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Implementation of a High Flow Nasal Cannula Management Protocol in the Pediatric ICU

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Contributors' Statement Page

Dr. Tori provided substantial contributions to study design, data collection, data analysis, and the review of the manuscript.

Dr. Abu-Sultaneh provided substantial contributions to literature search, study design, data analysis, manuscript preparation, and review of the manuscript.

Dr. Peterson performed substantial contributions to literature search, data collection, data analysis, manuscript preparation, and review of the manuscript.

Dr. Hassumani performed substantial contributions to data collection, manuscript preparation, and the review of manuscript.

Acrista Hole performed substantial contributions to study design, data collection and the review of the manuscript.

James Slaven performed substantial contributions to data analysis and the review of the manuscript.

All authors have approved the final manuscript as submitted and have agreed to be accountable for all aspects of the work.

ABSTRACT

Background

High Flow Nasal Cannula (HFNC) is a respiratory modality that has been adopted to support pediatric patients with bronchiolitis. There is no standardized protocol for initiation, escalation or weaning of HFNC in PICU. The aim of this respiratory therapist (RT)-driven quality improvement management protocol is to decrease HFNC duration.

Methods

An RT-driven HFNC management protocol based on an objective respiratory score was implemented in 2017 at a quaternary care children's hospital. Subjects included children less than the age of 2 years admitted to the PICU with bronchiolitis. All subjects needing HFNC were scored and placed within the protocol as appropriate for age, then weaned or escalated per the scoring tool. Comparison to pre-intervention control group was performed. Average HFNC duration per subject was used as the primary outcome measure. Protocol compliance was used as process measure. Non-invasive ventilation (NIV) use, intubation rate, and 30-day PICU readmission rate were used as balancing measures. RT satisfaction with HFNC management pre- and post-protocol implementation were measured.

Results

Protocol compliance was sustainable and above the goal of 80% after 4 months of protocol implementation. HFNC duration decrease from 2.5 to 2 days/subject during planning and then to

1.8 after protocol implementation. PICU length of stay (LOS) and hospital LOS decreased from 2.6 to 2.1 days and 5.7 to 4.7 days after protocol implementation, respectively. The use of NIV and the rate of intubation did not have significant change. RTs reported increased involvement in HFNC management decisions and appropriateness on how fast the team weaned HFNC.

Conclusions

A RT-driven HFNC management protocol can be safely implemented in a PICU and decrease HFNC duration, PICU LOS, and hospital LOS. It allows the RT to work independently to the highest extent of their scope of practice leading to improvement in RT job satisfaction.

INTRODUCTION

Bronchiolitis is a leading cause of healthcare utilization for infants across the US, with 1 in 5 children presenting to healthcare providers, and up to 3% of all infants requiring hospitalization[1]. Recent estimates report approximately 150,000 bronchiolitis hospitalizations per year[2]. National hospital charges related to bronchiolitis have been increasing over time, from $1.3 billion in 2000 to $1.7 billion in 2009[3].

High Flow Nasal Cannula (HFNC) is a relatively recent respiratory support modality which allows for higher flow rates of oxygen via heating and humidification of the breathing gas when compared with standard O2 therapy. HFNC has been utilized for subjects ranging in age from preterm neonates to adults and in a variety of disease states. The use of HFNC in bronchiolitis has led to a decrease in the need for intubation and hospital length of stay when compared to standard O2 therapy[4-8]. HFNC also decreases reintubation rates within 72 hours after extubation when compared with standard O2 therapy[9].

Despite the adoption of HFNC as a primary respiratory modality before using non-invasive ventilation (NIV) and intubation for bronchiolitis in pediatric intensive care units, there is no standardized protocol for initiation, escalation, or weaning of HFNC[10]. Respiratory therapist (RT) driven standardized management protocols have been successfully used in PICUs, demonstrating effective and efficient care[11-13]. Previous studies show that the implementation of inter-professional quality improvement initiatives not only improved patients' clinical outcomes and increased RT satisfaction, but also did not lead to an increase in adverse events[14, 15].

The aim of this quality improvement project was to decrease the duration of HFNC in the PICU via a standardized RT-driven HFNC management protocol.

MATERIALS & METHODS

Setting

This is a quality improvement study that was conducted at Riley Hospital for Children at Indiana University Health. Our PICU is a 36-bed multidisciplinary medical-surgical unit with approximately 2,500 admissions per year. HFNC by Fisher and Paykel Healthcare (Auckland, New Zealand) was used in our hospital and is only available in our intensive care units. Subjects are not transferred to the general pediatric ward until they are weaned to standard O2 therapy or room air. Traditionally, the HFNC initiation, escalation and weaning decisions have been managed by the PICU clinician team (attending, fellow, resident, and advance care providers). The study was reviewed and exempted by the Indiana University institutional review board as a quality improvement project prior to implementation.

Evaluation Failure Modes of HFNC Management in PICU

A group of pediatric intensivists, a pediatric hospitalist, PICU RTs, and information technology specialists met in July 2016 to analyze the failure modes and plan the HFNC management protocol (Figure 1).

RT-Driven HFNC Management Protocol Development, Documentation, and Implementation

Between September and October 2016 the team met to establish a protocol, plan education, data collection, data analysis and documentation in the electronic medical records (EMR) (Cerner Corporation, North Kansas City, Missouri, USA). The protocol utilized the Riley Hospital Respiratory Score to objectively assess clinical status of the subjects (Table 1). The score was initially created looking at five areas: respiratory rate, retractions, mental status, dyspnea, and SpO2 – which came from a review of other scoring systems[16-18]. The protocol was honed in to limit complexity, with the understanding that the protocol would be followed by a multi-professional group of healthcare team members with varying levels of knowledge, skills, and experience[19]. The scoring tool was incorporated in our EMR before protocol implementation. After the protocol was developed, it was added to the HFNC initiation order-set within the EMR, which was completed in August of 2017.

Implementation of the protocol occurred in October 2017. The HFNC management protocol is shown in detail in Table 2 and Figure 2. Briefly, when any subject was admitted to the PICU requiring HFNC, the subject was screened to determine whether they were appropriate for the protocol (see study population section below). If none of the exclusion criteria were met, the subject was included unless the physician specifically ordered the discontinuation of the protocol. Physician reasons for discontinuation were not protocolized or monitored. The protocol was printed, laminated and hung on every HFNC unit in our PICU.

Protocol Education

Protocol education was completed between August and October of 2017. The education plan consisted of a formal presentation and a case study with a written test to demonstrate understanding of the protocol and associated EMR documentation. The education was provided by the RT supervisor and the clinical specialists in the PICU. Questions and clarifications were provided to team members via electronic communication and daily huddles throughout the first two months of implementation. Re-education of RTs occurred in May of 2018. Protocol compliance audits were done twice weekly and feedback was provided to RTs regarding protocol adherence and audit findings monthly through email, face-to-face interactions, and during RT meetings and huddles.

Study Measures and Data Collection:

The pre-implementation period was between October 2015 and September 2017 and the post-implementation period occurred between October 2017 and January 2019. The HFNC duration was used as the primary outcome measure, while PICU length of stay (LOS) and hospital LOS were used as secondary outcome measures. Protocol compliance was used as a process measure. NIV use (which included CPAP and bi-level positive airway pressure), intubation rate, and 30-days PICU readmission rate were used as balancing measures. For duration of HFNC, data was extracted from EMR on a monthly basis to evaluate protocol effectiveness and to provide feedback to the team members. Protocol compliance was obtained by weekly auditing of all subjects requiring HFNC. Final analysis was conducted on data obtained from Virtual PICU Systems (VPS, LLC, Los Angeles, CA, USA). RT satisfaction was conducted pre- and post-

protocol implementation via electronic surveys using SurveyMonkey (Providence, RI, USA) that were sent to all core PICU RTs in June 2017 and January 2019, respectively.

Subject Population

The HFNC protocol was used in all subjects who required HFNC in the PICU. Exclusion criteria at initiation of the protocol were subjects requiring Heliox, nitric oxide, and continuous albuterol nebulization. A change was made in the protocol in April of 2019 to include subjects who were on continuous albuterol. For this manuscript, we only include subjects who were less than 24 months of age and had a primary diagnosis of bronchiolitis. Subjects requiring NIV or intubation were excluded from analysis of the outcome and process measures and were used only to monitor balancing measures.

Statistical Analysis

The QI Macros add-in for Excel Version 2018.09 (KnowWare International, Denver, CO) was used to generate the run charts and x-bar statistical process control charts of the outcome and process measures. To overcome the seasonal variation impacting the number of subjects with bronchiolitis admitted to PICU, subjects were divided into groups of ten. The upper control limit (UCL) and lower control limit (LCL) were calculated as three sigma above and below the center line (CL). We considered eight consecutive points above or below the CL to represent a special cause variation and this prompted a change in the CL[20]. Subject demographics and clinical characteristics in the pre-HFNC and HFNC weaning protocol were compared using appropriate parametric and nonparametric tests, Wilcoxon rank-sum test for continuous variables and Chi-Square tests for categorical variables, with Fisher's Exact tests being used when cell counts were

small. Statistical analysis of the subjects' characteristics between the two groups was performed using Stata Statistical Software Release STATA 12.1 (StatCorp LP, College Station, TX). A cutoff p-value of less than 0.05 was considered statistically significant.

RESULTS

During the HFNC weaning protocol pre-implementation period, there were 257 subjects admitted with bronchiolitis compared to 333 subjects in the implementation period (Supplemental Table 1). There was no significant difference in subject characteristics between pre and during HFNC protocol implementation periods except in female gender (p=0.023) and race/ethnicity (p=0.037).

Protocol compliance started with 50% and gradually improved to a median of 86%, which was above our goal of 80% (Figure 3). For the outcome measures, the average HFNC duration per subject dropped from 2.5 to 2 days during the planning period for the HFNC management protocol. After protocol implementation HFNC duration dropped further to 1.8 days (Figure 4-A). The average PICU length of stay (LOS) showed a drop from 2.6 to 2.1 days after protocol implementation (Figure 4-B). The average hospital LOS also dropped from 5.7 to 4.7 days after protocol implementation (Figure 4-C). The use of NIV and rate of intubation did not change after protocol implementation; (6.3% vs 3.7%, p=0.13 and 17.3% vs 14.5%, p=0.13), respectively. None of the subjects were readmitted to the PICU within 30-days in both the pre implementation and HFNC groups.

RTs reported an increase in their involvement in management decisions for subjects on HFNC in the PICU (44.5% to 67.9%, p<0.001) (Figure 5-A) and improved perceived appropriateness on

how fast the team weaned HFNC (41.7% to 63%. p<0.001) (Figure 5-B). In addition, RTs perceived they were less likely to be excluded from HFNC management decisions (62.9% to 39.3%, p<0.001) (Figure 5-C).

DISCUSSION

To our knowledge, this is the first reported RT-driven quality improvement HFNC management protocol in PICU. A RT-driven protocol can be safely implemented in the PICU and can result in decreased HFNC duration, PICU LOS and hospital LOS without increasing PICU readmission, NIV or intubation rates. In busy PICUs with high patient acuity, inter-professional collaboration between various team members is vital for quality and efficient care for all patients. Protocols which allow members of inter-professional team members to work with greater autonomy allow for improvement in both patient care and workflow.

We believe that the key components for a successful RT-driven management protocol are based on the following components; (1) involving inter-professional team members in analyzing failure modes and establishing the protocol, (2) integration of the protocol in EMR which improve the communication of protocol adherence between team members, (3) conducting education before implementation of the protocol, (4) frequent audits for protocol compliance, providing team members with feedback and re-education when needed, and (5) modifying the protocol to reach the project's goals[14, 15].

HFNC is becoming first-line therapy in many PICUs to treat patients with bronchiolitis. Standardized clinical pathways have consistently demonstrated cost effectiveness and improved

patient outcomes[21, 22], yet there are no standards for HFNC management of bronchiolitis patients[10]. The lack of guidelines on how to initiate, escalate, and wean this important modality can lead to variation of care, care team and family dissatisfaction, longer occupation of valuable PICU beds, and utilization of hospital resources.

We demonstrated decreases in HFNC duration, PICU LOS, and hospital LOS after implementation of HFNC management protocol in our PICU. A decrease in the PICU and hospital lengths of stay would decrease overall healthcare costs in an era when healthcare costs are increasing[23]. Our PICU LOS and hospital LOS were shorter than what was reported by Betters et. al despite having a younger population in our cohort; 2.1 days and 4.7 days compared to 6 days and 10 days, respectively[24]. The longer LOS in Betters et al could be explained by differences in patient population as they included patients with multiple disease processes in comparison to a more homogenous population in our study. They also used HFNC as a step-down respiratory support modality for patients who were intubated or required NIV. We also suspect that seasonal variation (which can affect viral severity) may contributed to the differences between our two studies.

In a comparison of our protocol to the report published by Betters et. al. regarding implementing a HFNC weaning protocol in their PICU[24], our management protocol can be more appealing to bedside RTs and clinical team members because it is straight-forward and simplified. Simplification of the protocol allows RTs with varying experience levels to implement it effectively. Our protocol also gives the RT autonomy, not only to wean HFNC, but to also select the initial flow and escalate the HFNC until achieving the respiratory score goal. Our protocol

was also designed to include physicians of different training levels (residents and fellows) when more escalation of care is needed. The protocol also used more frequent assessment to assure safety and efficacy in escalation and gradual weaning the HFNC, which may be considered a more acceptable approach than doing HFNC holiday as reported by Betters et al.

It is notable that the duration of HFNC dropped from 2.5 to 2 days during the planning period and prior to implementation of the HFNC management protocol. This was a larger decrease than that was observed during the implementation period (2 to 1.8 days). This could be in part due to informal early adoption of the HFNC protocol by RTs and physician prior to formal implementation date given that many of the team members were included in the establishing the protocol.

A major strength of our protocol is that it is RT-driven. This allows the RT to have independence to the fullest extent of their scope of practice. Despite this protocol adding relative value units to the workload of RTs, overall it was looked upon favorably. RTs reported that their job satisfaction and involvement improved after protocol implementation. This is important as burnout has been linked, across job disciplines, to contribute to worse patient outcomes[25]. This result supports prior studies demonstrating that respiratory care protocol use increases RT perceived job satisfaction[26]. Our protocol allows RTs to utilize their unique skill sets where best suited which can be helpful in busy, high acuity, intensive care units.

Limitations

This project utilized an initiative at a single center, making it potentially non-generalizable to other centers. The Riley Hospital Respiratory scores have not been validated before implementation, also potentially limiting the extrapolation of these findings. Although a recent study by Shein et. al. found that the retractions only score correlated with objective measure of patient work of breathing, the use of NIV and intubation and was comparable to more complex scores[19].

It should be noted, that while the protocol compliance improved over time, for 7 of 16 months of protocol implementation the compliance rate was below our goal of 80% (Fig. 3). Four of those 7 months were near the beginning of protocol implementation where the RT and clinical teams may need time to get more familiar and comfortable using the protocol. While we implemented regular education sessions for RTs, we realize that our protocol compliance reports could have been provided in a timelier manner to the RTs on our team. This could have allowed for more consistent compliance rates and might lead to larger reduction in HFNC duration.

It is possible that other extraneous factors may have influenced our PICU and hospital LOS, such as ward bed availability, ability for patients to tolerate oral intake, and family circumstances which may have prevented the patients from being able to discharge home safely. Several of these extraneous factors can be difficult to monitor and were outside of the scope of this study. It is also important to consider that provider fatigue may lead to decrease in compliance. We did not see this result, but also concluded the continued data analysis in January 2019.

While we had positive results after implementing our protocol, a multi-center quality improvement collaborative project is needed to confirm the benefits of this protocol in other centers with different HFNC practices and RT/clinical teams' staffing models. The safety and efficacy of using a modified version of this protocol (with limitation of maximum flow rate of HFNC) outside the PICU on a hospitalist service needs further investigation. Such modified protocol would free some of the limited PICU beds during months when viral respiratory illnesses can overwhelm PICUs

CONCLUSIONS

A Respiratory therapist-driven HFNC management protocol for bronchiolitis can be successfully implemented in a pediatric ICU. The protocol can decrease HFNC duration, as well as PICU and hospital lengths of stay. Such a protocol improves RT job satisfaction and aids in supporting RTs involvement as vital members of the PICU team.

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FIGURE LEGENDS

Figure 1: Key Driver Diagram for HFNC in PICU

EMR: electronic medical records; RN: registered nurse; HFNC: high flow nasal cannula; PICU: pediatric intensive care unit; RT: respiratory therapist

Figure 2: Riley Hospital HFNC Management Protocol

HFNC: high flow nasal cannula; MD: physician; NC: nasal cannula; RA: room air; RT: respiratory therapist

Figure 3: Run Chart for HFNC Management Protocol Compliance

Figure 3 annotation:

1. Respiratory therapist re-education

Figure 4 A: X-bar Control Chart for Patient's Average Duration of HFNC

Figure 4 B: X-bar Control Chart for Patient's Average PICU Length of Stay (LOS)

Figure 4 C: X-bar Control Chart for Patient's Average Hospital Length of Stay (LOS)

CL: center line; HFNC: high flow nasal cannula; PICU: pediatric intensive care unit; LCL: lower control limit; UCL: upper control limit

Figure 4 annotations:

1. First team meeting to establish the protocol (July 2016)
2. Development of Riley Hospital Respiratory Score (October 2016)
3. Finish electronic medical records protocol integration (August 2017)
4. Finish respiratory therapist education and protocol implementation (October 2017)
5. Respiratory therapist and Auditor re-education (May 2018)

Figure 5 A: Respiratory Therapists' Opinion of Their Involvement in HFNC Management Decisions in PICU

Figure 5 B: Respiratory Therapists' Opinion on How Fast the Team Weaned HFNC

Figure 5 C: Respiratory Therapists' Perception of Barriers to Weaning HFNC Efficiently

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QUICK LOOK

Current knowledge

High flow nasal cannula (HFNC) is a respiratory support modality with increasing usage in acute respiratory failure in pediatric patients. HFNC allows for higher flow rates of oxygen via heating and humidification of the breathing gas when compared with standard O2 therapy. HFNC has been utilized for subjects ranging in age from preterm neonates to adults and in a variety of disease states. The use of HFNC in bronchiolitis has led to decrease in the need for intubation and hospital length of stay when compared to standard O2 therapy.

What this paper contributes to our knowledge

A Respiratory therapist-driven HFNC management protocol for bronchiolitis can be successfully implemented in a pediatric ICU. Implementation can decrease HFNC duration, as well as PICU and hospital lengths of stay.

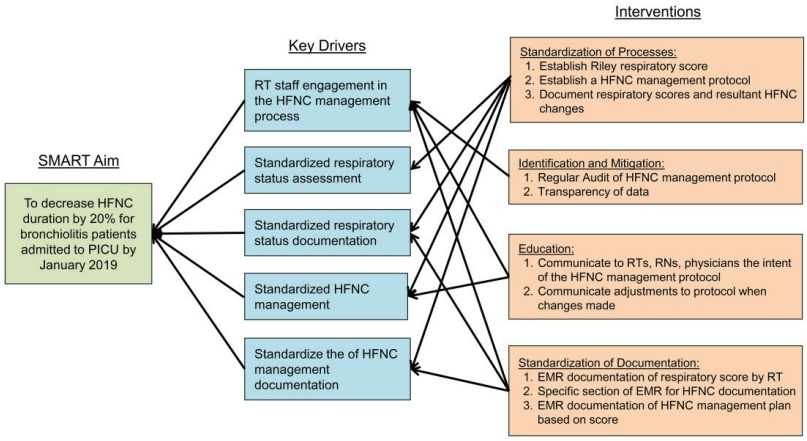

Figure 1-HFNC Key Driver Diagram

TABLE 1: Riley Hospital Respiratory Score

SCORE		0	1	2
Respiratory Rate	<1 year	≤ 60	61-70	> 70
	1-3 years	≤ 40	41-50	> 50
	4-5 years	≤ 34	35-42	>42
	6-12 years	≤ 30	31-38	>38
	≥13 years	≤ 16	17-24	>24
Work Of Breathing	All ages	***0-1 of the following***	***at least 2 of the following***	***2 or more of the following***
		Nasal Flaring	Nasal Flaring	Head Bobbing
		Subcostal Retractions	Subcostal Retractions	Grunting
		Substernal Retractions	Substernal Retractions	Supraclavicular Retractions
		Intercostal Retractions	Intercostal Retractions	Suprasternal Retractions
				Sternal Retractions

Table 2: HFNC Initial Settings and Escalation Guidelines

	Newborn Up to 1-month Yellow Cannula	**Infant** 1-12 months Purple Cannula	**Toddler** 1-5 years Green Cannula	**School-age** 6-12 years Green Cannula	**Adolescent/Adult** ≥ 13 years Clear Cannula
Initial Settings	6 L/min	8 L/min	10 L/min	12 L/min	15 L/min
Soft Escalation Notify PICU Resident	N/A	Increase flow by 2L Q 15-30 minutes to 14L	Increase flow by 2L Q 15-30 minutes to 20L	Increase flow by 2L Q 15-30 minutes to 20L	Increase flow by 5L Q 15-30 minutes to 40L
Hard Escalation Notify PICU Attending/Fellow	Increase flow by 2L Q 15-30 minutes to a maximum of 8L	Above 14L, increase flow by 2L Q 15-30 minutes to a maximum of 20L	Above 20L, increase flow by 2L Q 15-30 minutes to a maximum of 25L	Above 20L, increase flow by 2L Q 15-30 minutes to a maximum of 25L	Above 40L, increase flow by 5L Q 15-30 minutes to a maximum of 60L

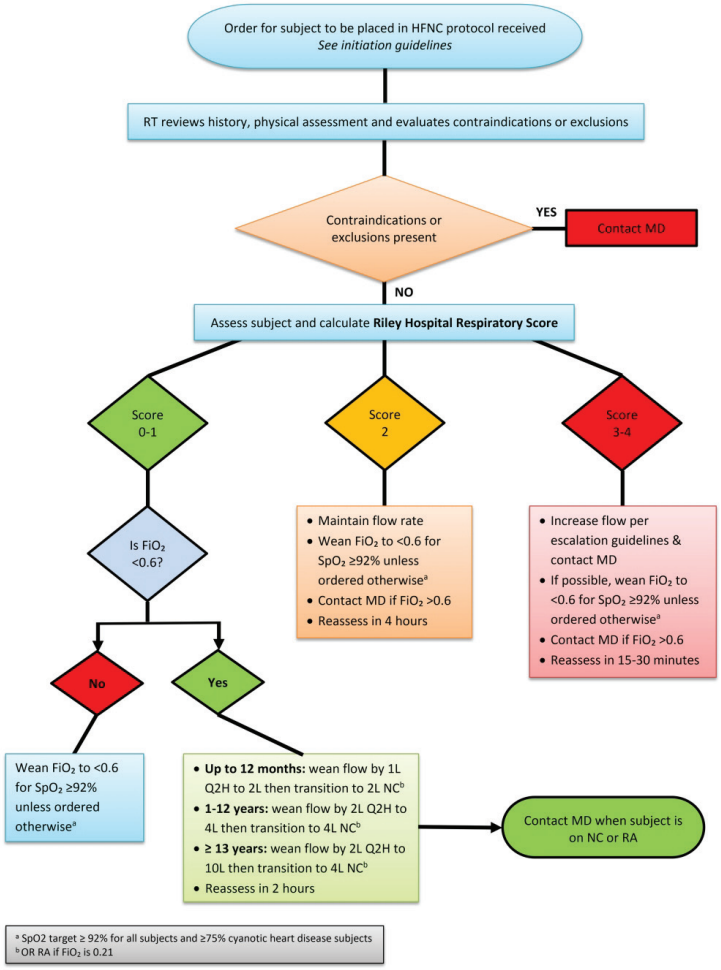

Figure 2-HFNC Flowchart

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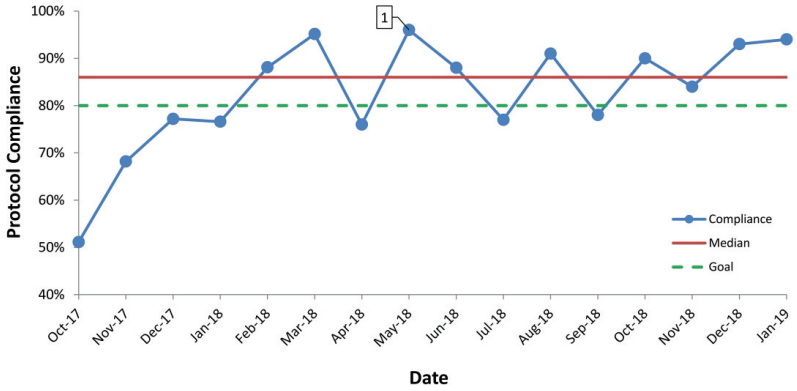

Figure 3-Protocol Compliance

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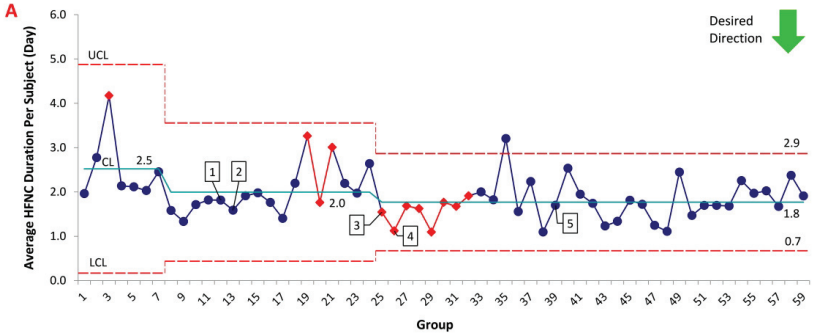

Figure 4 A-HFNC Duration

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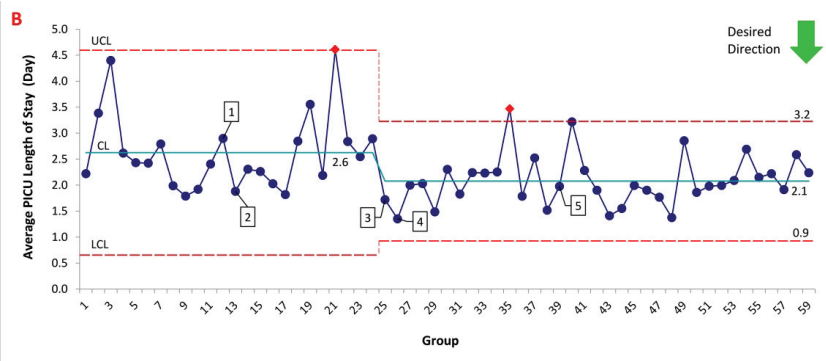

Figure 4 B-PICU LOS

119x51mm (1200 x 1200 DPI)

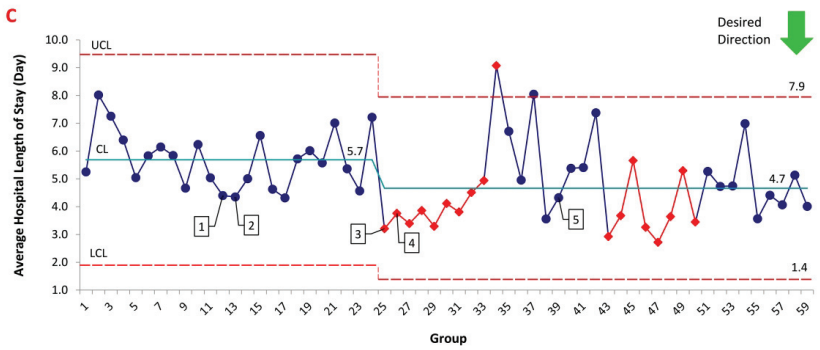

Figure 4 C-Hospital LOS

119x51mm (1200 x 1200 DPI)

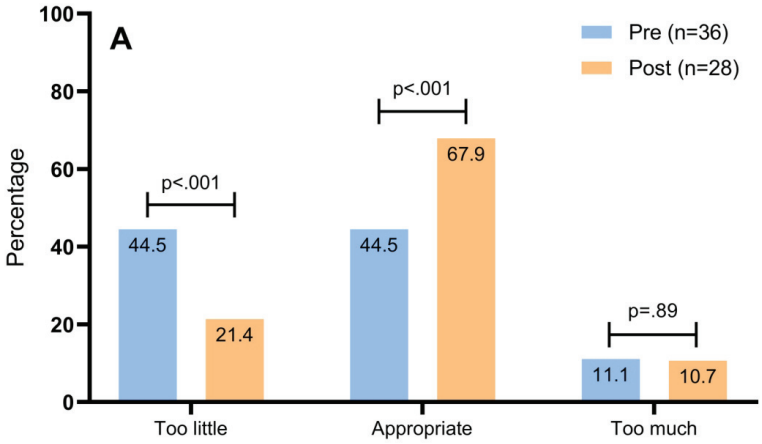

Figure 5 A - RT Satisfaction

150x87mm (300 x 300 DPI)

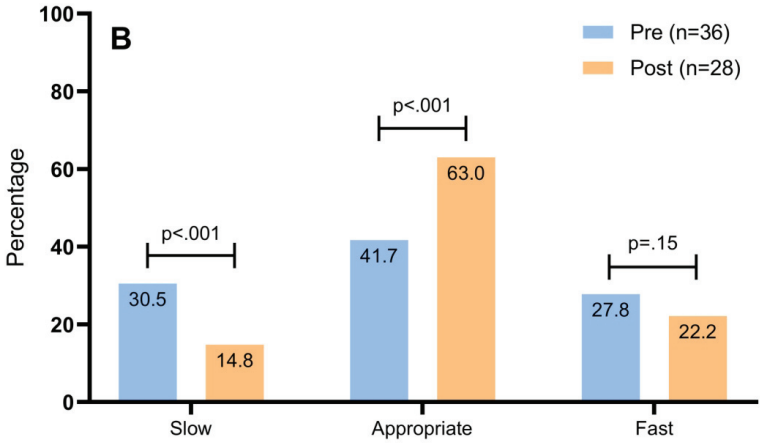

Figure 5 B - RT Satisfaction

150x87mm (300 x 300 DPI)

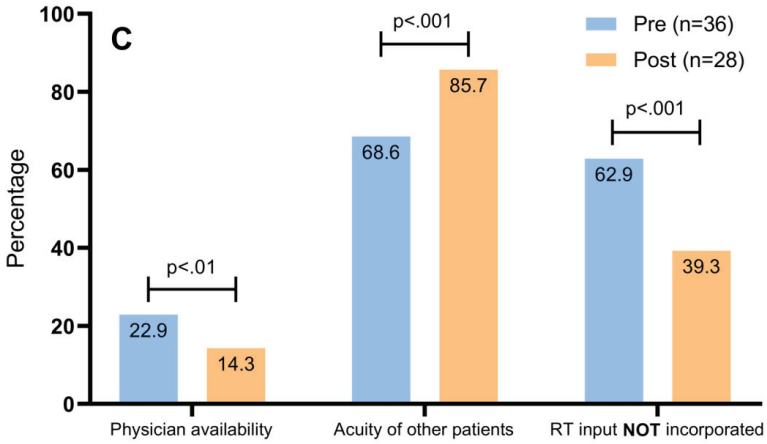

Figure 5 C - RT Satisfaction

150x86mm (300 x 300 DPI)