Characteristics of medication errors and adverse drug events in hospitals participating in the California Pediatric Patient Safety Initiative

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Purpose. The characteristics of medication errors and adverse drug events (ADEs) in hospitals participating in the California Pediatric Patient Safety Initiative (CaPPSI) were studied to identify opportunities for improvement.

Methods. Data were collected to identify pharmacy intervention medication errors (PIMEs) with significant harm potential and ADEs identified by a validated pediatric trigger method (TADEs) and by voluntary incident reports (VADEs) from November 2003 through April 2004. Electronic trigger identification was used. The primary outcomes measured were PIMEs, TADEs, and VADEs and the characteristics of these medication errors and ADEs. A secondary outcome measure was the positive predictive value of the trigger tool.

Results. The rates of PIMEs, TADEs, and VADEs were 2.67, 22.3, and 1.7 per 1000 patient days, respectively. PIMEs and ADEs occurred mostly among patients age one year or older during days 0 and 1 of admission and involved the following medication categories: antifungal and antibiotics, analgesics and antipyretics, and electrolytic-, caloric-, and water balance-replacement preparations. Most PIMEs involved an incorrect dosage or the wrong drug. Primary diagnoses differed between those with PIMEs and VADEs and those with TADEs. All medication processes were in need of improvement except dispensing. The trigger tool identified more ADEs than did voluntary incident reports by a factor of 11 and had a positive predictive value of 16.8%.

Conclusion. Baseline rates of PIMEs, TADEs, and VADEs for pediatric hospitals in California were determined through collaborative efforts of CaPPSI facilities. Identification of ADEs was more effective when a trigger tool was used than when incidents were voluntarily reported.

Index terms: Data collection; Dosage; Drugs, adverse reactions; Errors, medication; Hospitals; Methodology; Pediatrics; Pharmacy, institutional, hospital; Quality assurance; Reports

Am J Health-Syst Pharm. 2008; 65:2036-44

Children are particularly vulnerable to medication errors (MEs) and adverse drug events (ADEs) because of pharmacokinetic issues, difficulties in calculating dosages by weight or mass, and narrow therapeutic-to-lethal ranges of many medications used in pediatric patients. Though the majority of research has focused on adult patients, studies on MEs and ADEs have also established the impor...
Clinical Report  
California Pediatric Patient Safety Initiative

Research and quality-improvement projects on MEs and ADEs have relied on a variety of surveillance methods. The ability of these methods to identify MEs and ADEs varies significantly. The literature has demonstrated that more intensive detection processes lead to increased identification.\(^{19-30}\) As demonstrated in several studies, a trigger tool for ADE identification is more effective than voluntary incident reporting in identifying ADEs among adult and pediatric inpatients.\(^{21,29,30}\)

Collaborative efforts in health systems must first delineate ME and ADE baseline rates and characteristics for their own patient populations. Hospitals and health systems participating in collaborative efforts must agree on measures that will serve as markers for safe medication use in their particular settings and characterize MEs and ADEs in order to identify and implement changes in processes and systems that will lead to reductions in ME and ADE rates. The California Pediatric Patient Safety Initiative (CaPPSI) was a statewide collaborative effort of pediatric hospitals to reduce the occurrence of MEs and ADEs. The purpose of this study was to determine baseline ME and ADE rates and characterize MEs and ADEs in pediatric patients in the state-based collaborative. A secondary objective of this study was to affirm the effectiveness of a trigger tool using electronic records for ADE identification compared with that of voluntary incident reporting in the pediatric inpatient population.

**Methods**

**Study design.** This surveillance study was conducted as part of the CaPPSI and funded by the California HealthCare Foundation. The institutional review boards of each participating institution approved the study.

The five CaPPSI sites are freestanding, nonprofit, pediatrics teaching hospitals with academic affiliations located in California. The five CaPPSI sites are located in urban (\(n = 2\)), suburban (\(n = 2\)), and rural (\(n = 1\)) areas in northern (\(n = 1\)), central (\(n = 1\)), and southern (\(n = 3\)) California.

To be eligible for study inclusion, patients had to be inpatients at one of the CaPPSI hospitals and under age 18 years. Outpatients, inpatients in well-baby nurseries, and emergency department patients were not included.

**Data collection.** The five CaPPSI sites agreed to measure and submit deidentified data about pharmacy intervention MEs (PIMEs) and ADEs using a trigger tool and voluntary incident reporting. A data dictionary was created to standardize terms. Standardized data collection forms and a standardized database with uniform data-entry procedures were utilized by all sites. Pilot studies were conducted to refine the measures and the data collection and transmittal processes. Because case records could not be shared between sites due to their confidential and sensitive nature, two sets of case scenarios were created. Each set was scored by each site. The sites then discussed the scoring of the case scenarios.

Pharmacy interventions were defined as actions taken by pharmacists when they receive a medication order that contains an error. PIMEs with the potential for significant harm (i.e., the potential to cause significant permanent harm [severity G], a near-death event [severity H], or death [severity I]) that occurred from November 2003 through April 2004 were identified and confirmed by a second clinical reviewer. The following information was collected for each identified PIME: site, month and year of event, patient age, length of stay, principal diagnosis, hospital day when ME occurred, patient care unit in which ME occurred, intervention, and type of error.

ADEs were defined as “an injury, large or small, caused by the use (including non-use) of a drug. This may be as harmless as a drug rash or as serious as death from an overdose.”\(^{31}\) ADEs were identified using a pediatric trigger tool.\(^{30}\) A trigger has been described as “occurrences, prompts, or flags found on review of the medical record that trigger further investigation to determine the presence or absence” of an ADE.\(^{21}\) The CaPPSI sites used seven medication-use triggers and three laboratory value triggers, based on the Institute for Healthcare Improvement trigger tool\(^{32}\) and one from the Child Health Accountability Initiative,\(^{33}\) which were amenable to identification through electronic records. Trigger medications included diphenhydramine, vitamin K, flumazenil, antiemetics, naloxone, sodium polystyrene, and laxatives and stool softeners; trigger laboratory test values included a partial thromboplastin time of >100 seconds, a serum glucose concentration of >150 mg/dL, and hyperkalemia as defined by each hospital’s range of reference values. The discharge records of 40 randomly selected patients discharged at each facility during each month from November 2003 through April 2004 were reviewed by a pharmacist, physician, or nurse using the trigger tool. The first 30 days of each hospitalization in the patient’s medical record were reviewed. When a trigger was identified in the electronic clinical data repository that generated lists of trigger occurrences, a reviewer manually reviewed the chart to determine if a trigger was associated with an ADE that contributed to or resulted in temporary harm and required intervention (severity E) or was of greater severity (severity F–I) as defined by the National Coordinating Council for Medication Error Reporting and Prevention index.\(^{33,34}\) Identified ADEs were confirmed by...
another clinical reviewer. Information was collected to characterize the trigger-identified ADEs (TADEs), including hospital day that ADE occurred, patient care unit where ADE occurred, medication involved and route of administration, probability of an ADE based on the Naranjo et al.35 algorithm, intervention, severity of the ADE, and preventability of the ADE. The characteristics of the ME were documented for preventable TADEs with a severity rating of G–I. Additional information collected included the following characteristics of the patient and of the hospitalization: site, month and year of event, patient age, length of stay, principal diagnosis, and number of ADEs during the hospitalization.

ADEs were also identified through voluntary incident reports issued from November 2003 through April 2004. Voluntary incident reports were filed voluntarily by hospital staff regarding any event worthy of reporting. Hospital policies mandate reporting of ADEs. Voluntary-incident-report-identified ADEs (VADEs) were characterized in the same way as TADEs by a pharmacist, physician, or nurse.

The rates and characteristics of the PIMEs, TADEs, and VADEs were then assessed by the CaPPSI members to identify opportunities for improvement.

The total numbers of inpatient days, medication orders, and operating room time were collected for each hospital for a comparative 6-month period. Adjusted patient days were calculated to estimate the total inpatient and outpatient activity at the hospitals for a comparative 12-month period. A survey to characterize the culture of safety at the institution, known as the Stanford Patient Safety in Healthcare Organizations tool, was administered to hospital and medical staff.36

The primary outcomes measured were the numbers of identified PIMEs, TADEs, and VADEs and the characteristics of these MEs and ADEs. A secondary outcome measure was the positive predictive value of the trigger tool.

**Data analysis.** PIME, TADE, and VADE rates and event characteristics were analyzed using SAS (SAS Institute Inc., Cary, NC) and Stata/SE 8.2 (StataCorp, College Station, TX). The numbers of identified PIMEs, TADEs, and VADEs served as the numerators for the event rates. The denominators were the numbers of patient days and medication orders for PIME, TADE, and VADE and the number of patient discharges for patients identified with a TADE. For TADEs, the denominator was specifically calculated for the patients randomly selected for the trigger chart review. For PIMEs and VADEs, the denominator was relative to the number of all eligible denominator elements at risk for a PIME or VADE for the time period. Poisson distribution was used to calculate rates and confidence intervals (CIs). The proportions of MEs and ADEs with various characteristics, as delineated above, were calculated by using the exact binomial distribution for confidence limits. The positive predictive value of the trigger tool set was calculated for the triggers identified as a whole and by various descriptive factors. The ratio of TADEs to VADEs was also calculated. Median and first- and third-quartile values were calculated for patient characteristics. Logistic regression was used to assess the association between the presence of an ADE as the outcome with a set of risk factors (i.e., patient, encounter, and hospital characteristics) for the data on TADEs. The reliability of case scenario scoring was assessed using the agreement index.37

**Results**

**Hospital characteristics.** The total number of inpatient days for the 6-month period of November 2003 through April 2004 ranged from 25,763 to 41,831 for the five sites. For the same 6-month period, total operating room time ranged from 2,855 to 6,875 hours for the five sites, and total medication orders ranged from 114,768 to 142,803 for the three sites submitting data in a comparable manner (i.e., actual order counts). For the 12-month period of January through December 2003, the total adjusted patient days ranged from 60,882 to 206,720 for all five sites. Characteristics of PIMEs, TADEs, and VADEs by age, length of stay, hospital area, and hospital day of stay at time of event are provided in Table 1. All CaPPSI sites appeared to have a similar culture of safety, with 13–18% of sites providing “problematic” (i.e., absence of elements of a culture of safety) responses.

**Reliability.** The reliability among study sites in scoring characteristics of MEs and ADEs that rely heavily on the subjective judgment of data collectors in 20 case scenarios developed by the investigators was 85% for the agreement indexes.

**PIMEs.** Four of five CaPPSI sites submitted data on PIMEs that were categorized as having the potential for significant harm. The median age of patients for which PIMEs were reported was 3.83 years (quartile 1 = 0.44 year, quartile 3 = 11.9 years). The median length of stay was 11 days (quartile 1 = 3 days, quartile 3 = 35 days).

A total of 349 PIMEs of severity level G–I were identified for rates of 2.67 PIMEs per 1000 patient days (95% CI, 2.4–3.0) for the four sites combined and of 0.82 PIME per 1000 medication orders (95% CI, 0.73–0.91) for the three sites that submitted medication-order data. Eighty-eight percent of all PIMEs were recorded for patients age one year or older, and there appeared to be a relatively uniform distribution of PIMEs among the five age groups (Table 1). Forty-seven percent of PIMEs were recorded for patients with hospital stays of less than one week, reflecting the underlying
length-of-stay distribution. The most common medication categories related to PIMEs were antiinfectives or antibiotics (28%; 95% CI, 23–33%), analgesics and antipyretics (19%; 95% CI, 15–23%), electrolyte-, caloric-, and water balance-replacement preparations (16%; 95% CI, 12–20%), anticonvulsants (5%; 95% CI, 3–8%), anxiolytics, sedatives, and hypnotics (4%; 95% CI, 2–6%), and autonomic agents and cardiovascular drugs (3% each; 95% CI, 2–6%). Opioids were the main type of medication associated with PIMEs in the analgesic and antipyretic category. A large number of PIMEs appeared to occur for patients with primary diagnostic categories involving congenital anomalies (16%; 95% CI, 12–20%), the respiratory system (15%; 95% CI, 11–19%), neoplasms (10%; 95% CI, 7–13%), injury and poisoning (10%; 95% CI, 7–13%), and the digestive system (8%; 95% CI, 5–11%). Fifty-two percent of PIMEs occurred during days 0 and 1 of admission (Table 1); 57% occurred in noncritical care units, and 43% occurred in the neonatal intensive care unit (NICU), pediatric intensive care unit (PICU), or cardiothoracic intensive care unit (CTICU) areas. No PIMEs were reported for patients in the operating room or postanesthesia care unit.

Table 1. Characteristics of Pharmacy Intervention Medication Errors (PIMEs) and ADEs

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No. (%) Events [95% CI]</th>
<th>PIME (n = 349)</th>
<th>TADE (n = 79)</th>
<th>VADE (n = 278)</th>
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<tr>
<td><strong>Age</strong></td>
<td></td>
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<tr>
<td>&lt;30 days</td>
<td>43 (12.3) [9.1–16.2]</td>
<td>3 (3.8) [0.8–10.7]</td>
<td>35 (12.6) [8.9–17.1]</td>
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<tr>
<td>30 days to &lt;1 yr</td>
<td>67 (19.2) [15.2–23.7]</td>
<td>9 (11.4) [5.3–10.5]</td>
<td>59 (21.2) [16.6–26.5]</td>
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<tr>
<td>1 to &lt;5 yr</td>
<td>81 (23.2) [18.9–28.0]</td>
<td>15 (19.0) [11.0–29.4]</td>
<td>58 (20.9) [16.2–26.1]</td>
<td></td>
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<tr>
<td>5 to &lt;13 yr</td>
<td>84 (24.1) [19.7–28.9]</td>
<td>30 (38.0) [27.3–49.5]</td>
<td>76 (27.3) [22.2–33.0]</td>
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<tr>
<td>13 to &lt;18 yr</td>
<td>74 (21.2) [17.0–25.9]</td>
<td>22 (27.8) [18.3–39.1]</td>
<td>50 (18.0) [13.6–23.0]</td>
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<td><strong>Length of stay, days</strong></td>
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<tr>
<td>0–2</td>
<td>59 (16.9) [13.1–21.3]</td>
<td>11 (13.9) [7.2–23.5]</td>
<td>39 (14.0) [10.2–18.7]</td>
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<tr>
<td>5–6</td>
<td>27 (7.7) [5.2–11.1]</td>
<td>10 (12.7) [6.2–22.0]</td>
<td>26 (9.4) [6.2–13.4]</td>
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<tr>
<td>7–13</td>
<td>27 (7.7) [5.2–11.1]</td>
<td>3 (3.8) [0.8–10.7]</td>
<td>27 (9.7) [6.5–13.8]</td>
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<td>14–20</td>
<td>17 (4.9) [2.9–7.7]</td>
<td>0 (4.6) b</td>
<td>15 (5.4) [3.1–8.7]</td>
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</tr>
<tr>
<td>28–83</td>
<td>18 (5.1) [3.1–8.0]</td>
<td>8 (10.1) [4.5–19.0]</td>
<td>18 (6.5) [3.9–10.0]</td>
<td></td>
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<tr>
<td>84–147</td>
<td>12 (3.4) [1.8–5.9]</td>
<td>0 (4.6) b</td>
<td>5 (1.8) [0.6–4.1]</td>
<td></td>
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<tr>
<td>Unknown</td>
<td>5 (1.4) [7.2–23.5]</td>
<td>0 (4.6) b</td>
<td>0 (1.3) b</td>
<td></td>
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<tr>
<td><strong>Hospital unit</strong></td>
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<tr>
<td>NICU</td>
<td>42 (12.0) [8.8–15.9]</td>
<td>3 (3.8) [0.8–10.7]</td>
<td>33 (11.9) [8.3–16.3]</td>
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<tr>
<td>Noncritical care</td>
<td>200 (57.9) [51.9–62.5]</td>
<td>65 (82.3) [72.0–90.0]</td>
<td>153 (55.0) [49.0–61.0]</td>
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<tr>
<td>PICU</td>
<td>107 (30.6) [25.9–35.8]</td>
<td>7 (8.9) [3.6–17.4]</td>
<td>68 (24.5) [19.5–30.0]</td>
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<tr>
<td>OR/PACU</td>
<td>0 (1.0) b</td>
<td>7 (8.9) [3.6–17.4]</td>
<td>16 (5.7) [3.3–9.2]</td>
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<tr>
<td>Diagnostic unit</td>
<td>0 (1.0) b</td>
<td>0 (4.6) b</td>
<td>5 (1.8) [0.6–4.1]</td>
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<tr>
<td>Transport</td>
<td>0 (1.0) b</td>
<td>0 (4.6) b</td>
<td>2 (0.7) [0.09–2.6]</td>
<td></td>
</tr>
<tr>
<td>Missing</td>
<td>0 (1.0) b</td>
<td>0 (4.6) b</td>
<td>1 (0.3) [0.009–2.0]</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Hospital day at time of event</th>
<th>No. (%) Events [95% CI]</th>
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<th>TADE (n = 79)</th>
<th>VADE (n = 278)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–7</td>
<td>240 (68.8) [63.6–73.6]</td>
<td>45 (57.0) [45.3–68.0]</td>
<td>198 (71.2) [65.5–76.5]</td>
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<tr>
<td>8–13</td>
<td>32 (9.2) [6.4–12.7]</td>
<td>8 (10.1) [4.5–19.0]</td>
<td>22 (7.9) [5.0–11.7]</td>
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<td>21–27</td>
<td>10 (2.9) [1.4–5.2]</td>
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<td>84–147</td>
<td>7 (2.0) [0.8–4.1]</td>
<td>0 (4.6) b</td>
<td>5 (1.8) [0.6–4.1]</td>
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<tr>
<td>148–364</td>
<td>4 (1.1) [0.3–2.9]</td>
<td>0 (4.6) b</td>
<td>2 (0.7) [0.09–2.6]</td>
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</table>

bOne-sided, 97.5% CI.

*ADEs = adverse drug events, CI = confidence interval, TADE = trigger-identified ADE, VADE = voluntary-incident-report-identified ADE, NICU = neonatal intensive care unit, PICU = pediatric intensive care unit and cardiothoracic intensive care unit, OR = operating room, PACU = postanesthesia care unit, transport = in transit from one unit to another.

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(PACU). By definition, all PIMEs involved the prescribing or ordering process. The most common error types were overdose (63%; 95% CI, 58–68%), underdose (14%; 95% CI, 10–18%), and wrong drug (8%; 95% CI, 5–11%). The most common PIME intervention was to adjust the current medication (80%; 95% CI, 76–84%) or to discontinue the medication (11%; 95% CI, 8–15%).

TADEs. Three of five sites submitted data on ADEs identified by the trigger chart review method. The median patient age was 3.71 years (quartile 1 = 0.56 year, quartile 3 = 9.77 years). The median length of stay was 2 days (quartile 1 = 1 day, quartile 3 = 5 days), and the median number of medication orders per patient was 13 (quartile 1 = 7, quartile 3 = 22). Most patients spent no time in the operating room.

A total of 1669 triggers were identified using the trigger chart review method for rates of 11.2 ADEs per 100 discharges (95% CI, 8.7–13.7), 22.3 ADEs per 1000 patient days (95% CI, 17.3–27.4), and 5.4 per 1000 medication orders (95% CI, 4.2–6.7) for the three sites combined. Of all patients, 9.1% (95% CI, 6.8–11.3%) had a TADE. Based on the Naranjo et al.35 adverse drug reaction probability scale scores, 53% of the identified TADEs were probably or definitely related to medications, 46% were possibly related, and 1% were unlikely related to medications.

A total of 1669 triggers were identified at all sites combined, with 53.9% (95% CI, 48.4–59.4%) of all patients identified with a trigger. The positive predictive value for all triggers combined was 4.7% (95% CI, 3.7–5.8%) at the trigger level and 16.8% (95% CI, 12.6–21.1%) at the patient level (i.e., an ADE was identified for every 21 triggers identified and for every six patients identified with at least 1 trigger). Though not statistically significant, the predictive value for all triggers combined appeared to be affected by patient age at both the trigger and patient levels, with higher predictive values associated with older ages. At the patient level, the predictive value was 11.1% for neonates (95% CI, 1.7 to 23.9%), 14.6% for infants (95% CI, 3.6–25.6%), 11.3% for young children (95% CI, 4.5–18.2%), 20.5% for older children (95% CI, 12.4–28.5%), and 21.0% for adolescents (95% CI, 10.8–31.2%).

The positive predictive value of all triggers combined could not be assessed by primary diagnosis because the number of ADEs in each diagnostic category was too few.

Patients age one year or older had 84.8% of all TADEs (Table 1). The distribution of TADEs by ultimate length of stay appeared relatively uniform. The medication categories most commonly associated with TADEs were analgesics and antipyretics (37%; 95% CI, 26–48%), antineoplastic agents (24%; 95% CI, 15–35%), antibiotics (13%; 95% CI, 6–22%), hormones and synthetic substitutes (9%; 95% CI, 4–17%), and general anesthetics (6%; 95% CI, 2–14%). Opioids were the most common type of medication in the analgesics and antipyretics category associated with TADEs. About one of six TADEs involving an analgesic or antipyretic also involved another medication (anxiolytic, sedative, hypnotic, autonomic drug, general anesthetic, or vasodilating agent) or a combination of agents. A large number of TADEs appeared to occur in patients with primary diagnostic categories involving injury and poisoning (16%; 95% CI, 9–26%), neoplasms (15%; 95% CI, 8–25%), nonspecific factors influencing health status (14%; 95% CI, 7–24%), endocrine or metabolic diseases and musculoskeletal system (9% each; 95% CI, 4–17%), and blood and blood-forming organs (8%; 95% CI, 3–16%). Forty-two percent of TADEs occurred during days 0 and 1 of admission, and 82.3% occurred in noncritical care units, most likely reflecting the underlying distribution of patients among the units, with 12% of TADEs identified in patients receiving care in the NICU, PICU, and CTICU areas. Only 4 (5.1%) of the 79 trigger ADEs were documented for patients in the operating room or PACU area. Most TADEs (93.7%; 95% CI, 85.8–97.9%) had a severity level of E, causing temporary harm requiring some type of intervention. One caused a life-threatening event, and another was associated with death. Six (7.6%; 95% CI, 2.8–15.8%) of the 79 TADEs were preventable. The event associated with death was not preventable. Both severity level G and I TADEs were related to the process of prescribing or ordering and dose omission. The most common TADE outcome categories were gastrointestinal (59.5%), dermatological (17.7%), and renal or metabolic (16.5%). Fifteen percent of TADEs were associated with more than one outcome, primarily categorized as dermatological or gastrointestinal, along with another outcome category.

The logistic regression of the presence or absence of a TADE showed significant odds ratios (ORs) based on the hospital site, patient age, number of medication orders, and operating room time: OR = 6.6 (95% CI, 2.6–16.2) comparing one specific site to another specific site, OR = 4.4 (95% CI, 1.8–10.2) comparing one other specific site to one of the previous sites, OR = 1.15 (95% CI, 1.10–1.21) for age in years, OR = 1.025 (95% CI, 1.016–1.033) for medication order, and OR = 1.16 (95% CI, 0.97–1.38) for operating room time in minutes. Primary diagnostic category and length of stay were not significant variables in the logistic regression.

VADEs. All five sites submitted data on ADEs identified by voluntary incident reporting. The median age of patients with VADEs was 3.45 years (quartile 1 = 0.4 year, quartile 3 = 10.26 years). The median length of stay was 13 days (quartile 1 = 5 days, quartile 3 = 28 days).
A total of 278 ADEs were voluntarily reported at the five sites for rates of 1.7 per 1000 patient days (95% CI, 1.5–1.9) for the five sites combined and 0.57 per 1000 medication orders (95% CI, 0.50–0.65) for the three sites that reported medication-order data. The three sites contributing data to the TADE rate had a V ADE rate of 2.2 per 1000 patient days (95% CI, 1.9–2.5). Based on the Naranjo et al.35 adverse drug reaction rating scale scores, 31% of the identified ADEs were probably or definitely related to medications, 61% were possibly related, and 7% were unlikely related to medications.

Sixty-six percent of all VADEs were reported for patients one year or older. The distribution of VADEs by length of stay appeared relatively uniform. The medication categories most commonly associated with VADEs were electrolytic-, caloric-, and water balance-replacement preparations (30%; 95% CI, 25–36%), antiinfectives and antibiotics (24%; 95% CI, 19–29%), analgesics and antipyretics (18%; 95% CI, 14–23%), autonomic drugs (6%; 95% CI, 4–10%), and anxiolytics, sedatives, and hypnotics (6%; 95% CI, 4–10%). Thirty percent of VADEs were associated with more than one medication, especially VADEs associated with antiinfectives and antibiotics (n = 9) and analgesics and antipyretics (n = 8). A large number of VADEs appeared to occur in patients with primary diagnostic categories involving congenital anomalies (19%; 95% CI, 14–24%), the respiratory system (11%; 95% CI, 8–16%), and the digestive system and injury and poisoning (6% each; 95% CI, 4–10%). For a large number of VADEs, data on primary diagnosis were not submitted (19%; 95% CI, 15–25%). Forty-one percent of VADEs occurred during days 0 and 1 of admission, and 55% occurred in noncritical care units. Only 16 of the 278 VADEs were reported in patients in the operating room or PACU area, and 7 occurred during intra-

hospital transport or in a diagnostic area. Most VADEs (90.6%; 95% CI, 86.6–93.8%) were categorized as severity level E (i.e., involving temporary harm requiring some type of intervention). Eighty-five (30.6%; 95% CI, 25.2–36.3%) of the 278 VADEs were preventable. The 1 event associated with death was not preventable. Of the 7 MEs categorized as severity level G or H, 3 were associated with administration, 1 with dispensing, and 3 with monitoring. The error types involved monitoring (n = 3), overdose (n = 2), wrong drug (n = 1), and wrong duration (n = 1). Of the 13 root-cause categories reported for the 7 MEs of severity level G and H, human factors were associated with 6 MEs, contributing factors with 4, communication with 2, and labeling with 1. The most common VADE outcome categories were dermatological (61%), cardiovascular or peripheral vascular (54%), and respiratory (22%). Forty-seven percent of VADEs were associated with more than one outcome and primarily included cardiovascular or peripheral vascular combined with another outcome category.

**Discussion**

The CaPPSI sites were the first state-based pediatric collaborative to successfully implement a system to collect and share data on PIMEs with the potential for significant harm and ADEs identified by a pediatric trigger tool and by voluntary incident reports. CaPPSI established a necessary measurement foundation related to medication management for this unique effort to provide data on baseline rates and characteristics of MEs and ADEs from the pediatric inpatient setting and to identify opportunities for improvement and possible interventions.

**PIMEs.** The CaPPSI sites identified over a six-month period 349 medication errors resulting from the prescribing or ordering process at the four sites that submitted data. Overall, 2.67 errors were reported per 1000 patient days or 0.82 errors per 1000 medication orders. These error rates are comparable to the rates of 1.22 per 1000 patient days and 0.54 per 1000 medication orders reported in a study at a tertiary care hospital that included data for both adult and pediatric patients.38 It is not clear if the severity of the errors in that study and the CaPPSI study are equivalent. The rate of errors in our study is about four times less than the 4.02 per 1000 medication orders reported in another study conducted in a teaching hospital.39 It is unclear from the report how similar the patient population at that hospital and that study’s definition of “serious errors” were to those of the CaPPSI project. The CaPPSI collaborative only studied PIMEs with the potential to cause permanent harm, a life-threatening event, or death, which may account for the lower rate of serious errors found in the current study.

The characteristics of the PIMEs identified by the CaPPSI sites suggest that opportunities for improvement in pediatric inpatient prescribing at these sites should focus on children who meet one or more of the following criteria: patients age one year or older, patients in their first two calendar days of hospitalization, patients with a primary diagnosis of congenital anomalies or respiratory disease, patients receiving care in nonoperating-room hospital areas, and patients receiving analgesics, antiinfectives, and electrolytic-, caloric-, or water balance-replacement preparations. We also believe that a careful review of drug dosage and drug choice would increase patient safety and prevent many of the errors discovered through pharmacy interventions.

**ADEs.** The CaPPSI sites identified a total of 79 ADEs using the trigger tool, for overall rates of 11.2 ADEs per 1000 discharges, 22.3 ADEs per 1000 patient days, and 5.4 ADEs per 1000 medication orders. Approxi-
mately 1 in 11 of all patients sampled had an ADE. Though we used a smaller set of triggers that were identifiable by electronic records, the results were similar in magnitude to those observed in two studies that used manual searches of paper charts with a longer list of trigger medications and laboratory test values: 11.1 ADEs per 100 discharges in the Child Health Accountability Initiative study and 27.4 ADEs per 100 discharges reported in a study from a group that included “a high proportion of pediatric hospitals.” However, the rate of TADEs in our study was significantly higher than the rates reported in two other pediatric studies (2.3 TADEs per 100 discharges, and 6.6 TADEs per 1000 patient days or 6 TADEs per 100 discharges) utilizing different ADE identification methods. This might be due to the trigger method’s increased ability to identify ADEs compared with other identification methods. In fact, the rate of ADE identification in this study was approximately 10 times higher by the trigger method than by voluntary incident report. The CaPPSI sites identified a total of 278 VADEs, for overall rates of 1.7 VADEs per 1000 patient days and 0.57 VADEs per 1000 medication orders. These rates were slightly higher than the rate of 0.60 per 1000 patient days noted in a Child Health Accountability Initiative study but much lower than the rate of adverse events found in the present study using the trigger method.

The characteristics of the CaPPSI sites’ TADEs and VADEs suggest that opportunities for improvement in pediatric medication management at these sites should focus on children who meet one or more of the following criteria: patients’ age one year or older; patients in their first two calendar days of hospitalization; patients with a primary diagnosis of injuries, neoplasms, conditions related to International Classification of Diseases, Ninth Revision V-codes (i.e., factors influencing health status and contact with health services other than a disease or injury, such as health screenings, aftercare of a disease or injury, newborn birth status); congenital anomalies, respiratory system; patients for whom multiple medications are prescribed; patients undergoing procedures in the operating room; and patients treated outside of critical care units. TADE characteristics suggest that CaPPSI sites should give serious consideration to enhancing prescribing and ordering safeguards to prevent drug interactions and dose omissions, while VADE characteristics suggest a need to focus on administration and monitoring issues, especially compliance with the “five rights” (i.e., right patient, right drug, right dose, right schedule and rate, and right duration) and human factors related to communication and medication labeling. Likewise, TADEs were often associated with gastrointestinal, dermatological, and renal or metabolic signs or symptoms, while VADEs were often associated with dermatological, cardiovascular, and respiratory manifestations; these signs and symptoms may serve as early alerts to the clinician in the presence of ADEs requiring intervention and mitigation. Surveillance of both TADEs and VADEs, in addition to PIMEs, appears to provide a more comprehensive view of a system’s medication management system than monitoring only one of these indicators alone.

Other considerations. Despite the use of a data dictionary, it was difficult in this study to collect and count data in a uniform manner. Two of the CaPPSI sites were able to count total doses but not medication orders so that the denominator could not be used to analyze their data. Two sites did not follow the study protocol and did not submit TADE data for patients who did not have an identified TADE; therefore, it was impossible to calculate TADE rates for those sites. Thus, the information from this project reflects the sites that were able to submit data. Focusing on the issue of harm and its prevention, CaPPSI reviewed MEs that led to or had the potential to lead to severe ADEs and was therefore able to provide information on severe PIMEs and MEs associated with TADEs and VADEs; however, valuable information on MEs leading to a higher volume of though less severe MEs was not provided by this project. Early in the collaborative, it was determined that collecting and submitting data on all levels of ME severity would not be feasible in the context of this study and probably not in the context of the resources available in the normal workflow. Future patient safety collaboratives will also face the dilemma of balancing the importance of having information versus the feasibility of collecting and analyzing data.

Despite these difficulties, the strength of these findings is their multisite, collaborative foundation using common definitions and data collection methods. As already described, CaPPSI’s intent was to identify opportunities for improvement that would decrease actual harm to pediatric inpatients. As a preliminary step in identifying potential improvement opportunities, interventions already implemented at each of the sites identified by systematic review of patient safety practices, funded by the Agency for Healthcare Research and Quality, including medication safety practices, were assessed and revealed that while two of the sites had five of six practices in place, the other three had, at most, two practices in place. The practices with either the highest impact or strength of evidence that had not been implemented and warrant future consideration were computerized monitoring for potential ADEs, computerized physician order entry (CPOE), clinical decision support, and clinical pharmacist consultation services; the two practices of lower impact or strength of evidence were use of...
automated medication dispensing devices and a unit-dose distribution system. Though not formally studied, PIME, TADE, and VADE rates did not seem related to the number of these practices in place. A CPOE system must offer excellent pediatric dosage checking to prevent the serious errors found by CaPPSI. Since the time of the study, all five CaPPSI sites have implemented additional ME- and ADE-reduction strategies. Two sites subsequently participated in a separate collaborative to reduce ADEs related specifically to opioids, and one site participated in the Institute for Healthcare Improvement 100,000 Lives Campaign to decrease preventable inpatient mortality through six interventions, including medication reconciliation. Future studies should focus on the effect of these subsequent performance-improvement activities.

CaPPSI was the first statewide group of pediatric hospitals to determine common medication management quality indicators, collect and submit the data in a uniform manner, and analyze the data for opportunities for improvement. In that process, baseline rates of PIMEs, TADEs, and VADEs were identified as benchmarks for the facilities involved in the initiative and possibly for other pediatric hospitals. CaPPSI reaffirmed the effectiveness of the pediatric trigger tool for ADE identification over voluntary incident reporting in the pediatric inpatient population.

Conclusion

Baseline rates of PIMEs, TADEs, and VADEs for pediatric hospitals in California were determined through collaborative efforts of CaPPSI facilities. Identification of ADEs was more effective when a trigger tool was used than when incidents were voluntarily reported.

References

33. National Coordinating Council for Medi-


