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SPECIAL ARTICLE

Changes in Medical Errors after Implementation of a Handoff Program

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ABSTRACT

BACKGROUND

Miscommunications are a leading cause of serious medical errors. Data from multicenter studies assessing programs designed to improve handoff of information about patient care are lacking.

METHODS

We conducted a prospective intervention study of a resident handoff-improvement program in nine hospitals, measuring rates of medical errors, preventable adverse events, and miscommunications, as well as resident workflow. The intervention included a mnemonic to standardize oral and written handoffs, handoff and communication training, a faculty development and observation program, and a sustainability campaign. Error rates were measured through active surveillance. Handoffs were assessed by means of evaluation of printed handoff documents and audio recordings. Workflow was assessed through time–motion observations. The primary outcome had two components: medical errors and preventable adverse events.

RESULTS

In 10,740 patient admissions, the medical-error rate decreased by 23% from the preintervention period to the postintervention period (24.5 vs. 18.8 per 100 admissions, $P<0.001$), and the rate of preventable adverse events decreased by 30% (4.7 vs. 3.3 events per 100 admissions, $P<0.001$). The rate of nonpreventable adverse events did not change significantly (3.0 and 2.8 events per 100 admissions, $P=0.79$). Site-level analyses showed significant error reductions at six of nine sites. Across sites, significant increases were observed in the inclusion of all prespecified key elements in written documents and oral communication during handoff (nine written and five oral elements; $P<0.001$ for all 14 comparisons). There were no significant changes from the preintervention period to the postintervention period in the duration of oral handoffs (2.4 and 2.5 minutes per patient, respectively; $P=0.55$) or in resident workflow, including patient–family contact and computer time.

CONCLUSIONS

Implementation of the handoff program was associated with reductions in medical errors and in preventable adverse events and with improvements in communication, without a negative effect on workflow. (Funded by the Office of the Assistant Secretary for Planning and Evaluation, U.S. Department of Health and Human Services, and others.)

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Preventable adverse events — injuries due to medical errors — are a major cause of death among Americans. Although some progress has been made in reducing certain types of adverse events,[1-3] overall rates of errors remain extremely high.[4] Failures of communication, including miscommunication during handoffs of patient care from one resident to another, are a leading cause of errors; such miscommunications contribute to two of every three "sentinel events," the most serious events reported to the Joint Commission.[5] The omission of critical information and the transfer of erroneous information during handoffs are common.[6] As resident work hours have been reduced, handoffs between residents have increased in frequency.[7]

Improving handoffs has become a priority in efforts to improve patient safety.[8,9] The Accreditation Council for Graduate Medical Education now requires training programs to provide formal instruction in handoffs and to monitor handoff quality.[9] However, few studies have rigorously evaluated the effectiveness of handoff-improvement programs.[6,7,10]

In a single-center study, we found that the implementation of a handoff program was associated with a reduction in medical-error rates and improvements in communications between residents at change of shift.[11] After performing this study, we developed a bundle of interventions around a refined mnemonic, I-PASS (illness severity, patient summary, action list, situation awareness and contingency plans, and synthesis by receiver).[12,13] We hypothesized that multicenter implementation of the I-PASS Handoff Bundle would lead to improvements in communication and patient safety.

METHODS

STUDY DESIGN

We conducted a prospective systems-based intervention study on inpatient units at nine pediatric residency training programs in the United States and Canada, after receiving approval from the institutional review boards at all participating institutions. Each site was assigned to one of three staggered intervention and data-collection waves from January 2011 through May 2013. At each site, we measured preintervention outcomes of interest for a 6-month period. During the following 6 months, the intervention was implemented. Six months of postintervention data collection followed, matched by time of year to the preintervention data collection at that site. Data on medical errors, the quality of written and oral handoffs (as described below), and demographic characteristics and medical complexity were collected for all patients on the study units. During the intervention, all residents received training in handoff practices and were required to use I-PASS handoff processes while working on study units. However, only residents who provided written informed consent contributed additional observational, demographic, and survey data. Residents were offered small incentives (e.g., cookies and gift cards) to provide data.

STUDY INSTITUTIONS

Nine pediatric residency training programs, ranging in size from 36 to 182 residents, were identified as data-collection sites through professional academic networks, as described elsewhere.[14] Each site determined which study unit (all non–intensive care units) to include in the intervention. There was heterogeneity across sites with regard to medical complexity among patients. At baseline, no sites had a standardized handoff program in place.[12]

INTERVENTION

We developed the I-PASS Handoff Bundle through an iterative process based on the best evidence from the literature, our previous experience, and our previously published conceptual model.[12,14] The I-PASS Handoff Bundle included the following seven elements: the I-PASS mnemonic, which served as an anchoring component for oral and written handoffs and all aspects of the curriculum[13]; a 2-hour workshop[15] (to teach TeamSTEPPS[16] teamwork and communication skills, as well as I-PASS handoff techniques), which was highly rated[12]; a 1-hour role-playing and simulation session[17] for practicing skills from the workshop; a computer module[18] to allow for independent learning; a faculty development program[19,20]; direct-observation tools[21] used by faculty to provide feedback to residents; and a process-change and culture-change campaign,[22] which included a logo, posters, and other materials to ensure program adoption and sustainability. A detailed description of all curricular elements and the I-PASS mnemonic have been published elsewhere and are provided in Table S1 in the Supplementary Appendix, available with the full text of this article at NEJM.org.[12,15,17-19,21-23] I-PASS is copyrighted by Boston Children's Hospital, but all materials are freely available.

Each site integrated the I-PASS structure into oral and written handoff processes; an oral handoff and a written handoff were expected for every patient. Written handoff tools with a standardized I-PASS format were built into the electronic medical record programs (at seven sites) or word-processing programs (at two sites). Each site also maintained an implementation log that was reviewed regularly to ensure adherence to each component of the handoff program.

STUDY OUTCOMES

Medical Errors and Adverse Events

We used a well-established surveillance process[24-28] to measure our two-component primary outcome: rates of medical errors (preventable failures in processes of care) and preventable adverse events (unintended consequences of medical care that lead to patient harm). We also assessed nonpreventable adverse events, which were not expected to change after the intervention. At each site, a research nurse reviewed all medical records and orders on the study unit 5 days per week (Monday reviews included a review of the weekend), formal incident reports from the hospital incident-reporting system, solicited reports from nurses working on the study unit, and daily medical-error reports from residents, collected through daily postshift surveys. Two physician investigators who were unaware of whether a given incident occurred before or after the intervention classified each suspected incident as an adverse event (i.e., harm due to medical care), a near miss or error with little potential for harm, or an exclusion (i.e., an incident determined to be neither a medical error nor an adverse event) (70% agreement; kappa, 0.47; 95% confidence interval [CI], 0.44 to 0.50). Physician reviewers further classified all adverse events as preventable (i.e., due to a medical error) or nonpreventable (i.e., due to a medical intervention with no error in the medical care delivery process) (72% agreement; kappa, 0.44; 95% CI, 0.36 to 0.52). Discordant classifications were reconciled by discussion between the paired reviewers. Examples of errors and events are provided in Tables S2A and S2B in the Supplementary Appendix.

Assessment of Written and Oral Handoffs

Each handoff consisted of both a written document and an in-person oral communication between residents. We collected copies of all written handoff documents on each weekday morning and evening at each site and audiotaped evening oral handoffs when a research assistant was present conducting time–motion observations (further details are given below). Research nurses who were aware of the intervention period evaluated a random sample of written handoff documents (a total of 432, or 24 per study period per site [half from the morning, half from the evening]) and audio recordings of oral handoffs (a total of 207, or approximately 12 per study period per site) for the presence of key handoff data elements. We compared the rates of inclusion of these elements within the document or recording for each patient before and after the intervention.

Resident Workflow Patterns and Satisfaction

We conducted time–motion observations throughout the preintervention and postintervention periods to measure the time spent by residents in various activities. Our primary interest was the time spent at the computer, conducting handoffs, and in direct patient care. To collect these data, research assistants followed individual residents for 8 to 12 hours, recording start and stop times for all activities with the use of a Microsoft Access database that included 12 major and 114 minor possible activities. Observation blocks included a representative ratio of hours from all 24 hours of the day and weekdays versus weekends. In addition, an end-of-rotation survey was administered to each resident to assess perceptions of handoff training.

STATISTICAL ANALYSIS

We compared medical-error rates before and after the intervention by means of Poisson regression, with a dichotomous covariate for before versus after the intervention and a fixed effect for site. We compared the percentage of written and oral handoffs (individual patient entries and discussions) that included key data elements with the use of generalized-estimating-equation z-tests that accounted for clustering based on the date of the handoff discussion or document with a fixed effect for site.[29,30] To compare time–motion data before and after the intervention, we used a generalized-estimating-equation z-test, accounting for clustering according to observation session with a fixed effect for site. This approach was based on a Dirichlet distribution, which is a distribution for the percentage of time that a continuous variable (in this case, time) is in each category. When the Bonferroni correction for multiple testing was used, two-sided P values of less than 0.025 were considered to indicate statistical significance for the two-part primary hypothesis test (postintervention change in rates of overall medical errors and postintervention change in rates of preventable adverse events across all sites). Because the other tests of hypotheses (for the main outcomes within each site as well as other outcomes overall and within each site) were more exploratory in nature, the Bonferroni correction was not used, and two-sided P values of less than 0.05 were considered to indicate statistical significance. All analyses were completed with the use of SAS/STAT software, version 9.2 (SAS Institute).

On the basis of data from our single-site study,[11] we determined that 6 months of data collection at each site would be sufficient for more than 90% power to detect a 20% relative reduction in overall error rates and for 80% power to detect a 28% relative reduction in the rate of preventable adverse events at each site (alpha level of 0.025 with the use of a Bonferroni correction).

RESULTS

STUDY PATIENTS AND RESIDENT PHYSICIANS

We reviewed 10,740 patient admissions (5516 preintervention and 5224 postintervention) for the presence of medical errors. Length of stay, medical complexity, and the sex and age of patients did not differ significantly between the preintervention and postintervention periods, nor did the respective proportions of patients who were white (41.2% and 41.4%, P=0.38) and who were enrolled in public insurance programs (55.1% and 54.2%, P=0.61) (Table 1).

A total of 875 residents (representing 95.4% of those approached) provided written informed consent to participate. Response rates for postshift surveys used as part of medical-error surveillance were similar in the preintervention and postintervention periods (93.1% [1729 completed surveys] and 93.3% [1489 completed surveys], respectively; P=0.88).

MEDICAL ERRORS AND ADVERSE EVENTS

From the preintervention period to the postintervention period, significant reductions were observed for both components of our primary outcome: the I-PASS Handoff Bundle was associated with a 23% relative reduction in the overall medical-error rate across all sites combined (24.5 vs. 18.8 errors per 100 admissions, P<0.001) and a 30% relative reduction in the rate of preventable adverse events (4.7 vs. 3.3 events per 100 admissions, P<0.001). The rate of near misses and nonharmful medical errors decreased by 21% (19.7 vs. 15.5 near misses and nonharmful errors per 100 admissions, P<0.001) (Table 2). There was no significant change in the rate of nonpreventable adverse events (3.0 and 2.8 events per 100 admissions, P=0.79). Rates of errors that were diagnostic, related to medical history or physical examination, multifactorial, and related to therapies other than medications and procedures decreased significantly, whereas rates of errors related to medications, procedures, falls, and nosocomial infections did not change. In site-level analyses, significant reductions in error rates were observed in six of the nine participating institutions (Table 3).

WRITTEN AND ORAL HANDOFF QUALITY

The 432 written handoff documents examined yielded 5752 unique patient handoffs for evaluation (Fig. 1), and the 207 oral handoff sessions yielded 2281 unique patient handoffs (Fig. 2). I-PASS implementation was followed by significant improvements in the inclusion of all nine written handoff elements evaluated and all five oral handoff elements evaluated (see Tables S3 and S4 in the Supplementary Appendix for site-level data). The mean duration of in-person oral handoff sessions did not change significantly after the intervention (duration before and after the intervention, 2.4 and 2.5 minutes per patient, respectively; P=0.55).

RESIDENT WORKFLOW PATTERNS AND SATISFACTION

We collected 8128 hours of time–motion data (preintervention period, 3510 hours; postintervention period, 4618 hours). For all sites combined, there was no significant change in the percentage of time in a 24-hour period spent in contact with patients and families (before and after the intervention, 11.8% and 12.5%, respectively; P=0.41), creating or editing the computerized handoff document (1.6% and 1.3%, P=0.54),

Table 1. **Characteristics of Patients before and after Implementation of the I-PASS Handoff Bundle, According to Site.***

Site No.	Length of Stay			Medical Complexity†			Female Sex			Age		
	Before	After	P Value	Before	After	P Value	Before	After	P Value	Before	After	P Value
	days			*no. of children (%)*			*no. of children (%)*			*years*		
1	7.9±13.7	8.1±15.0	0.22	316 (61.6)	272 (67.0)	0.09	270 (52.6)	193 (47.5)	0.13	7.0±6.2	7.7±6.5	0.11
2	13.0±25.0	11.0±18.4	0.34	184 (62.8)	165 (67.9)	0.22	131 (44.7)	116 (48.1)	0.43	4.5±5.1	5.3±5.6	0.17
3	6.0±10.6	6.2±10.5	0.80	293 (55.8)	317 (59.9)	0.30	252 (48.0)	245 (45.5)	0.42	6.7±6.0	6.4±5.8	0.24
4	2.8±5.6	3.9±13.2	0.85	126 (21.9)	100 (20.3)	0.52	252 (44.1)	228 (46.5)	0.42	4.8±5.3	4.0±4.9	0.003
5	5.0±9.7	4.1±8.3	0.29	583 (61.6)	567 (58.3)	0.15	427 (45.1)	445 (45.9)	0.73	3.7±5.4	4.1±5.7	0.58
6	3.2±5.3	3.1±5.3	0.31	268 (29.4)	264 (29.6)	0.95	424 (46.5)	410 (46.0)	0.81	7.7±6.1	7.6±6.2	0.82
7	5.1±9.6	4.9±6.4	0.88	266 (51.3)	205 (47.7)	0.27	238 (45.9)	208 (48.4)	0.44	5.2±5.7	5.0±6.1	0.23
8	3.6±5.8	3.3±6.2	0.78	160 (46.4)	170 (48.7)	0.54	156 (45.2)	141 (40.4)	0.20	7.0±6.7	6.8±6.8	0.80
9	3.2±8.7	3.1±5.9	0.51	180 (20.7)	215 (24.0)	0.10	395 (45.5)	425 (47.4)	0.40	5.2±5.7	5.1±5.8	0.89
Overall	4.9±0.13	4.8±0.14	0.59	2376 (43.2)	2275 (43.6)	0.40	2545 (46.3)	2411 (46.3)	0.99	5.7±0.08	5.7±0.08	0.90

* Plus–minus values are means ±SD. Within each site, demographic characteristics before and after the intervention were compared with the use of the Pearson chi-square test for dichotomous variables and the Wilcoxon rank-sum (two-sample) test for continuous variables. For all sites combined, demographic characteristics before and after the intervention were compared with the use of the Cochran–Mantel–Haenszel test for dichotomous variables and a stratified Wilcoxon test for continuous variables, to account for site effects. Data on age, length of hospital stay, sex, insurance status, and race for all patients admitted to the study unit were obtained from hospital administrative databases at each site.

† Medical complexity was defined to be present for each patient whose condition could be classified as belonging to one of three commonly published categories based on *International Classification of Diseases, 9th Revision*, diagnostic and procedural codes[31]: a complex chronic condition,[32] neurologic impairment,[33] or a condition for which technological assistance was required.[34]

Table 2. Incidence of Medical Errors, Preventable Adverse Events, and Medical-Error Subtypes before and after Implementation of the I-PASS Handoff Bundle.

Variable	Before Implementation (N=5516)	After Implementation (N=5224)	P Value
	total no. (no./100 admissions)		
Overall medical errors	1349 (24.5)	981 (18.8)	<0.001
Preventable adverse events	261 (4.7)	173 (3.3)	<0.001
Near misses and nonharmful medical errors	1088 (19.7)	808 (15.5)	<0.001
Medical-error subtype			
Errors related to diagnosis (incorrect, delayed, omitted)	184 (3.3)	111 (2.1)	<0.001
Errors related to therapy other than medication or procedure	112 (2.0)	77 (1.5)	0.04
Errors related to history and physical examination	43 (0.8)	0	< 0.001
Other and multifactorial errors	239 (4.3)	106 (2.0)	<0.001
Medication-related errors	660 (12.0)	580 (11.1)	0.28
Procedure-related errors	83 (1.5)	85 (1.6)	0.49
Falls	13 (0.2)	8 (0.2)	0.37
Nosocomial infections	15 (0.3)	14 (0.3)	0.79

working at the computer (16.2% and 16.5%, P=0.81), or writing on printed copies of the handoff document (0.5% and 0.6%, P=0.19).

Significantly more residents reported having received handoff training after the intervention (60.3% before the intervention vs. 98.9% after the intervention, P<0.001). The proportion of residents who rated the overall quality of their handoff training as very good or excellent increased significantly after the intervention (27.8% before the intervention vs. 72.2% after the intervention, P<0.001).

Table 3. Incidence of Medical Errors before and after Implementation of the I-PASS Handoff Bundle, According to Site.

Site No.	Admissions Reviewed		Medical Errors		
	Before	After	Before	After	P Value
	no.		*total no. (no./100 admissions)*		
1	511	406	276 (54.0)	121 (29.8)	<0.001
2	294	242	76 (25.9)	38 (15.7)	0.01
3	526	538	296 (56.3)	214 (39.8)	<0.001
4	586	496	95 (16.2)	47 (9.5)	0.003
5	951	974	210 (22.1)	253 (26.0)	0.08
6	911	893	131 (14.4)	92 (10.3)	0.01
7	521	430	99 (19.0)	87 (20.2)	0.67
8	346	349	72 (20.8)	58 (16.6)	0.20
9	870	896	94 (10.8)	71 (7.9)	0.05
Overall	5516	5224	1349 (24.5)	981 (18.8)	<0.001

DISCUSSION

We found that implementation of the I-PASS Handoff Bundle across nine academic hospitals was associated with a 23% relative reduction in the rate of all medical errors and a 30% relative reduction in the rate of preventable adverse events. We also found significant decreases in rates of specific types of medical errors, including diagnostic errors. Site-level reductions in the overall rate of medical errors were observed at six of the nine participating sites. As anticipated, the rate of nonpreventable adverse events did not change. The quality of written and oral handoff communications significantly improved, which provided evidence that the I-PASS Handoff Bundle was successfully implemented across multiple sites and was likely to have accounted for the observed reduction in medical errors. This error reduction occurred without an increase in the time required to complete handoffs or a decrease in residents' direct contact time with patients. These findings support calls from professional and federal bodies to improve the patient-handoff process.[7-9]

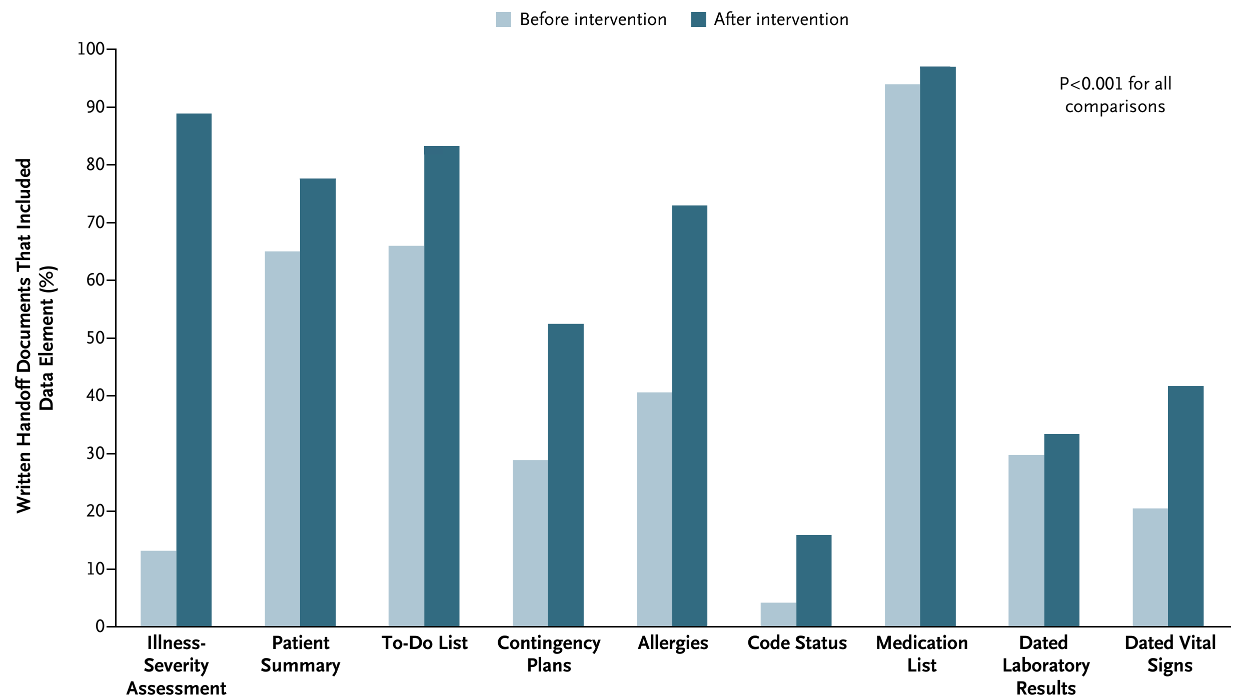

Figure 1. Percentage of Written Handoff Documents That Included Key Data Elements (All Sites Combined).

Key quality elements evaluated for written handoffs included an illness-severity assessment, patient summary (defined as a written handoff of at least three of the following: summary statement, events leading up to admission, hospital course, ongoing assessment, and active plans), to-do list (defined as a clearly written list of "to-do" items or a statement of "nothing to do"), contingency plans (defined as an indication of what to do if adverse contingencies occurred, or an explicit statement that no adverse contingencies were anticipated), allergy list, code status, medication list, dated laboratory tests, and dated vital signs. In the analysis of all sites combined, significant improvements were seen in every category. In the site-level analyses, significant improvements were observed in the frequency of inclusion of illness severity (nine of nine sites), a patient summary (six of nine sites), a to-do list (five of nine sites), and contingency plans (nine of nine sites) (Table S3 in the Supplementary Appendix). A total of 432 written handoff documents that included 5752 unique patients were reviewed (a mean of approximately 13 patients per written handoff document).

This work builds substantially on our previous single-institution study, in which we found that implementing a prototype handoff-improvement program was associated with reductions in medical errors.[11] We designed our current study to address several limitations of the single-center study. First, we performed a multicenter study to improve study generalizability. Second, we collected data on preintervention and postintervention error rates at the same time of year at each site, to control for potential time-of-year confounding. Third, with the help of experts at multiple sites, we simplified the mnemonic and developed a more robust curriculum[12] to enhance the generalizability, implementation, and sustainability of the intervention.

One of the major concerns about resident duty-hour limits is that although sleep deprivation increases the risk of performance failures and medical errors,[27,35-37] reducing work hours leads to more patient handoffs and the potential for more handoff-related errors.[38] However, our study shows that the risk of handoff-related errors can be significantly reduced. Implementing handoff-improvement programs such as the I-PASS Handoff Bundle may potentiate the effectiveness of work-hour reductions, because doing both together may concurrently reduce both fatigue and handoff-related errors.

Our study design precludes definitively establishing a causal link between implementation of the I-PASS Handoff Bundle and improved patient safety. However, we believe it most likely that the safety improvements were due to our intervention because we saw parallel improvements in handoff processes, which was a plausible mech-

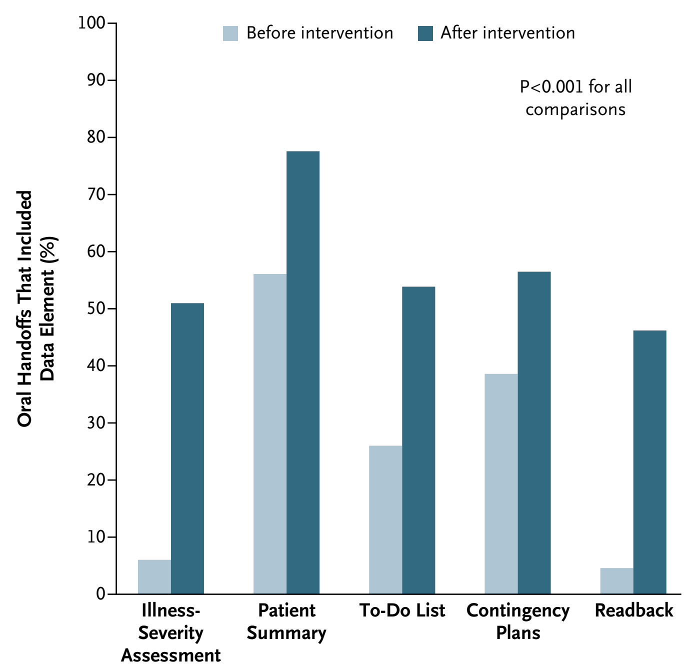

Figure 2. Percentage of Oral Handoffs That Included Key Data Elements (All Sites Combined).

Key elements evaluated for oral handoffs included an illness-severity assessment, patient summary (defined as an oral handoff of at least three of the following: summary statement, events leading up to admission, hospital course, ongoing assessment, and active plans), to-do list (defined as a clearly articulated list of "to-do" items or a statement of "nothing to do"), contingency plans (defined as an indication of what to do if adverse contingencies occur, or an explicit indication that no adverse contingencies were anticipated), and readback by the receiver (defined as readback mostly performed with small correction required or readback fully performed without need for correction). In the analysis of all sites combined, significant improvements were seen in every category. In the site-level analyses, significant increases were observed in the frequency of inclusion of illness severity (nine of nine sites), a patient summary (seven of nine sites), a to-do list (seven of nine sites), contingency plans (seven of nine sites), and readback (nine of nine sites) (Table S4 in the Supplementary Appendix). A total of 207 oral handoff sessions that included 2281 patients were reviewed (a mean of approximately 11 patients per handoff session).

anism by which reductions in errors could have occurred; the rates of nonpreventable adverse events (i.e., those not due to medical error) did not change; and the reproducibility of improvements in processes and outcomes across multiple sites increases the likelihood that the changes seen were related to the intervention at each site.

The nurses and research assistants who collected data had to be aware of the intervention period. We addressed this by training all data collectors, none of whom were study investigators, in a standardized process to objectively collect data on errors regardless of study schedule. In addition, every suspected medical error was reviewed by two physicians who were unaware of the intervention period. Reviewers' agreement on incident classification and preventability was similar to that in previous patient-safety studies, and we reconciled discordant classifications.[11,39]

We found substantial interinstitutional variation in baseline error rates. Although our study was not designed to compare rates between sites, the patient populations and study units varied substantially among institutions, which may have contributed to the variation in baseline error rates.

Although the implementation of the I-PASS Handoff Bundle was associated with an overall reduction in medical errors, error rates did not change significantly at three of the nine sites. The reason for this is unclear, because significant improvements in written and oral handoff processes were observed at all sites. Because error rates are the product of numerous interacting hospital structures and processes, it is possible that institution-specific factors, such as variation in the ascertainment of error data, inconsistent implementation of the program, or other unmeasured factors, were responsible for the lack of improvement in error rates at some sites. Our study may also have been underpowered to detect improvements in error rates at some sites. Further research on the role of site-specific factors might explain these variations.

Our intervention focused on pediatric inpatient units; the extent to which the I-PASS Handoff Bundle is applicable to other disciplines, specialties, and settings is not yet known. Future studies will be required to determine the broader applicability of the intervention.

We chose to combine several educational and process changes into a single bundled intervention because numerous successful patient-safety interventions have used this approach.[1,2,40] Although bundling appears to have been effective in this instance, it prevents us from determining which elements of the intervention were most essential.

In conclusion, we found that implementation of the I-PASS Handoff Bundle was associated with significant reductions in medical errors and preventable adverse events. Site-level changes in error rates were observed at most participating institutions.

The opinions and conclusions expressed herein are solely those of the authors and should not be construed as representing the opinions or policy of any agency of the federal government.

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Disclosure forms provided by the authors are available with the full text of this article at NEJM.org.

APPENDIX

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