberg WS. Automatic notifications mediated by anesthesia information management systems reduce the frequency of prolonged gaps in blood pressure documentation. *Anesth Analg* 2011;113:356–63.]

Reference 51

Methods: “Our goal was to determine the reliability of AIMS and CQI reports of adverse clinical events that had been witnessed and recorded by research assistants. The AIMS and CQI records of 995 patients aged 2–12 years were analyzed to determine if anesthesia providers had properly documented the emesis events that were observed and recorded by research assistants who were present in the operating room at the time of induction.”

Results: “Research assistants recorded eight cases of emesis during induction that were confirmed with the attending anesthesiologist at the time of induction. AIMS yielded a sensitivity of 38 % (95 % confidence interval [CI] 8.5–75.5 %), while the sensitivity of CQI reporting was 13 % (95 % CI 0.3–52.7 %).”

[Simpao AF, Pruitt EY, Cook-Sather SD, Gurnaney HG, Rehman MA. The reliability of manual reporting of clinical events in an anesthesia information management system (AIMS). *J Clin Monit Comput* 2012;26:437–9.]

Reference 52

Review article focused on clinical decision support design considerations and applications in anesthesia practice.

[Rothman B, Leonard JC, Vigoda MM. Future of Electronic Health Records: Implications for Decision Support. Mt Sinai J Med 2012;79:757–68.]

Reference 53

Methods: “Before the study was conducted, the institution lacked a highly reliable process to document the date and time of self-administration of beta-blockers prior to hospital admission. Because of this, compliance with the beta-blocker quality measure was poor (~65%). To improve this measure, the anesthesia care team was made responsible for documenting perioperative beta-blockade. Clear documentation guidelines were outlined, and an electronic Anesthesia Information Management System (AIMS) was configured to facilitate complete documentation of the beta-blocker quality measure. In addition, real-time electronic alerts were generated using Smart Anesthesia Messenger (SAM), an internally developed decision-support system, to notify users concerning incomplete beta-blocker documentation.”

Results: “Weekly compliance for perioperative beta-blocker documentation before the study was $65.8 \pm 16.6\%$, which served as the baseline value. When the anesthesia care team started documenting perioperative beta-blocker in AIMS, compliance was $60.5 \pm 8.6\%$ ($p = .677$ as compared with baseline). Electronic alerts with SAM improved documentation compliance to $94.6 \pm 3.5\%$ ($p < .001$ as compared with baseline).”

[Nair BG, Peterson GN, Newman S-F, Wu W-Y, Kolios-Morris V, Schwid HA. Improving documentation of a beta-blocker quality measure through an anesthesia information management system and real-time notification of documentation errors. *Jt Comm J Qual Patient Saf* 2012;38:283–8.]

Reference 54

Methods: “Patients were randomized to either graphically (intervention) or numerically (control) guided administration of therapy. Goals were set and treatments and concordance with guidance noted, where applicable. Anaesthesia was provided by one of three experienced anaesthetists well acquainted with Navigator™. The primary objective was to determine whether the use of graphical display decision support more efficiently enables the achievement of oxygen delivery targets. This was quantitated as percentage time in the target zone and averaged standardized distance from the target centre.”

Results: “The mean percentage time in the target zone was 36.7% for control and 36.5% for intervention. The averaged standardized difference was 1.5 in control and 1.6 in intervention. There was no significant difference in fluid balances. There was a high level of concordance between decision support recommendation and anaesthetist action (84.3%).”

[Sondergaard S, Wall P, Cocks K, Parkin WG, Leaning MS. High concordance between expert anaesthetists' actions and advice of decision support system in achieving oxygen delivery targets in high-risk surgery patients. *Br J Anaesth* 2012;108:966–72.]

Reference 55

Methods: “Medical information of surgical patients is routinely entered in our anaesthesia information management system (AIMS), which includes automated reminders for PONV management based on the simplified risk score by Apfel and colleagues. This study included consecutive adult patients undergoing general anaesthesia for elective noncardiac surgery who were treated according to the normal clinical routine. The presence of PONV was recorded in the AIMS both during the recovery period and at 24 h. Two periods were studied: one without the use of DS (control period) and one with the use of DS (support period). DS consisted of reminders on PONV both in the preoperative screening clinic and at the time of anaesthesia.”

Results: “In the control period, 981 patients, of whom 378 (29%) were high-risk patients, received general anaesthesia. Overall, 264 (27%) patients experienced PONV within 24 h. In the support period, 1681 patients, of whom 525 (32%) had a high risk for PONV, received general anaesthesia. In this period, only 378 (23%) patients experienced PONV within 24 h after operation. This difference is statistically significant ($P=0.01$).”

[Kooij FO, Vos N, Siebenga P, Klok T, Hollmann MW, Kal JE. Automated reminders decrease postoperative nausea and vomiting incidence in a general surgical population. *Br J Anaesth* 2012;108:961–5.]

Reference 56

Methods: “This study analyzed differences in the accuracy of Certified Registered Nurse Anesthetists’ (CRNAs) recall of specific patient variables during the course of an actual anesthetic case. CRNAs using AIMS were compared to CRNAs using MERS. Accuracy of recalled values of 10 patient variables was measured: highest and lowest values for heart rate, systolic blood pressure, inspiratory pressure, and end-tidal carbon dioxide levels, lowest oxygen saturation and total fluid volume. Four tertiary care facilities participated in this research; two of which used MERS, two utilized AIMS.”

Results: “A total of 214 subjects participated in this study; 106 in the computerized recordkeeping group, and 108 in the manual entry recordkeeping group. Demographic covariates were analyzed to ensure homogeneity between groups and facilities. No significant statistical differences were identified between the accuracy of recall among the groups. There was no difference in the accuracy of practitioners’ recall of patient variables when using computerized or manual entry recordkeeping systems, suggesting little impact on vigilance.”

[Davis TC, Green JA, Colquhoun A, Hage BL, Biddle C. Anesthesia recordkeeping: accuracy of recall with computerized and manual entry recordkeeping. J Clin Monit Comput 2012;26:163–9.]

Reference 57

Description of the Pediatric Regional Anesthesia Network in the United States – a multi-institution collaboration to aggregate outcome data for the practice of regional anesthesia in pediatrics. This article describes the group and offers preliminary analysis of the data.

[Polaner DM, Martin LD, the PRAN Investigators. Quality assurance and improvement: the Pediatric Regional Anesthesia Network. *Pediatr Anesth* 2012;22:115–9.]

Reference 58

Methods: “We constructed a centralized database to collect detailed prospective data on all regional anesthetics performed by anesthesiologists at the participating centers. Data were uploaded via a secure Internet connection to a central server. Data were rigorously audited for accuracy and errors were corrected. All anesthetic records were scrutinized to ensure that every block that was performed was captured in the database. Intraoperative and postoperative complications were tracked until their resolution. Blocks were categorized by type and as single-injection or catheter (continuous) blocks.”

Results: “A total of 14,917 regional blocks, performed on 13,725 patients, were accrued from April 1, 2007 through March 31, 2010. There were no deaths or complications with sequelae lasting >3 months (95% CI 0–2;10,000). Single-injection blocks had fewer adverse events than continuous blocks, although the most frequent events (33% of all events) in the latter group were catheter-related problems. Ninety-five percent of blocks were placed while patients were under general anesthesia. Single-injection caudal blocks were the most frequently performed (40%), but peripheral nerve blocks were also

frequently used (35%), possibly driven by the widespread use of ultrasound (83% of upper extremity and 69% of lower extremity blocks).”

[Polaner DM, Taenzer AH, Walker BJ, Bosenberg A, Krane EJ, Suresh S, Wolf C, Martin LD.

Pediatric Regional Anesthesia Network (PRAN): a multi-institutional study of the use and incidence of complications of pediatric regional anesthesia.. *Anesth Analg* 2012;115:1353–64.]

Reference 59

Methods: “We examined the need for improved planning capabilities for optimizing OR

efficiency through key informant interviews and refined the needs identified through an expert consensus approach. We interviewed 11 directors and managers of perioperative service lines at six Midwest hospitals, which represented a range of bedsizes and primary, secondary and tertiary hospitals. We then used a modified Delphi approach to determine big-picture operational and business needs and opportunities.”... “Data from (i) a large Midwest tertiary referral hospital (involving complex surgeries across 18 ORs) and (ii) a large city-county safety-net hospital (involving general, trauma, and specialty surgeries across 10 ORs) included 12 months of executed OR schedules for on-time starts, surgery durations (by procedure), and turnover and sterilization times. Discrete event durations were used as input for our scheduling model. Key hospital personnel and subject matter experts helped identify information gaps and/or inconsistencies during observational studies.”

Results: “Our phase-I interviews with OR administrators and managers consistently identified advanced strategic planning and operational decision-making tools as essential, yet unavailable, for optimizing OR efficiency. Specific, high-priority objectives necessary to drive efficiency included: increasing utilization of OR during core hours and decreasing over-utilization (e.g. overtime) during other times; leveling workload (e.g. balancing surgical schedules and staffing with anticipated demand); identifying opportunities for improving workflow; and assessing need and future return on investment (ROI) for additional key resources (e.g. adding anesthesiologists or surgical nurses). The most critical issues identified by OR Directors included: (1) utilization (to increase the number of cases or new services/specialties); (2) workload leveling (to decrease day-to-day and throughout shift variation in rooms running); and (3) efficiency and workflow (to better use existing staff and resources). Their key performance indicators were similar, and performance metrics were obtained when available, otherwise respondents reported recent estimates. Across all sites, OR utilization (proportion of ORs with cases running during day shift) averaged 60% (30-70%), workload ranged from zero rooms running to maximum capacity (widely variable at all sites), on-time starts averaged 57% (20-80%), and the mean turn-over time was 25.3 minutes (21-30 min). Overall highest priorities ... included: (1) tools to support and/or balance patient and staff scheduling and (2) decision support and analytics for planning perioperative services.”

[Doebbeling BN, Burton MM, Wiebke EA, Miller S, Baxter L, Miller D, Alvarez J, Pekny J.

Optimizing perioperative decision making: improved information for clinical workflow planning. AMIA Annu Symp Proc 2012;2012:154–63.]

Reference 60

Review article focusing on Anesthesia Information Management Systems elements including pre-operative, intra-operative, post-operative, software components, hardware components, staffing, billing and quality assurance.

[Shah NJ, Tremper KK, Kheterpal S. Anatomy of an Anesthesia Information Management System. *Anesthesiol Clin* 2011;29:355–65.]

Reference 61

Special review article discussing considerations for implementation of an AIMS.

[Muravchick S, Caldwell JE, Epstein RH, Galati M, Levy WJ, O'Reilly M, Plagenhoef JS, Rehman M, Reich DL, Vigoda MM. Anesthesia Information Management System Implementation: A Practical Guide. *Anesth Analg* 2008;107:1598–608.]

Reference 62

Methods: “The study was conducted in a Korean teaching hospital where the EMR was implemented in October 2008. One hundred paper anesthesia records from July to September 2008 and 150 electronic anesthesia records during the same period in 2009 were randomly sampled. Thirty-four essential items were selected out of all the anesthesia items and grouped into automatically transferred items and manual entry items. 1, .5 and 0 points were given for each item of complete entry, incomplete entry and no entry

respectively. The completeness of documentation was defined as the sum of the scores.

The influencing factors on the completeness of documentation were evaluated in total and by the groups.”

Results: “The average completeness score of the electronic anesthesia records was 3.15% higher than that of the paper records. A multiple regression model showed the type of the anesthesia record was a significant factor on the completeness of anesthesia records in all items ($\beta = 0.98$, $p < 0.05$) and automatically transferred items ($\beta = 0.56$, $p < 0.01$). The type of the anesthesia records had no influence on the completeness in manual entry items.”

[Jang J, Yu SH, Kim CB, Moon Y, Kim S. The effects of an electronic medical record on the completeness of documentation in the anesthesia record. *Int J Med Inform* 2013;82:702–7.]

Reference 63

Methods: “Anesthesia information management systems (AIMS) are being increasingly used in the operating room to document anesthesia care. We developed a system, Smart Anesthesia Manager™ (SAM) that works in conjunction with an AIMS to provide clinical and billing decision support. SAM interrogates AIMS database in near real time, detects issues related to clinical care, billing and compliance, and material waste. Issues and the steps for their resolution are brought to the attention of the anesthesia provider in real time through “pop-up” messages overlaid on top of AIMS screens or text pages.”

Results: “SAM improved compliance to antibiotic initial dose and redose to $99.3 \pm 0.7\%$ and $83.9 \pm 3.4\%$ from $88.5 \pm 1.4\%$ and $62.5 \pm 1.6\%$, respectively. Beta-blocker protocol compliance increased to $94.6 \pm 3.5\%$ from $60.5 \pm 8.6\%$. Inadvertent gaps (>15 min) in blood pressure monitoring were reduced to 34 ± 30 min/1000 cases from 192 ± 58 min/1000 cases. Additional billing charge capture of invasive lines procedures worth \$144,732 per year and 1,200 compliant records were achieved with SAM. SAM was also able to reduce wastage of inhalation anesthetic agents worth \$120,168 per year.”

[Nair BG, Newman SF, Peterson GN, Schwid HA. Smart Anesthesia Manager™ (SAM)--a real-time decision support system for anesthesia care during surgery. IEEE Trans Biomed Eng 2013;60:207–10.]

Reference 64

Methods: “Anesthesia cases were evaluated to determine whether they met the definition for appropriate anesthesia start time over 4 separate, 45-day calendar cycles: the pre-study period, study period, immediate post-study period, and 3-year follow-up period. During the study period, providers were randomly assigned to either a control or an alert group. Providers in the alert cohort received an automated alphanumeric page if the anesthesia start time occurred concurrently with the patient entering the OR, or more than 30 minutes before entering the OR. Three years after the intervention period, overall compliance was analyzed to assess learned behavior.”

Results: “Baseline compliance was $33\% \pm 5\%$. During the intervention period, providers in the alert group showed $87\% \pm 6\%$ compliance compared with $41\% \pm 7\%$ compliance in the control group ($P < 0.001$). Long-term follow-up after cessation of the alerts showed $85\% \pm 4\%$ compliance.”

[Freundlich RE, Barnett CS, Mathis MR, Shanks AM, Tremper KK, Kheterpal S. A randomized trial of automated electronic alerts demonstrating improved reimbursable anesthesia time documentation. *J Clin Anesth* 2013;25:110–4.]

Reference 65

Methods: “The authors conducted a randomized controlled trial on anesthesia providers caring for patients with potential ALI. Patients with an average or last collected ratio of partial pressure of arterial oxygen to inspired fraction of oxygen less than 300 were randomized to providers being sent an alert with a recommended V_t of 6 cc/kg predicted body weight or conventional care. Primary outcomes were V_t /kg predicted body weight administered to patients. Secondary outcomes included ventilator parameters, length of postoperative ventilation, and death.”

Results: “The primary outcome was a clinically significant reduction in mean V_t from 508–458 cc ($P = 0.033$), with a reduction in V_t when measured in cc/kg predicted body weight from 8 to 7.2 cc/kg predicted body weight ($P = 0.040$). There were no statistically significant changes in other outcomes or adverse events associated with either arm.”

[Blum JM, Stentz MJ, Maile MD, Jewell E, Raghavendran K, Engoren M, Ehrenfeld JM.

Automated alerting and recommendations for the management of patients with preexisting hypoxia and potential acute lung injury: a pilot study. *Anesthesiology* 2013;119:295–302.]

Reference 66

Methods: “A near real-time AIMS-based decision support module, Smart Anesthesia Manager

(SAM), was used to detect selected scenarios contributing to hypotension and hypertension. Specifically, hypotension (systolic blood pressure <80 mm Hg) with a concurrent high concentration (>1.25 minimum alveolar concentration [MAC]) of inhaled drug and hypertension (systolic blood pressure >160 mm Hg) with concurrent phenylephrine infusion were detected, and anesthesia providers were notified via “pop-up” computer screen messages. AIMS data were retrospectively analyzed to evaluate the effect of SAM notification messages on hypotensive and hypertensive episodes.”

Results: “For anesthetic cases 12 months before (N = 16913) and after (N = 17132) institution of SAM messages, the median duration of hypotensive episodes with concurrent high MAC decreased with notifications (Mann Whitney rank sum test, $P = 0.031$). However, the reduction in the median duration of hypertensive episodes with concurrent phenylephrine infusion was not significant ($P = 0.47$). The frequency of prolonged episodes that lasted >6 minutes (sampling period of SAM), represented in terms of the number of cases with episodes per 100 surgical cases (or percentage occurrence), declined with notifications for both hypotension with >1.25 MAC inhaled drug episodes ($\Delta = -0.26\%$ [confidence interval, -0.38% to -0.11%], $P < 0.001$) and hypertension with phenylephrine infusion

episodes ($\Delta = -0.92\%$ [confidence interval, -1.79% to -0.04%], $P = 0.035$). For hypotensive events, the anesthesia providers reduced the inhaled drug concentrations to <1.25 MAC 81% of the time with notifications compared with 59% without notifications ($P = 0.003$). For hypertensive episodes, although the anesthesia providers' reduction or discontinuation of the phenylephrine infusion increased from 22% to 37% ($P = 0.030$) with notification messages, the overall response was less consistent than the response to hypotensive episodes.”

[Nair BG, Horibe M, Newman S-F, Wu W-Y, Peterson GN, Schwid HA. Anesthesia Information Management System-Based Near Real-Time Decision Support to Manage Intraoperative Hypotension and Hypertension. *Anesth Analg* 2014;118:206–14.]

Reference 67

Methods: “Blood utilization data for 53,526 patients undergoing 1,632 different surgical procedures were gathered from an anesthesia information management system. A novel algorithm based on previously defined criteria was used to create an MSBOS for each surgical specialty. The economic implications were calculated based on the number of blood orders placed, but not indicated, according to the MSBOS.”

Results: “Among 27,825 surgical cases that did not require preoperative blood orders as determined by the MSBOS, 9,099 (32.7%) had a type and screen, and 2,643 (9.5%) had a crossmatch ordered. Of 4,644 cases determined to require only a type and screen, 1,509 (32.5%) had a type and crossmatch ordered. By using the MSBOS to eliminate

unnecessary blood orders, the authors calculated a potential reduction in hospital charges and actual costs of \$211,448 and \$43,135 per year, respectively, or \$8.89 and \$1.81 per surgical patient, respectively.”

[Frank SM, Rothschild JA, Masear CG, Rivers RJ, Merritt WT, Savage WJ, Ness PM.

Optimizing preoperative blood ordering with data acquired from an anesthesia information management system. *Anesthesiology* 2013;118:1286–97.]

Reference 68

Methods: “Anesthesia information management system data were retrieved from the 160,207 scheduled noncardiac cases in adults of 1,253 procedures at a hospital.”

Results: “Neither assuming a Poisson distribution of mean erythrocyte units transfused, nor grouping rare procedures into larger groups based on their anesthesia Current Procedural Terminology code, was reliable. In contrast, procedures could be defined to have minimal estimated blood loss (less than 50 ml) based on low incidence of transfusion and low incidence of the hemoglobin being checked preoperatively. Among these procedures, when the lower 95% confidence limit for erythrocyte transfusion was less than 5%, type and screen was shown to be unnecessary. The method was useful based on including multiple differences from the hospital’s maximum surgical blood order schedule and clinicians’ test ordering (greater than or equal to 29% fewer type and screen). Results were the same with a Bayesian random effects model.”

[Dexter F, Ledolter J, Davis e, Witkowski TA, Herman JH, Epstein RH. Systematic criteria for type and screen based on procedure's probability of erythrocyte transfusion.

Anesthesiology 2012; 116:768–78.]

Reference 69

Technical communication describing a human factors approach to designing perioperative status boards.

[Egeth M, Soosaar J, Shames A, Margolies R, Gurnaney H, Rehman M. Operative heuristics: optimizing perioperative status boards. Biomed Instrum Technol 2013;Suppl:64–7.]

Reference 70

Methods: “The developed data analysis tool is embedded in an Oracle Business Intelligence Environment, which processes data to simple and understandable performance tachometers and tables. The underlying data analysis is based on scientific literature and the projects teams experience with tracked data. The system login is layered and different users have access to different data outputs depending on their professional needs. The system is divided in the tree profile types Manager, Anesthesiologist and Surgeon. Every profile includes subcategories where operators can access more detailed data analyses. The first data output screen shows general information and guides the user towards more detailed data analysis. The data recording system enabled the registration of 14.675 surgical operations performed from 2009 to 2011.”

Results: “Raw utilization increased from 44% in 2009 to 52% in 2011. The number of high complexity surgical procedures (≥ 120 minutes) has increased in certain units while decreased in others. The number of unscheduled procedures performed has been reduced (from 25% in 2009 to 14% in 2011) while maintaining the same percentage of surgical procedures. The number of overtime events decreased in 2010 (23%) and in 2011 (21%) compared to 2009 (28%) and the delays expressed in minutes are almost the same (mean 78 min). The direct link found between the complexity of surgical procedures, the number of unscheduled procedures and overtime show a positive impact of the project on OR management. Despite a consistency in the complexity of procedures (19% in 2009 and 21% in 2011), surgical groups have been successful in reducing the number of unscheduled procedures (from 25% in 2009 to 14% in 2011) and overtime (from 28% in 2009 to 21% in 2011).”

[Agnoletti V, Buccioli M, Padovani E, Corso RM, Perger P, Piraccini E, Orelli RL, Maitan S, Amore DD, Garcea D, Vicini C, Montella TM, Gambale G. Operating room data management: improving efficiency and safety in a surgical block. BMC Surg 2013;13:1–1.]

Reference 71

Case report with accompanying root cause analysis of events leading to miscommunication among three separate medical care teams.

[Freundlich RE, Grondin L, Tremper KK, Saran KA, Kheterpal S. Automated electronic reminders to prevent miscommunication among primary medical, surgical and anaesthesia providers: a root cause analysis. *BMJ Qual Saf.* 2012;21:850–4.]

Reference 72

Methods: “We compared 2006, pre operations management and EHR implementation, to 2010, post implementation. Operations management consisted of: communication to staff of perioperative vision and metrics, obtaining credible data and analysis, and the implementation of performance improvement processes. The EHR allows: identification of delays and the accountable service or person, collection and collation of data for analysis in multiple venues, including operational, financial, and quality. Metrics assessed included: operative cases, first case on time starts; reason for delay, and operating revenue.”

Results: “In 2006, 19,148 operations were performed (13,545 in the Main Operating Room (OR) area, and 5603, at satellite locations); first case on time starts were 12%; reasons for first case delay were not identifiable; and operating revenue was \$115.8 M overall, with \$78.1 M in the Main OR area. In 2010, cases increased to 25,856 (+35%); Main OR area increased to 13,986 (+3%); first case on time starts improved to 46%; operations outside the Main OR area increased to 11,870 (112%); case delays were ascribed to nurses 7%, anesthesiologists 22%, surgeons 33%, and other (patient, hospital) 38%. Five surgeons (7%) accounted for 29% of surgical delays and 4 anesthesiologists (8%) for 45% of

anesthesiology delays; operating revenue increased to \$177.3 M (+ 53%) overall, and in the Main OR area rose to \$101.5 M (+30%).”

[Foglia RP, Alder AC, Ruiz G. Improving Perioperative Performance: The Use of Operations Management and the Electronic Health Record. J Pediatr Surg 2013;48:95–8.]

Reference 73

Methods: “The authors analyzed adults undergoing common day case-eligible surgical procedures by using the American College of Surgeons’ National Surgical Quality Improvement Program database from 2005 to 2010. Common day case-eligible surgical procedures were identified as the most common outpatient surgical Current Procedural Terminology codes provided by Blue Cross Blue Shield of Michigan and Medicare publications. Study variables included anthropometric data and relevant medical comorbidities. The primary outcome was morbidity or mortality within 72h. Intraoperative complications included adverse cardiovascular events; postoperative complications included surgical, anesthetic, and medical adverse events.”

Results: “Of 244,397 surgeries studied, 232 (0.1%) experienced early perioperative morbidity or mortality. Seven independent risk factors were identified while controlling for surgical complexity: overweight body mass index, obese body mass index, chronic obstructive pulmonary disease, history of transient ischemic attack/stroke, hypertension, previous cardiac surgical intervention, and prolonged operative time.”

[Mathis MR, Naughton NN, Shanks AM, Freundlich RE, Pannucci CJ, Chu Y, Haus J, Morris M, Kheterpal S. Patient selection for day case-eligible surgery: identifying those at high risk for major complications. *Anesthesiology* 2013;119:1310–21.]

Reference 74

Methods: “Among the 311,940 OR cases in a 7-year time series from 1 hospital, there were 3962 cases for which (1) there had been previously at least 30 cases of the same combination of scheduled procedure(s), surgeon, and type of anesthetic and (2) the actual OR time exceeded the 0.9 quantile of case duration before the case started. A Bayesian statistical method was used to calculate the mean (expected) minutes remaining in the case at the 0.9 quantile. The estimate was compared with the actual minutes from the time of the start of closure until the patient exited the OR.”

Results: “The mean \pm standard error of the pairwise difference was 0.2 ± 0.4 minutes. The Bayesian estimate for the 0.9 quantile was exceeded by $10.2\% \pm 0.01\%$ of cases (i.e., very close to the desired 10.0% rate).”

[Tiware V, Dexter F, Rothman BS, Ehrenfeld JM, Epstein RH. Explanation for the Near-Constant Mean Time Remaining in Surgical Cases Exceeding Their Estimated Duration, Necessary for Appropriate Display on Electronic White Boards. *Anesth Analg* 2013;117:487–93.]

Reference 75

Methods: “Four tertiary care centers participating in the Multicenter Perioperative Outcomes Group used a consistent structured patient history and airway examination and airway outcome definition. DMV was defined as grade 3 or 4 mask ventilation, and DL was defined as grade 3 or 4 laryngoscopic view or four or more intubation attempts. The primary outcome was DMV combined with DL. Patients with the primary outcome were compared to those without the primary outcome to identify predictors of DMV combined with DL using a non-parsimonious logistic regression.”

Results: “Of 492,239 cases performed at four institutions among adult patients, 176,679 included a documented face mask ventilation and laryngoscopy attempt. Six hundred ninety-eight patients experienced the primary outcome, an overall incidence of 0.40%. One patient required an emergent cricothyrotomy, 177 were intubated using direct laryngoscopy, 284 using direct laryngoscopy with bougie introducer, 163 using videolaryngoscopy, and 73 using other techniques. Independent predictors of the primary outcome included age 46 yr or more, body mass index 30 or more, male sex, Mallampati III or IV, neck mass or radiation, limited thyromental distance, sleep apnea, presence of teeth, beard, thick neck, limited cervical spine mobility, and limited jaw protrusion (c-statistic 0.84 [95% CI, 0.82–0.87]).”

[Kheterpal S, Healy D, Aziz MF, Shanks AM, Freundlich RE, Linton F, Martin LD, Linton J, Epps JL, Fernandez-Bustamante A, Jameson LC, Tremper T, Tremper KK, Multicenter Perioperative Outcomes Group (MPOG) Perioperative Clinical Research Committee. Incidence, predictors, and outcome of difficult mask ventilation combined with difficult

laryngoscopy: a report from the multicenter perioperative outcomes group.
Anesthesiology 2013;119:1360–9.]

Reference 76

Review article of multi-center outcomes registries, focusing on the multi-center perioperative outcomes group (MPOG) based in the United States.

[Kheterpal S. Clinical research using an information system: the multicenter perioperative outcomes group. Anesthesiol Clin 2011;29:377–88.]

Reference 77

Review article describing the Anesthesia Quality Institute, a national outcomes reporting group based in the United States.

[Dutton RP, Dukatz A. Quality improvement using automated data sources: the anesthesia quality institute. Anesthesiology Clinics 2011;29:439–54.]

Reference 78

Methods: “Children ≤ 18 years old who had an anesthetic between January 1, 2003, and August 30, 2008, at the Royal Children’s Hospital, Melbourne, Australia, were included for this study. Data were analyzed by merging a database for every anesthetic performed with an accurate electronic record of mortality of children who had ever been a Royal Children’s Hospital patient. Cases of children dying within 30 days and 24 hours of an anesthetic

were identified and the patient history and anesthetic record examined. Anesthesia-related death was defined as those cases whereby a panel of 3 senior anesthesiologists all agreed that anesthesia or factors under the control of the anesthesiologist more likely than not influenced the timing of death.”

Results: “During this 68-month period, 101,885 anesthetics were administered to 56,263 children. The overall 24-hour mortality from any cause after anesthesia was 13.4 per 10,000 anesthetics delivered and 30-day mortality was 34.5 per 10,000 anesthetics delivered. The incidence of death was highest in children ≤ 30 days old. Patients undergoing cardiac surgery had a higher incidence of 24-hour and 30-day mortality than did those undergoing noncardiac surgery. From 101,885 anesthetics there were 10 anesthesia-related deaths. The incidence of anesthesia-related death was 1 in 10,188 or 0.98 cases per 10,000 anesthetics performed (95% confidence interval, 0.5 to 1.8). In all 10 cases, preexisting medical conditions were identified as being a significant factor in the patient’s death. Five of these cases (50%) involved children with pulmonary hypertension.”

[van der Griend BF, Lister NA, McKenzie IM, Martin N, Ragg PG, Sheppard SJ, Davidson AJ. Postoperative Mortality in Children After 101,885 Anesthetics at a Tertiary Pediatric Hospital. *Anesth Analg* 2011;112:1440–7.]

Reference 79

Methods: “We developed 2 Web-based systems: an ACGME case-log visualization tool, and Residents Helping in Navigating OR Scheduling (Rhinos), an interactive system that solicits OR assignment requests from residents and creates resident profiles. Resident profiles are snapshots of the cases and procedures each resident has done and were derived from AIMS records and ACGME case logs. A Rhinos pilot was performed for 6 weeks on 2 clinical services. One hundred sixty-five requests were entered and used in OR assignment decisions by a single attending anesthesiologist. Each request consisted of a rank ordered list of up to 3 ORs. Residents had access to detailed information about these cases including surgeon and patient name, age, procedure type, and admission status. Success rates at matching resident requests were determined by comparing requests with AIMS records.”

Results: “Of the 165 requests, 87 first-choice matches (52.7%), 27 second-choice matches (16.4%), and 8 third-choice matches (4.8%) were made. Forty-three requests were unmatched (26.1%). Thirty-nine first-choice requests overlapped (23.6%). Full implementation followed on 8 clinical services for 8 weeks. Seven hundred fifty-four requests were reviewed by 15 attending anesthesiologists, with 339 first-choice matches (45.0%), 122 second-choice matches (16.2%), 55 third-choice matches (7.3%), and 238 unmatched (31.5%). There were 279 overlapping first-choice requests (37.0%). The overall combined match success rate was 69.4%. Separately, we developed an ACGME case-log visualization tool that allows individual resident experiences to be compared against case minimum(Kheterpal et al., 2013)s as well as resident peer groups.”

[Wanderer JP, Charnin J, Driscoll WD, Bailin MT, Baker K. Decision Support Using Anesthesia Information Management System Records and Accreditation Council for Graduate Medical Education Case Logs for Resident Operating Room Assignments. *Anesth Analg* 2013;117:494–9.]

Reference 80

Methods: “We extracted 3 years of electronic PACU data” (January 1, 2010 to December 31, 2012) “from a tertiary care medical center. At this hospital, PACU admissions were limited by neither inadequate PACU staffing nor insufficient PACU beds. We developed a model decision support system that simulated alerts to the PACU charge nurse. PACU census levels were reconstructed from the data at a 1-minute level of resolution and used to evaluate if subsequent delays would have been prevented by such alerts. The model assumed there was always a patient ready for discharge and an available hospital bed. The time from each alert until the maximum census was exceeded (“alert lead time”) was determined. Alerts were judged to have utility if the alert lead time fell between various intervals from 15 or 30 minutes to 60, 75, or 90 minutes after triggering. In addition, utility for reducing over utilized OR time was assessed using the model by determining if 2 patients arrived from 5 to 15 minutes of each other when the PACU census was at 1 patient less than the maximum census.”

Results: “At most, 23% of alerts arrived 30 to 60 minutes prior to the admission that resulted in the PACU exceeding the specified maximum capacity. When the notification window was extended to 15 to 90 minutes, the maximum utility was <50%. At most, 45% of alerts

potentially would have resulted in reassigning the last available PACU slot to 1 OR versus another within 15 minutes of the original assignment.”

[Ehrenfeld JM, Dexter F, Rothman BS, Minton BS, Johnson D, Sandberg WS, Epstein RH. Lack of Utility of a Decision Support System to Mitigate Delays in Admission from the Operating Room to the Postanesthesia Care Unit. *Anesth Analg* 2013;117:1444–52.]

Reference 81

Methods: “Eighty-one pairs of handwritten and computer-generated neurosurgical anesthesia records were retrospectively compared by using a matched sample design. Systolic arterial pressure (SAP), diastolic arterial pressure (DAP), and heart rate (HR) data for each 5-min interval were transcribed from handwritten records.”

Results: “In computerized records, the median of up to 20 values was calculated for SAP, DAP, and HR for each consecutive 5-min epoch. The peak, trough, standard deviation, median, and absolute value of the fractional rate of change between adjacent 5-min epochs were calculated for each case. Pairwise comparisons were performed by using Wilcoxon tests. For SAP, DAP, and HR, the handwritten record peak, standard deviation, and fractional rate of change were less than, and the trough and median were larger than, those in corresponding computer records (all with $P < 0.05$, except DAP median and HR peak).”

[Reich DL, Wood RK, Mattar R, Krol M, Adams DC, Hossain S, Bodian CA. Arterial blood pressure and heart rate discrepancies between handwritten and computerized anesthesia records. *Anesth Analg* 2000;91:612–6.]

Reference 82

Methods: “During the years 1997 and 1998, all relevant data from anesthetic procedures were recorded online using the automated anesthesia information system NarkoData. The data from 8,078 general anesthesia procedures using endotracheal intubation were exported via ‘structured query language’ (SQL) from the AIMS database into a statistics program after excluding children (age < 14), patients who received atropine during induction and procedures with use of extracorporeal circulation. The effects of drug administration on systolic, diastolic and mean arterial blood pressure (SBP, DBP, MBP), heart rate (HR) and arterial oxygen saturation (SpO₂) were analyzed prior to induction and at 5, 10 and 15 minutes following bolus administration of the hypnotic agent. The data were classified into three groups based on the induction agent used: thiopental, etomidate or propofol and further separated into two groups based on ASA status ($ASA \leq II$ and $ASA > II$). The mean and standard deviations were calculated for each parameter at each point in time. Statistical comparisons were performed to determine whether the results for each time point differed from the previous time point.”

Results: “There was a significant decrease in blood pressure (MAP, SBP, DBP) after bolus administration of all three hypnotics in all of the 8,078 procedures analyzed. The decrease was greater in patients of ASA class > II than in those of ASA class $\leq II$. Propofol caused

the greatest drop in blood pressure whereas etomidate caused the least. During the observation period the HR also fell in each group, except for thiopental where an initial rise of the HR could be observed. An initial rise of SpO₂ was recorded in each group with no differences observed between the individual hypnotics.”

[Benson M, Junger A, Fuchs C, Quinzio L, Böttger S, Hempelmann G. Use of an anesthesia information management system (AIMS) to evaluate the physiologic effects of hypnotic agents used to induce anesthesia. J Clin Monit Comput 2000;16:183–90.]

Reference 83

Methods: “... to identify factors that are associated with hypotension after the induction of spinal anesthesia (SpA) by using an anesthesia information management system. Hypotension was defined as a decrease of mean arterial blood pressure of more than 30% within a 10-min interval, and relevance was defined as a therapeutic intervention with fluids or pressors within 20 min.”

Results: “From January 1, 1997, to August 5, 2000, data sets from 3315 patients receiving SpA were recorded on-line by using the automatic anesthesia record keeping system NarkoData. Hypotension meeting the predefined criteria occurred in 166 (5.4%) patients. Twenty-nine patient-, surgery-, and anesthesia-related variables were studied by using univariate analysis for a possible association with the occurrence of hypotension after SpA. Logistic regression with a forward stepwise algorithm was performed to identify independent variables ($P < 0.05$). The discriminative power of the logistic regression

model was checked with a receiver operating characteristic curve. Calibration was tested with the Hosmer-Lemeshow goodness-of-fit test. The univariate analysis identified the following variables to be associated with hypotension after SpA: age, weight, height, body mass index, amount of plain bupivacaine 0.5% used for SpA, amount of colloid infusion before puncture, chronic alcohol consumption, ASA physical status, history of hypertension, urgency of surgery, surgical department, sensory block height of anesthesia, and frequency of puncture. In the multivariate analysis, independent factors for relevant hypotension after SpA consisted of three patient-related variables ('chronic alcohol consumption,' odds ratio [OR] = 3.05; 'history of hypertension,' OR = 2.21; and the metric variable 'body mass index,' OR = 1.08) and two anesthesia-related variables ('sensory block height,' OR = 2.32; and 'urgency of surgery,' OR = 2.84). The area of 0.68 (95% confidence interval, 0.63– 0.72) below the receiver operating characteristic curve was significantly greater than 0.5 ($P < 0.01$). The goodness-of-fit test showed a good calibration of the model ($H=4.3$, $df=7$, $P=0.7$; $C=7.3$, $df=8$, $P=0.51$)."

[Hartmann B, Junger A, Klasen J, Benson M, Jost A, Banzhaf A, Hempelmann G. The incidence and risk factors for hypotension after spinal anesthesia induction: an analysis with automated data collection. *Anesth Analg* 2002;94:1521–9.]

Reference 84

Methods: "A retrospective observational analysis was performed on consecutive patients undergoing non-cardiac surgical procedures at a university-affiliated hospital prior to and after the institution of a computerized reminder system. The reminder system presented

the clinician with a series of on-screen dialog boxes prior to the redose time for the specific prophylactic antibiotic administered preoperatively. Antibiotic redosing was defined as appropriate if it occurred within 30 min prior to or after the due time, calculated as twice the half-life of the specific antibiotic. Patients were excluded if the case duration was less than twice the half-life of the administered prophylactic antibiotic, or if no prophylactic antibiotic was given.”

Results: “A total of 287 cases were included in the study (148 pre-intervention, 139 post-intervention). Patient age, case length, and American Society of Anesthesiologists (ASA) score stratification did not differ between the groups. Use of the reminder system resulted in an increase in the appropriate redosing of antibiotics from 20% prior to institution of the reminder to 58% after institution ($p < 0.001$).”

[St Jacques P, Sanders N, Patel N, Talbot TR, Deshpande JK, Higgins M. Improving timely surgical antibiotic prophylaxis redosing administration using computerized record prompts. *Surg Infect (Larchmt)* 2005;6:215–21.]

Reference 85

Methods: “[The University of Michigan] anesthesia department decided to assume the responsibility for timing and administration of antibiotic prophylaxis and we initiated a multitiered approach to remind the anesthesiologist to administer the prophylactic antibiotics. We used our anesthesia clinical information system to implement practice guidelines for timely antibiotic administration and to generate reports from the database to

provide specific feedback to individual care providers with the goal of ensuring that patients receive antibiotic prophylaxis within 1 h of incision.”

Results: “Before the initiation of this project, 69% of eligible patients received antibiotics within 60 min of the incision. After the program began, there was a steady increase in compliance to 92% 1 yr later. Provider-specific feedback increases compliance with practice guidelines related to timely administration of prophylactic antibiotics.”

[O Reilly M, Talsma A, VanRiper S, Kheterpal S, Burney R. An Anesthesia Information System Designed to Provide Physician-Specific Feedback Improves Timely Administration of Prophylactic Antibiotics. *Anesth Analg* 2006;103:908–12.]

Reference 86

Methods: “We used an anesthesia information management system (AIMS) to devise a score for predicting antiemetic rescue treatment as an indicator for postoperative nausea and vomiting (PONV) in the postanesthesia care unit (PACU). Furthermore, we wanted to investigate whether data collected with an AIMS are suitable for comparable clinical investigations.”

Results: “Over a 3-yr period (January 1, 1997, to December 31, 1999), data sets of 27,626 patients who were admitted postoperatively to the PACU were recorded online by using the automated anesthesia record keeping system NarkoData[®] (IMESO GmbH, Hüttenberg, Germany). Ten patient-related, 5 operative, 15 anesthesia-related, and 4

postoperative variables were studied by using forward stepwise logistic regression. Not only can the probability of having PONV in the PACU be estimated from the 3 previously described patient-related (female gender, odds ratio [OR] = 2.45; smoker, OR = 0.53; and age, OR = 0.995) and one operative variables (duration of surgery, OR = 1.005), but 3 anesthesia-related variables (intraoperative use of opioids, OR = 4.18; use of N₂O, OR = 2.24; and IV anesthesia with propofol, OR = 0.40) are predictive. In implementing an equation for risk calculation into the AIMS, the individual risk of PONV can be calculated automatically.”

[Junger A, Hartmann B, Benson M, Schindler E, Dietrich G, Jost A, Béye-Basse A, Hempelmann G. The use of an anesthesia information management system for prediction of antiemetic rescue treatment at the postanesthesia care unit. *Anesth Analg* 2001;92:1203–9.]

Reference 87

Methods: “The influence of methods for record keeping on the documentation of vital signs was assessed for the Anesthesia Information Management System (AIMS) NarkoData. We compared manually entered blood pressure readings with automatically collected data... The data sets were split into two groups, “manual” and “automatic”. We evaluated the effect of automatic data collection on the incidence of corrected data, data validity and data variation.” Study evaluated anesthetics occurring between January 1, 1997 and December 31, 1998.

Results: “Blood pressure readings of 37,726 data sets were analyzed. We could assess that the method of documentation did influence the data quality. It could not be assessed whether the incorrectness of data during automatic data gathering was caused by artefacts of by the anesthesiologist.” There was a higher frequency of correction of data values in the automatic data collection group compared to the manual collection group.

[Benson M, Junger A, Quinzio L, Fuchs C, Michel A, Sciuk G, Marquardt K, Dudeck J, Hempelmann G. Influence of the method of data collection on the documentation of blood-pressure readings with an Anesthesia Information Management System (AIMS). *Methods Inf Med* 2001;40:190–5.]

Reference 88

Methods: “The goal of this study was to determine the effect of several interventions on the voluntary completion rate of QA documentation. We hypothesized that optimizing workflow integration would increase both QA completion rates and complication capture rates and promote long-term successful changes in reporting behavior. Whereas electronic scanning of anesthetic records may automate some aspects of QA, there will continue to be a need for anesthesiologists to enter QA documentation that cannot be automated.”

Results: “Starting from a baseline completion rate of 48%, we instituted a series of interventions. We successively increased the completion rate to 55% (education), 68% (workflow integration), and 78% (individual feedback). Each intervention increased the completion rate from the previous intervention ($P < 0.001$). The increased completion rate suggests

better overall data capture, because the percentage of ‘no complication’ entries decreased. After the study period, the completion rate increased to 94%, principally because of the improved workflow integration.”

[Vigoda MM, Gencorelli F, Lubarsky DA. Changing Medical Group Behaviors: Increasing the Rate of Documentation of Quality Assurance Events Using an Anesthesia Information System. *Anesthesia & Analgesia* 2006;103:390–5.]

Reference 89

Methods: “We first developed a statistical strategy to predict whether moving the case would decrease overtime labor costs for first shift nurses and anesthesia providers. The strategy was based on using historical case duration data stored in a surgical services information system. Second, we estimated the incremental overtime labor costs achieved if our strategy was used for moving cases versus movement of cases by an OR manager who knew in advance exactly how long each case would last.”

Results:” We found that if our strategy was used to decide whether to move cases, then depending on parameter values, only 2.0 to 4.3 more min of overtime would be required per case than if the OR manager had perfect retrospective knowledge of case durations. The use of other information technologies to assist in the decision of whether to move a case, such as real-time patient tracking information systems, closed-circuit cameras, or graphical airport-style displays can, on average, reduce overtime by no more than only 2 to 4 min per case that can be moved.”

“The overtime labor costs in units of hours equaled the sum of the hours of overtime and the penalty (in units of hours) for moving the case. If our strategy was used to decide whether to move cases, then depending on parameter values the overtime labor costs would be 0.03 to 0.07 h (2.0 to 4.3 min) higher than if the OR manager had perfect retrospective knowledge of case durations. To put this result into perspective, the mean \pm SD of case durations equaled 2.23 ± 1.45 h. The overtime labor costs in units of dollars would equal the cost per hour of overtime work in the surgical suite multiplied by these 0.03 to 0.07 h of overtime.”

[Dexter F. A strategy to decide whether to move the last case of the day in an operating room to another empty operating room to decrease overtime labor costs. *Anesth Analg* 2000;91:925–8.]

Reference 90

Methods: “The authors analyzed 1 yr of operating room information system data from two academic, tertiary hospitals and Monte-Carlo simulations of a 15– operating room hospital surgical suite.”

Results: “Confidence interval widths for the mean turnover times at the hospitals were negligible when compared with the variation in sample mean turnover times among 31 hospitals. The authors developed a statistical method to estimate the proportion of all turnovers that were prolonged (> 15 min beyond mean) and that occurred during specified hours of the day. Confidence intervals for the proportions corrected for the effect of multiple comparisons.

Statistical assumptions were satisfied at the two studied hospitals. The confidence intervals achieved family-wise type I error rates accurate to within 0.5% when applied to between five and nineteen 4-week periods of data. The diurnal pattern in the proportions of all turnovers that were prolonged provided different, more managerially relevant information than the time course throughout the day in the percentage of turnovers at each hour that were prolonged.”

[Dexter F, Epstein RH, Marcon E, Ledolter J. Estimating the incidence of prolonged turnover times and delays by time of day. *Anesthesiology* 2005;102:1242–8, discussion 6A.]

Reference 91

Methods: “In this study, we tested to what extent data extracted from the AIMS could be suitable for the supervision and time-management of operating rooms. From 1995 to 1999, all relevant data from 103,264 anesthetic procedures were routinely recorded online with the automatic anesthesia record keeping system NarkoData. The program is designed to record patient related time data, such as the beginning of anesthesia or surgical procedure, on a graphical anesthesia record sheet. The total number minutes of surgery and anesthesia for each surgical subspecialty per hour/day and day of the year was calculated for each of the more than 40 ORs, amounting to a total of 112 workstations.”

Results: “It was possible to analyze the usage and the utilization of ORs at the hospital for each day of the year since 1997. In addition, annual and monthly evaluations are made available. It is possible to scrutinize data of OR usage from different points of view:

queries on the usage of an individual OR, the usage of ORs on certain days or the usage of ORs by a certain surgical subspecialty may be formulated. These data has been used repeatedly in our hospital for decision making in OR management and planning.”

[Junger A, Benson M, Quinzio L, Michel A, Sciuk G, Brammen D, Marquardt K, Hempelmann G. An Anesthesia Information Management System (AIMS) as a tool for controlling resource management of operating rooms. *Methods Inf Med* 2002;41:81–5.]

Reference 92

Methods: “Median occupation times were determined from a retrospective analysis of 12 consecutive months of operating activity (966 patients). These data were prospectively used in surgical planning, with a daily occupation limit set at 10 hours. After four months collecting data, daily recorded (ROT) and predicted (POT) occupation times were compared. The surgical activity during that test period (group A) was compared to the activity of the same period in the previous year (group B) and the evolution of the waiting lists for surgery were analysed for each of the operators.”

Results: “At the end of the four-month observation period, 317 surgical cases spread over 105 operating days were recorded. The correlation between ROT and POT was strong ($r = 0.911$, $p < 0.001$). The relative error in this prediction was 13 ± 11 min. In comparison with group B, group A was characterized by a significant reduction in occurrence ($p = 0.015$) and duration ($p = 0.007$) of time limit overruns and in variability of daily

occupation time ($p < 0.001$). The waiting list was reduced for all operators at the end of the test period.”

[Broka SM, Jamart J, Louagie YA. Scheduling of elective surgical cases within allocated block-times: can the future be drawn from the experience of the past? *Acta Chir Belg* 2003;103:90–4.]

Reference 93

Methods: “At hospitals without detailed managerial accounting data but with overall longer than average diagnosis-related groups (DRG)-adjusted lengths of stays (LOS), some administrators do not aggressively hire the nurses needed to maintain surgical hospital capacity. The consequence of this (long-term) decision is that day-of-surgery admit cases are delayed or cancelled from a lack of beds. The anesthesiologists suffer financially. In this paper, we show how publicly released national LOS data can be applied specifically to these cases. We applied the method to 1 year of data from two academic hospitals. Each case’s LOS was compared to the United States national average LOS for cases with the same DRG.”

Results: “A total of 8,050 and 10,099 hospitalizations, respectively. Among all surgical admissions, mean LOS was 2.5 days longer than the national average for Hospital #1 (95% confidence interval [CI], 2.1 to 2.8) and 3.1 days longer for Hospital #2 (95% CI, 2.8 to 3.4). Among patients undergoing elective, scheduled surgery with day of surgery

admission, mean LOS was 0.7 days less than average for Hospital #1 (0.6 to 0.9) and 1.2 days less than average for Hospital #2 (1.1 to 1.4).”

[Dexter F, Lubarsky DA. Using length of stay data from a hospital to evaluate whether limiting elective surgery at the hospital is an inappropriate decision. J Clin Anesth 2004;16:421–5.]

Reference 94

Methods: “The goal of this project was to determine whether a standardized surgical time, generated by the Operating Room Information System (ORIS), could be used as an accurate predictor of actual surgical time. Utilizing retrospective, quantitative data from the ORIS database, frequency distributions by surgical speciality, were completed. Chi-square analysis was applied to determine the significance of the frequency distributions.” The ORIS time is calculated by averaging the time taken for the last ten identical procedures and eliminating the highest and lowest times.

Results: “7,028 surgeries performed at Peter Lougheed Center of the Calgary General Hospital” were evaluated between February 28, 1999 and September 1, 1999. “The study outcome indicates that ORIS computer generated procedure times were not an accurate predictor of actual surgical time. Further follow-up will be required to determine if alternate scheduling methodologies would lead to higher accuracy rates.”

[Sorge M. Computerized O.R. scheduling: is it an accurate predictor of surgical time? Can Oper Room Nurs J 2001;19:7–18.]

Reference 95

Case study of an implementation of a perioperative information system in a multi-hospital health system.

[Ames L. An enterprise answer. An integrated delivery network's perioperative information system paid for itself by maximizing OR use, cutting costs, reducing waste and increasing billings. *Health Manag Technol* 2004;25:44–47–8.]

Reference 96

Methods: “To select spinal and epidural anesthetics that did not also involve general anesthesia, 57,240 automated anesthesia records were scanned. Obstetrical patients and patients younger than age 12 yr were excluded. The electronic records selected were then scanned for episodes of moderate (heart rate < 50 and > 40 beats/min) or severe (heart rate < 40 beats/min) bradycardia.”

Results: “A total of 6,663 cases (11.6%) met the inclusion criteria. Among the 677 cases of bradycardia (10.2%) were 46 cases of severe bradycardia (0.7%). In the final multivariate logistic regression analysis, baseline heart rate less than 60 beats/min ($P < 0.0001$) and male gender ($P < 0.05$) contributed significantly to risk for a severe bradycardia episode (odds ratio [OR], 14.1 and 95% confidence interval [CI], 6.9–28.0, and OR, 2.1 and 95% CI, 1–4.3, respectively). For the 631 episodes of moderate bradycardia (9.5%), the final multivariate model included baseline heart rate less than 60 beats/min (OR, 16.2; 95% CI,

12.4–22.0), age younger than 37 yr (OR, 1.4; 95% CI, 1.1–1.7), male gender (OR, 1.4; 95% CI, 1.2–1.8), nonemergency status (OR, 1.7; 95% CI, 1.2–2.4), β -blockers (OR, 1.6; 95% CI, 1.1–2.3), and case duration (OR, 2.0; 95% CI, 1.6–2.4) as significant risk factors. Time of occurrence of a bradycardia event was distributed widely across the entire duration of a case.”

[Lesser JB, Sanborn KV, Valskys R, Kuroda M. Severe bradycardia during spinal and epidural anesthesia recorded by an anesthesia information management system. *Anesthesiology* 2003;99:859–66.]

Reference 97

Methods: “Three types of complications were predefined: minor, severe and those specific for regional anaesthesia. A total of 1006 anaesthetic charts, including general, regional and intravenous anaesthesia, were randomly selected and retrospectively screened by an external assessor. The retrospective assessment of complications was compared to the recordings in the data management system for operative procedures (DMS) as a part of routine quality assurance. Cohen’s kappa statistics was used to indicate agreement between two raters.”

Results: “Both methods identified complications in 115 procedures (11.4%). The methods, however, did not identify complications in same procedures. There was a fairly close agreement ($P < 0.001$) between the methods in detecting all (Cohen’s kappa 0.72), minor (0.67) and severe (0.66) complications and those specific for regional anaesthesia (0.78).

Fifty-eight complications were detected either by retrospective assessment or routine reporting, i.e. the two raters disagreed in 58 complications. Thirteen severe complications recorded in the DMS could not be retrospectively identified. The agreement did not depend on ASA class, the urgency or the length of procedures or on the type of anaesthesia.”

[Niskanen M, Tuovinen T, Purhonen S, Vauhkonen S, Hendolin H. Quality assurance in anaesthetic practice: comparison between two methods in detecting complications. *Acta Anaesthesiol Scand* 2002;46:896–901.]

Reference 98

Methods: “In 1998, data of all anesthetic procedures, including the data set for quality assurance of the German Society of Anaesthesiology and Intensive Care Medicine (DGAI), was recorded online with the Anesthesia Information Management System (AIMS) NarkoData4Ö (Imeso GmbH). SQL (Structured Query Language) queries based on medical data were defined for the automatic detection of common adverse events. The definition of the SQL statements had to be in accordance with the definition of the DGAI for perioperative adverse events: A potentially harmful change of parameters led to therapeutic interventions by an anesthesiologist.”

Results: “During 16,019 surgical procedures, anesthesiologists recorded 911 (5.7%) adverse events manually, whereas 2966 (18.7%) events from the same database were detected automatically. With the exception of hypoxemia, the incidence of automatically detected

events was considerably higher than that of manually recorded events. Fourteen and a half percent (435) of all automatically detected events were recorded manually.”

[Benson M, Junger A, Fuchs C, Quinzio L, Böttger S, Jost A, Uphus D, Hempelmann G. Using an anesthesia information management system to prove a deficit in voluntary reporting of adverse events in a quality assurance program. J Clin Monit Comput 2000;16:211–7.]

Reference 99

Methods: “In this study, an Anesthesia Information Management System (AIMS) is used for the comparison of manually recorded adverse events with automatically detected events from anesthesiological procedures. In 1998, data from all anesthesia procedures, including the data set for quality assurance defined by the German Society of Anesthesiology and Intensive Care (DGIA), were recorded online with the documentation software NarkoData 4 (IMESO GmbH, Hüttenberg, Germany) followed by storage into a relational database (Oracle Corporation). The occurrence of manually recorded adverse events, as defined by the DGAI, is compared with automatically detected events. Automated detection was done with SQL-statements. The following adverse events were selected: hypotension, hypertension, bradycardia, tachycardia and hypovolemia.”

Results: “Data obtained from 16,019 electronic anesthesia records show that in 911 patients (5.7%), one of the selected adverse events was documented manually whereas in 2,996 patients (18.7%) an adverse event was detected automatically. The incidence of automatically detected events is obviously higher compared to manually recorded events.

With the help of an AIMS, automatic detection proved significant deficiencies in the manual documentation of adverse events.”

[Benson M, Junger A, Michel A, Sciuk G, Quinzio L, Marquardt K, Hempelmann G.

Comparison of manual and automated documentation of adverse events with an Anesthesia Information Management System (AIMS). *Stud Health Technol Inform* 2000;77:925–9.]

Reference 100

Methods: “The Australian Incident Monitoring Study (AIMS) database of the Australian Patient Safety Foundation (APSF) was reviewed from its inception in April 1987 to October 1997.”

Results: “A total of 5600 AIMS reports were lodged in that period. Reports in which fatigue was listed as a Factor Contributing to Incident were examined. This occurred in 152 reports, or 2.7% of all reports. Confidence interval analysis suggested that fatigue was associated with various concurrently reported factors. These included pharmacological incidents (especially syringe swaps) and time of day. Other factors significantly associated with fatigue reports were haste, distraction, inattention and failure to check equipment. Relieving anaesthetists and healthy patients were reported more often as factors minimizing incidents. Anaesthetists reporting fatigue more often reported incidents during induction. These data suggest that fatigue alleviation strategies and equipment checking routines, improved workplace design (including drug ampoule and

syringe labeling protocols) and regulation of working hours will facilitate minimization of fatigue-related incidents.”

[Morris GP, Morris RW. Anaesthesia and fatigue: an analysis of the first 10 years of the Australian Incident Monitoring Study 1987-1997. *Anaesth Intensive Care* 2000;28:300–4.]

Reference 101

Methods: “The AIMS database contains incidents reported between 1998 and December 2001.

The reporting form contains a freehand section for a narrative describing the event as well as sections requesting patients’ demographics and outcomes. The database ... was searched for pharmaceutical incidents as coded by the reporting anaesthetists. A randomly selected sample of 100 reports was initially studied by all the authors and used to develop a coding system for subsequent analysis. This coding system was then tested on a further 100 incidents by individual reviewers and the results were then compared between the four reviewers to ensure consistency.”

Results: “Eight hundred and ninety-six incidents relating to drug error were reported to the Australian Incident Monitoring Study. Syringe and drug preparation errors accounted for 452 (50.4%) incidents, including 169 (18.9%) involving syringe swaps where the drug was correctly labeled but given in error, and 187 (20.8%) due to selection of the wrong ampoule or drug labeling errors. The drugs most commonly involved were neuromuscular blocking agents, followed by opioids. Equipment misuse or malfunction accounted for a

further 234 (26.1%) incidents; incorrect route of administration 126 (14.1%) incidents; and communication error 35 (3.9%) incidents. The outcomes of these events included minor morbidity in 105 (11.7%), major morbidity in 42 (4.7%), death in three (0.3%) and awareness under anaesthesia in 40 (4.4%) incidents. Contributing factors included inattention, haste, drug labeling error, communication failure and fatigue. Factors minimizing the events were prior experience and training, rechecking equipment and monitors capable of detecting the incident.”

[Abeysekera A, Bergman IJ, Kluger MT, Short TG. Drug error in anaesthetic practice: a review of 896 reports from the Australian Incident Monitoring Study database. *Anaesthesia* 2005;60:220–7.]

Reference 102

Review article describing the National Care Record, a national electronic health record in the United Kingdom.

Abstract: “The National Care Record for England is planned to be delivered as part of the National Programme for Information Technology (NPfIT) by the National Health Service Connecting for Health. It will be made up from a National Summary Care Record, Local Detailed Care Records and from images in Picture Archiving and Communication Systems. Full benefits for clinical care will only come when there is true integration of the clinical records systems which enables rapid clinical decision support, a consistent user interface, single entry of data items and analysis of information across the full spectrum of

clinical care. Currently there are few hospitals with fully electronic anaesthetic or critical care systems, and these are only partly linked to the hospital systems. This limits their benefit to patient care and health care staff. As NPfIT is being mandated for all hospitals in England it is essential to consider now how the next generation of anaesthetic and intensive care systems will integrate with it.”

[Tackley R. Integrating anaesthesia and intensive care into the National Care Record. British Journal of Anaesthesia 2006;97:69–76.]

Reference 103

Special article describing a framework for a coherent approach to an integrated incident reporting system. “There is currently an opportunity to ‘get it right’ by international cooperation via the World Health Organization to develop an integrated framework incorporating systems that can accommodate information from all sources, manage and monitor things that go wrong, and allow the worldwide sharing of information and the dissemination of tools for the implementation of strategies which have been shown to work.”

[Runciman WB, Williamson JAH, Deakin A, Benveniste KA, Bannon K, Hibbert PD. An integrated framework for safety, quality and risk management: an information and incident management system based on a universal patient safety classification. Qual Saf Health Care 2006;15:i82–i90.]

Reference 104

Methods: “A regionally” (Newcastle, New South Wales, Australia) “organized system aiming to facilitate reporting and retrieval of information about potentially recurring anaesthetic-related problems has been established, covering 20 separate hospitals. Components of the system include a reporting package to facilitate use by anaesthetists in busy clinical practice; centralized clerical support; supervision by anaesthetists; reports and laminated cards supplied to the patient; and a permanently accessible database. A new classification system for difficulties in airway management has been developed as part of the system.”

Results: “After initial establishment, the system has been utilized by a broad cross-section of anaesthetists in the region. The first 350 reports are described. The reporting rate is approximately 0.3% of all anaesthetics given in the region. We believe the success of this system has been primarily due to features aiming to facilitate reporting, ‘local’ ownership and supervision by clinical anaesthetists.”

[Kerridge RK, Crittenden MB, Vutukuri VL. A multiple-hospital anaesthetic problem register: establishment of a regionally organized system for facilitated reporting of potentially recurring anaesthetic-related problems. *Anaesth Intensive Care* 2001;29:106–12.]

Reference 105

Methods: “The German Society of Anaesthesiology and Intensive Care Medicine evaluates voluntary, standardized, everyday, perioperative anaesthesia outcome measures. A standard minimal data set is collected for national benchmarking. This article reviews the

implementation of a data acquisition system in one academic centre that has participated in this long-term nationwide project since its initiation in 1992.”

Results: “The population studied comprised 96,107 patients up to 1997. The overall incidence of anaesthesia-related incidents, events and complications (IEC) was 22%. Results are presented and discussed for 63 different IEC, seven functional system categories and five severity grades. The proposed methodology, using computer-readable records, was suitable for comprehensive and detailed outcome documentation. However, an extensive data validation system was necessary. IEC reporting results were largely dependent on the documentation culture. The future of outcome tracking in routine anaesthesia may lie in multi-centre comparisons with multi-variate-adjusted risk and comorbidity data from each provider’s integrated information system.”

[Bothner U, Georgieff M, Schwilk B. Building a large-scale perioperative anaesthesia outcome-tracking database: methodology, implementation, and experiences from one provider within the German quality project. *Br J Anaesth* 2000;85:271–80.]

Reference 106

Methods: “This report utilized data from the Australian Incident Monitoring Study (AIMS-ICU) national database to identify common problems and contributing factors associated with the use and maintenance of arterial lines.”

Results: “A review of narratives, keywords and contributing factors yielded 251 reports outlining 376 incidents. Of these, 15% describing line insertion problems, 66% line use and maintenance problems and 19% patient injuries. Inadequate line securing, accidental line dislodgement, incorrect set-up, distal ischaemia and infection featured prominently. As a result of the incident, 49% of patients involved suffered no ill effect, 28% minor physiological complications and 15% suffered major adverse effects. Multiple contributing factors were selected from each report, with lack of knowledge, rule-based errors, high unit activity, and lack of support staff or supervision selected most frequently. This study highlights the need to employ meticulous insertion technique, line set-up, securing, frequent line assessment and the early removal of lines no longer essential to patient care. Support and education of staff as well as the development of protocols are important for the safe use of arterial lines.”

[Durie M, Beckmann U, Gillies DM. Incidents relating to arterial cannulation as identified in 7,525 reports submitted to the Australian incident monitoring study (AIMS-ICU). *Anaesthesia and Intensive Care* 2002;30:60–5.]

Reference 107

Methods: “Of the first 6271 incidents reported to AIMS, those reports which noted ‘pre-operative assessment inadequate/incorrect’ or ‘pre-operative patient preparation inadequate/incorrect’ were extracted. Each form was reviewed separately by three specialist anaesthetists and relevant information was entered onto a Microsoft Excel spreadsheet (Microsoft Corporation, Seattle, USA). Data were entered as originally recorded on the

individual AIMS reports. The following data fields were analysed: nature of surgery, surgical category, whether seen by an anaesthetist pre-operatively, whether seen by the same anaesthetist pre-operatively, American Society of Anesthesiologists (ASA) status, outcome, whether the incident was preventable, and suggested corrective strategies. Categories were developed to group common problems leading to adverse events. In some fields (e.g. suggested corrective strategies) more than one answer was recorded.”

Results: “The Australian Incident Monitoring Study database was examined for incidents involving inadequate pre-operative patient preparation and/or evaluation. Of 6271 reports, 727 had appropriate keywords, of which 197 (3.1%) were used for subsequent analysis. All surgical categories were represented. In 10% of reports the patient was not reviewed pre-operatively by an anaesthetist, whilst in 23% the anaesthetist involved in the operating theatre had not performed the pre-operative assessment. Death followed in seven cases, major morbidity in 23 cases, admission to a high-dependency unit or intensive care unit in 17 cases, and surgery was cancelled in nine cases. Poor airway assessment, communication problems and inadequate evaluation were the most common contributing factors. Respondents indicated that the incident was preventable in 57% of cases.”

[Kluger MT, Tham EJ, Coleman NA, Runciman WB, Bullock MF. Inadequate pre-operative evaluation and preparation: a review of 197 reports from the Australian incident monitoring study. *Anaesthesia* 2000;55:1173–8.]

Reference 108

Methods: “The AIMS project is a voluntary, self-reporting audit of actual or potential incidents that occur during anaesthesia [12]. Incidents are reported on a standard form, using a combination of tick boxes that relate to patients’ demographics, contributing and alleviating factors, and suggested corrective strategies along with outcome of the incident. In addition, respondents complete a free narrative relating to the incident. The reports are coded from the key words and free text, and added to the database. The ongoing project has been approved by the Royal Adelaide Hospital Ethics Committee and by the Commonwealth of Australia Department of Health and Aged Care.”

Results: “Four hundred and nineteen incidents that occurred in the recovery room were extracted from the Anaesthetic Incident Monitoring Study database, representing 5% of the total database of 8372 reports. Incidents were reported mainly in daylight hours, with over 50% occurring in ASA 1–2 patients. The most common presenting problems related to respiratory/airway issues (183; 43%), cardiovascular problems (99; 24%) and drug errors (44; 11%). One hundred and twenty-two events (29%) led to a major physiological disturbance and required management in the High Dependency Unit or Intensive Care Unit. Contributing factors cited included error of judgement (77; 18%), communication failure (57; 14%) and inadequate pre-operative preparation (29; 7%), whilst factors minimising the incident included previous experience (97; 23%), detection by monitoring (72; 17%) and skilled assistance (54; 13%). Staffing and infrastructure of the recovery room needs to be supported, with ongoing education and quality assurance programmes developed to ensure that such events can be reduced in the future.”

[Kluger MT, Bullock MFM. Recovery room incidents: a review of 419 reports from the Anaesthetic Incident Monitoring Study (AIMS). *Anaesthesia* 2002;57:1060–6.]