Improving Respiratory Rate Accuracy in the Hospital: A Quality Improvement Initiative

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Respiratory rate (RR) is a predictor of adverse outcomes. However, RRs are inaccurately measured in the hospital. We conducted a quality improvement (QI) initiative using plan-do-study-act methodology on one inpatient unit of a safety-net hospital to improve RR accuracy. We added time-keeping devices to vital sign carts and retrained patient-care assistants on a newly modified workflow that included concomitant RR measurement during automated blood pressure measurement. The median RR was 18 (interquartile range [IQR] 18-20) preintervention versus 14 (IQR 15-20) postintervention. RR accuracy, defined as ±2 breaths of gold-standard measurements, increased from 36% preintervention to 58% postintervention ($P < .01$). The median time for vital signs decreased from 2:36 minutes (IQR, 2:04-3:20) to 1:55 minutes (IQR, 1:40-2:22; $P < .01$). The intervention was associated with a 7.8% reduced incidence of tachypnea-specific systemic inflammatory response syndrome (SIRS = 2 points with RR > 20; 95% CI, –13.5% to –2.2%). Our interdisciplinary, low-cost, low-tech QI initiative improved the accuracy and efficiency of RR measurement. *Journal of Hospital Medicine* 2019;14:673-677. © 2019 Society of Hospital Medicine

Respiratory rate (RR) is an essential vital sign that is routinely measured for hospitalized adults. It is a strong predictor of adverse events.[1,2] Therefore, RR is a key component of several widely used risk prediction scores, including the systemic inflammatory response syndrome (SIRS).[3]

Despite its clinical utility, RR is inaccurately measured.[4-7] One reason for the inaccurate measurement of RR is that RR measurement, in contrast to that of other vital signs, is not automated. The gold-standard technique for measuring RR is the visual assessment of a resting patient. Thus, RR measurement is perceived as time-consuming. Clinical staff instead frequently approximate RR through brief observation.[8-11]

Given its clinical importance and widespread inaccuracy, we conducted a quality improvement (QI) initiative to improve RR accuracy.

METHODS

Design and Setting

We conducted an interdisciplinary QI initiative by using the plan–do–study–act (PDSA) methodology from July 2017 to February 2018. The initiative was set in a single adult 28-bed medical inpatient unit of a large, urban, safety-net hospital consisting of general internal medicine and hematology/oncology patients. Routine vital sign measurements on this unit occur at four- or six-hour intervals per physician orders and are performed by patient-care assistants (PCAs) who are nonregistered nursing support staff. PCAs use a vital signs cart equipped with automated tools to measure vital signs except for RR, which is manually assessed. PCAs are trained on vital sign measurements during a two-day onboarding orientation and four to six weeks of on-the-job training by experienced PCAs. PCAs are directly supervised by nursing operations managers. Formal continuing education programs for PCAs or performance audits of their clinical duties did not exist prior to our QI initiative.

Intervention

Intervention development addressing several important barriers and workflow inefficiencies was based on the direct observation of PCA workflow and information gathering by engaging stakeholders, including PCAs, nursing operations management, nursing leadership, and hospital administration (PDSA cycles 1-7 in Table). Our modified PCA vital sign workflow incorporated RR measurement during the approximate 30 seconds needed to complete automated blood pressure measurement as previously described.[12] Nursing administration purchased three stopwatches (each $5 US) to attach to vital signs carts. One investigator (NK) participated in two monthly one-hour meetings, and three investigators (NK, KB, and SD) participated in 19 daily 15-minute huddles to conduct stakeholder engagement and educate and retrain PCAs on proper technique (total of 6.75 hours).

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TABLE. **PDSA Cycles for the Design and Implementation of a Quality Improvement Initiative to Improve Respiratory Rate Accuracy**

Cycle	Plan	Do	Study	Act
1	RRs are inaccurately recorded.	Observe patient-care assistants (PCAs) during routine vital sign measurements.	PCAs did not accurately assess for chest rises and instead often used "spot" measurements.	RR measurement appears inaccurate. Need to quantify RR accuracy.
2	Gold-standard RR will be more accurate than PCA RR.	Compare blinded gold-standard RRs with PCA RR (n = 100 paired observations).	PCA RR median 18 (IQR 18-20) versus gold-standard RR median of 12 (IQR 12-18), and 36% were accurate (±2 breaths/min).	PCA RRs are inaccurate compared with the gold-standard technique. Assess barriers to accurate measurement.
3	PCAs will report several barriers to measuring RR accurately.	Interview a convenience sample of PCAs about barriers to accurate RR measurement.	PCAs reported inadequate time to observe chest rises. Patient-care demands limited time that could be spent on vital signs. PCAs did not have a time-keeping device.	Map PCA vital signs workflow and quantify the time spent.
4	PCAs lack an efficient workflow.	Observe PCAs vital sign process and record total time to complete vital sign measurement (n = 50).	PCAs did not count chest rises and did not use the 45 seconds during automated BP measurement efficiently. Median time to record vital signs was 2:36 minutes (IQR, 2:04-3:20).	Design intervention: (1) modify PCA workflow such that RR is measured during the automated BP cycle (Figure S1); (2) add a time-keeping device to the vital sign cart; (3) educate PCAs on importance of RR.
5	PCAs are unaware of the importance of RR.	Assess PCA awareness of and teach importance of RR to PCAs during monthly staff meeting and daily huddles.	PCAs were unaware of the clinical implications of RR. After teaching, PCAs subjectively felt empowered because their vital sign measurements are so heavily utilized by physicians.	Train PCAs to record RR accurately.
6	PCAs will be properly taught how to measure RR during new hire orientation.	Add RR measurement to the new employee orientation.	Onboarding PCAs were never taught proper technique prior to starting on-the-job training. Training for RR was well received.	Current PCAs will need to be retrained to measure vital signs using the new workflow.
7	Current PCAs can be retrained to measure RR.	Train PCAs to measure RR during BP measurement per new workflow.	PCAs reported that the new workflow was more efficient and time saving.	Measure whether the intervention improved RR accuracy.
8	The intervention will improve PCA RR accuracy.	Compare blinded gold-standard RR to PCA RR postintervention (n = 100 paired observations).	PCA RR median of 14 (IQR 15-20) versus gold-standard RR of 14 (IQR 14-20), and 58% were accurate (±2 breaths/min).	The intervention improved RR accuracy. Need to measure the intervention's effect on time.
9	The new workflow is time-neutral compared with previous workflow.	Observe PCAs and record total time to complete vital sign measurement (n = 50 paired observations).	Median time for vital sign completion was 1:55 minutes (IQR 1:40-2:22). On average, was 41 seconds faster with the new workflow ($P < .001$).	New workflow was more efficient. Given that only a small number of patients were sampled, RR variability was studied as a proxy of accuracy by using EHR data for all patients on the intervention unit compared with two control units not exposed to the intervention.
10	RR recorded in the EHR on the intervention unit will have increased variability.	Compare EHR RR distribution and variability from the intervention unit with those from two control units.	The distribution of RRs on the intervention unit exhibited increased variability postintervention (Figure), whereas that of the RRs on control unit was unchanged.	Intervention succeeded in improving RR accuracy as assessed by gold-standard measurements and analyses of RRs recorded in the EHR data.

Abbreviations: EHR, electronic health record; IQR, interquartile range; PCA, patient-care assistants; PDSA, plan-do-study-act; RR, respiratory rate.

Evaluation

The primary aim of this QI initiative was to improve RR accuracy, which was evaluated using two distinct but complementary analyses: the prospective comparison of PCA-recorded RRs with gold-standard recorded RRs and the retrospective comparison of RRs recorded in electronic health records (EHR) on the intervention unit versus two control units. The secondary aims were to examine time to complete vital sign measurement and to assess whether the intervention was associated with a reduction in the incidence of SIRS specifically due to tachypnea.

Respiratory Rate Accuracy

PCA-recorded RRs were considered accurate if the RR was within ±2 breaths of a gold-standard RR measurement performed by a trained study member (NK or KB). We conducted gold-standard RR measurements for 100 observations pre- and postintervention within 30 minutes of PCA measurement

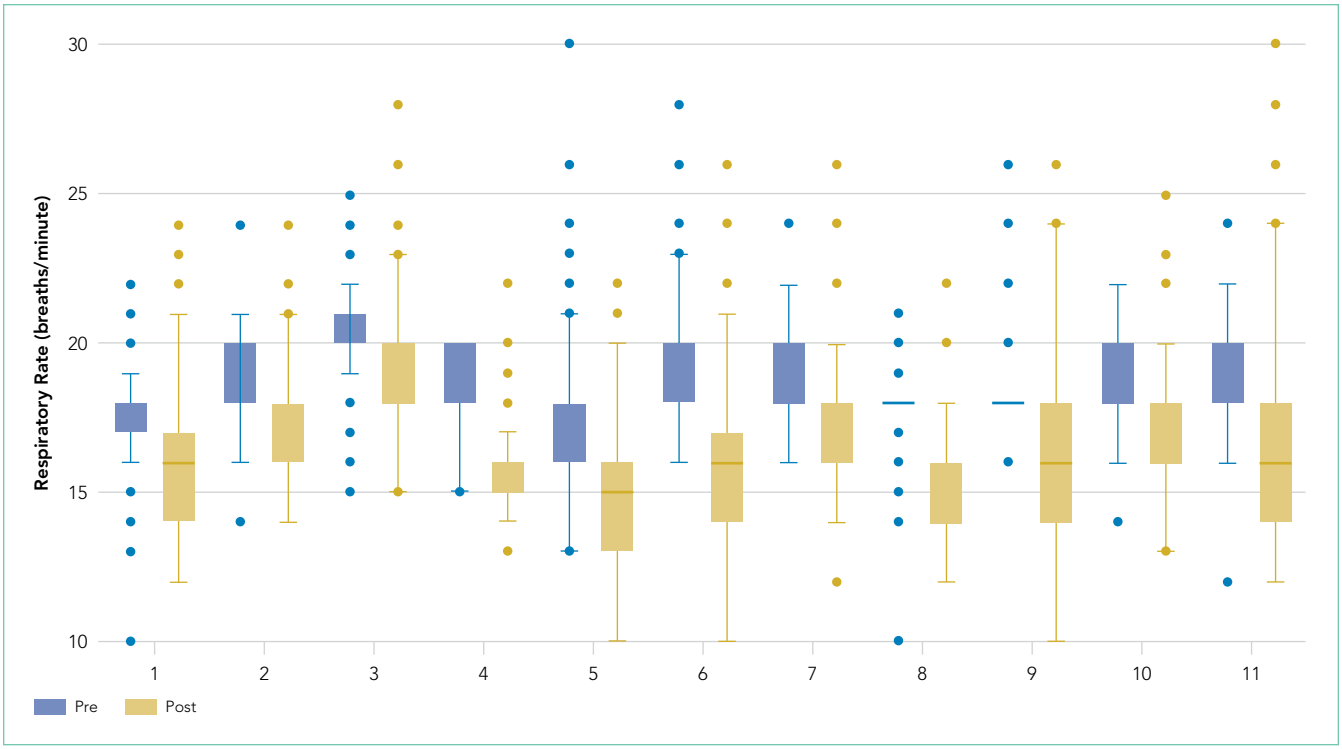

FIG. Distribution of Recorded Respiratory Rates by 11 Individual PCAs Pre- and Postintervention.[a]

[a]Individual PCAs were included if they recorded ≥100 respiratory rates during the postintervention period.
Abbreviations: PCA, patient-care assistant

to avoid Hawthorne bias.

We assessed the variability of recorded RRs in the EHR for all patients in the intervention unit as a proxy for accuracy. We hypothesized on the basis of prior research that improving the accuracy of RR measurement would increase the variability and normality of distribution in RRs.[13] This is an approach that we have employed previously.[7] The EHR cohort included consecutive hospitalizations by patients who were admitted to either the intervention unit or to one of two nonintervention general medicine inpatient units that served as concurrent controls. We grouped hospitalizations into a preintervention phase from March 1, 2017-July 22, 2017, a planning phase from July 23, 2017-December 3, 2017, and a postintervention phase from December 21, 2017-February 28, 2018. Hospitalizations during the two-week teaching phase from December 3, 2017-December 21, 2017 were excluded. We excluded vital signs obtained in the emergency department or in a location different from the patient's admission unit. We qualitatively assessed RR distribution using histograms as we have done previously.[7]

We examined the distributions of RRs recorded in the EHR before and after intervention by individual PCAs on the intervention floor to assess for fidelity and adherence in the PCA uptake of the intervention.

Time

We compared the time to complete vital sign measurement among convenience samples of 50 unique observations pre- and postintervention using the Wilcoxon rank sum test.

SIRS Incidence

Since we hypothesized that improved RR accuracy would reduce falsely elevated RRs but have no impact on the other three SIRS criteria, we assessed changes in tachypnea-specific SIRS incidence, which was defined a priori as the presence of exactly two concurrent SIRS criteria, one of which was an elevated RR.[3] We examined changes using a difference-in-differences approach with three different units of analysis (per vital sign measurement, hospital-day, and hospitalization; see footnote for Appendix Table 1 for methodological details. All analyses were conducted using STATA 12.0 (StataCorp, College Station, Texas).

RESULTS

Respiratory Rate Accuracy

Prior to the intervention, the median PCA RR was 18 (IQR 18-20) versus 12 (IQR 12-18) for the gold-standard RR (Appendix Figure 1), with only 36% of PCA measurements considered accurate. After the intervention, the median PCA-recorded RR was 14 (IQR 15-20) versus 14 (IQR 14-20) for the gold-standard RR and a RR accuracy of 58% ($P < .001$).

For our analyses on RR distribution using EHR data, we included 143,447 unique RRs (Appendix Table 2). After the intervention, the normality of the distribution of RRs on the intervention unit had increased, whereas those of RRs on the control units remained qualitatively similar pre- and postintervention (Appendix Figure 2).

Notable differences existed among the 11 individual PCAs

(Figure) despite observing increased variability in PCA-recorded RRs postintervention. Some PCAs (numbers 2, 7, and 10) shifted their narrow RR interquartile range lower by several breaths/minute, whereas most other PCAs had a reduced median RR and widened interquartile range.

Time

Before the intervention, the median time to complete vital sign measurements was 2:36 (IQR 2:04-3:20). After the intervention, the time to complete vital signs decreased to 1:55 (IQR, 1:40-2:22; $P < .001$), which was 41 less seconds on average per vital sign set.

SIRS Incidence

The intervention was associated with a 3.3% reduction (95% CI, –6.4% to –0.005%) in tachypnea-specific SIRS incidence per hospital-day and a 7.8% reduction (95% CI, –13.5% to –2.2%) per hospitalization (Appendix Table 1). We also observed a modest reduction in overall SIRS incidence after the intervention (2.9% less per vital sign check, 4.6% less per hospital-day, and 3.2% less per hospitalization), although these reductions were not statistically significant.

DISCUSSION

Our QI initiative improved the absolute RR accuracy by 22%, saved PCAs 41 seconds on average per vital sign measurement, and decreased the absolute proportion of hospitalizations with tachypnea-specific SIRS by 7.8%. Our intervention is a novel, interdisciplinary, low-cost, low-effort, low-tech approach that addressed known challenges to accurate RR measurement,[8,9,11] as well as the key barriers identified in our initial PDSA cycles. Our approach includes adding a time-keeping device to vital sign carts and standardizing a PCA vital sign workflow with increased efficiency. Lastly, this intervention is potentially scalable because stakeholder engagement, education, and retraining of the entire PCA staff for the unit required only 6.75 hours.

While our primary goal was to improve RR accuracy, our QI initiative also improved vital sign efficiency. By extrapolating our findings to an eight-hour PCA shift caring for eight patients who require vital sign checks every four hours, we estimated that our intervention would save approximately 16:24 minutes per PCA shift. This newfound time could be repurposed for other patient-care tasks or could be spent ensuring the accuracy of other vital signs given that accurate monitoring may be neglected because of time constraints.[11] Additionally, the improvement in RR accuracy reduced falsely elevated RRs and thus lowered SIRS incidence specifically due to tachypnea. Given that EHR-based sepsis alerts are often based on SIRS criteria, improved RR accuracy may also improve alarm fatigue by reducing the rate of false-positive alerts.[14]

This initiative is not without limitations. Generalizability to other hospitals and even other units within the same hospital is uncertain. However, because this initiative was conducted within a safety-net hospital, we anticipate at least similar, if not increased, success in better-resourced hospitals. Second, the long-term durability of our intervention is unclear, although EHR RR variability remained steady for two months after our intervention (data not shown).

To ensure long-term sustainability and further improve RR accuracy, future PDSA cycles could include electing a PCA "vital signs champion" to reiterate the importance of RRs in clinical decision making and ensure adherence to the modified workflow. Nursing champions act as persuasive change agents that disseminate and implement healthcare change,[15] which may also be true of PCA champions. Additionally, future PDSA cycles can obviate the need for labor-intensive manual audits by leveraging EHR-based auditing to target education and retraining interventions to PCAs with minimal RR variability to optimize workflow adherence.

In conclusion, through a multipronged QI initiative we improved RR accuracy, increased the efficiency of vital sign measurement, and decreased SIRS incidence specifically due to tachypnea by reducing the number of falsely elevated RRs. This novel, low-cost, low-effort, low-tech approach can readily be implemented and disseminated in hospital inpatient settings.

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