Identifying infants at risk for Paediatric Intensive Care Unit transfer during High Flow Nasal Cannula on the general ward: an observational descriptive study

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Introduction

Although incidence rates of respiratory insufficiency in paediatrics are unknown, bronchiolitis, asthma and pneumonia are the most common causes for acute hospitalization of infants.[1,2,3] Failure of the respiratory system inhibits normalization of levels of arterial oxygen, carbon dioxide or both. Moreover, the work of breathing increases due to inadequate gas exchange.[4] Indications are fast breathing, nasal flaring, thoracoabdominal paradoxical movement and intercostal-, subcostal-, and stern mastoid contractions.[4] Severe respiratory failure is associated with morbidity and mortality in 30-50% of critically ill infants.[5,6]

Treatment of respiratory insufficiency at general wards is limited, whereas only a maximum of 60-80% oxygen-concentrations can be achieved (10 to 15 L/min). In case intensified therapy is required, children can be transferred to the Pediatric Intensive Care Unit (PICU). The availability of these beds is limited and only eligible for children suffering severe illnesses. Therefore, oxygen support on a general ward becomes more common.

In a pilot-study, Bressan et al showed an increasing application of High Flow Nasal Cannula (HFNC) on general wards.[7] In HFNC a high rate flow (max 70 L/min) of warmed and humidified high concentrated oxygen (max 100%), is provided in a comfortable way through plastic prongs placed in the nares of the infant.[8,9] The gas exchange becomes more efficient, by reducing the work of breathing, in order to perceive a recommended patient saturation of ≥95%.[8,9,10]

Although HFNC becomes more common on a general ward, there is a gap of knowledge as to how to identify deteriorated infants. Early warming instruments could be beneficial for medical staff in discriminating infants at risk for PICU-transfer.[11] Therefore, the Wilhelmina Children Hospital (WKZ) embedded the earlier implemented Bedside Pediatric Early Warning Score (Bedside PEWS, within this study referred to as PEWS) during HFNC on the general ward.[12]

Although PEWS showed the ability to predict deterioration in a general paediatric population, no evidence exists of its applicability during HFNC on a general ward. During validation, the number of vital parameters varied over time. Initially 11 parameters were evaluated (i.e. hearth rate, systolic blood pressure, capillary refill, pulses, bolus fluid, respiratory rate, respiratory effort, saturation, oxygen therapy, level of consciousness and temperature), but 4 items (i.e. pulses, bolus fluid, level of consciousness and temperature) were excluded for further validation in an international multicentre case-control study.[12,13] Generally, nurses score 0, 2 or 4 points to vital parameters that deviate from the age-dependent reference values, in order to monitor the status of the infant. In case a PEWS of 8 was perceived, this cut-off point discriminated deteriorated cases from controls who had no events (sensitivity and specificity, 0.57 and 0.94).[13] Furthermore, temperature was added as eighth parameter (sensitivity and specificity, 0.67 and 0.88).[14] An accurate cut-off point is key to treatment decision-making, improves staff motivation and patient outcomes.[14]

Currently, the HFNC-protocol of the WKZ is deviating from the recommended PEWS of 8, because the oxygen parameter of PEWS is dichotomous instead of continue, as required during HFNC due to fluctuating high oxygen-concentrations. Therefore, this redundant parameter is compensated in the WKZ by adding 2 additional points to PEWS in case HFNC is provided. The total PEWS-score increases from 28 to 30 and therefore, infants in the WKZ, are at risk for a PICU-transfer in case PEWS ≥10.

Adjustments in cut-off PEWS could have consequences for nursing staff. In case of high rates of false-positive PEWS and increased interrelated workload, motivational problems of using PEWS could result in a failure to identify deterioration.[14] Furthermore, as a consequence of the high oxygen-concentrations during HFNC, infants visibly look better in relation to the actual PEWS-score. Therefore, nurses could deviate from the time interval of the HFNC-protocol and become nonadherent. Both consequences jeopardize patient outcomes.[15]

This study could add value to the national guideline ‘HFNC on a general ward’ in The Netherlands by investigating whether a cut-off point of PEWS ≥10 is accurate for clinicians to identify deterioration, the implications of this cut-off point for nursing staff and if oxygen-concentration as additional parameter supports to alarming PEWS in order to identify the risk of PICU-transfers during HFNC on the general ward.

Research question

Primary question of this study: What are the implications of an alarming cut-off PEWS of ≥10 on the general ward in the WKZ, in order to identify infants (aged ≤18) at risk of PICU-transfer during HFNC? Is the cut-off PEWS of ≥10 valid, in order to discriminate between a PICU-transfer or remaining on the general ward? Moreover, what are the consequences of the cut-off value for protocol adherence of nursing staff? Finally, is the provided oxygen-concentration applicable as additional parameter, besides PEWS, to identify increased risk of PICU-transfer?

Methods

Design

A quantitative observational descriptive longitudinal study was conducted between January and July 2017. A cohort of infants, receiving HNFC on the general ward between January 2014 and December 2016, was abstracted and observed. Therefore, these data are retrospective. PEWS-scores and related PICU-transfers were abstracted and dichotomized. Retrospective relationships were statistically analysed and practical implications were described. In addition, protocol adherence of nursing staff was investigated.

Setting

The WKZ is a tertiary referral university hospital with a regional function of paediatric specialities, in the centre of The Netherlands. It was sampled because, an embedded PICU is required when HFNC is applied in the initial phase. PEWS was implemented in December 2012, after clinical staff was educated. HFNC was implemented on 3 of the 4 general wards one year later, December 2013, containing a total of 38 beds in this hospital.

Sample

In order to restrain potential selection bias, all infants receiving HFNC between January 2014 until December 2016, were found eligible using a consecutive sample. Although, the starting location of HFNC could differ between the general ward or the PICU, due to the severity of the respiratory insufficiency at the beginning of the admission, only PEWS registered on the general ward were abstracted. Examples of other diagnoses than respiratory insufficiency were: drowning, cystic fibroses or stem-cell transplants. Cases in which HFNC was provided after surgery or as part of a extubating process were excluded.

In addition, nursing staff adherence to the protocol was investigated. All nursing staff employed between January 2014 and December 2016, at the 3 wards providing HFNC, were found eligible using a consecutive sample. They were specially educated in paediatrics and in the use of HFNC and the HFNC-protocol.

Instrumentation

Two instrumentations were used during this study: PEWS and HFNC-device. HFNC-device of Fisher and Payckel provided two separate options which can be tuned and adjusted both independently: a configuration of flow (2-70 L/min) and high oxygen-concentrations (up to 100%).[3]

PEWS is an early warning instrument with an overall AUROC curve (95% CI), of 0.87 (0.85-0.89).[13] It existed of 8 parameters: heart rate, systolic blood pressure, capillary refill, respiratory rate, respiratory effort, oxygen-saturation, oxygen-therapy and temperature. These parameters had corresponding age-dependent references: 0-3 months; 3 months to 1 year; 1-4 years; 4-12 years and 12 years and older. Therefore, it has been validated for children aged between 0-18 years.[13]

Nurses scored each parameter, rating a score from 0 till 4, and electronically entered PEWS according to protocol (Fig 1). Two parameters had a respiratory focus: oxygen-therapy and oxygen-saturation. In case oxygen-therapy was required 2 points were ranked for 'extra oxygen' and 4 points for a Non-Rebreathing Mask. Oxygen-saturation of >94% was considered normal (i.e. no points), a saturation between 91%-94% received 1 point and <91% was ranked with 2 points. Generally, the absolute range of PEWS is 0 till 28. Taking into account the two additional points, in case HFNC was provided in the WKZ, maximum PEWS increased till 30.

Data collection

Ethical approval for this study was obtained by the Medical Research Ethics Committee (MREC) of the University Hospital Utrecht (protocol number 17-113/C), and concluded that the Medical Research Involving Human Subjects Act (WMO) does not apply.[16] Parental consent was assumed, due to hospital policy, based on an opt-out regulation.

From January 2017 until July 2017, data of eligible children received HFNC on the general ward between January 2014 - January 2017, were abstracted and anonymized. Baseline and clinical characteristics were abstracted such as: age, sex, diagnosis, PEWS, oxygen-concentrations, length of HFNC and vital parameters. In case all missing values of PEWS and/or oxygen-concentrations occurred, infants were excluded.

The prognosis was that infants would be stabilising or a PICU-transfer occurred within 4,5 hours after the start of HFNC (Fig. 2). Therefore, a maximum of four measuring moments were abstracted. Three measures were included: PEWS, oxygen-concentration and vital parameters. Moreover, for each moment the location of the infant was registered (i.e. general ward or PICU). In case infants had more frequent HFNC-admissions, only the first episode with subsequent four PEWS were abstracted. Length of hospitalization, amount of HFNC-days and time intervals between PEWS were calculated, based on the exact time rounded at full and half hours.

The first measuring moment (t0) was before HFNC started. In case the 3 measures lacked or not registered within an hour previous to the start of HFNC, subsequent measures and time intervals were abstracted. For infants that were admitted from the PICU to the general ward, t0 was lacking. HFNC started at the second measure moment (t1). Measures could be observed before or after this start, but within the frame of one hour. If the infant continued HFNC on the general ward, subsequent PEWS were abstracted (t2 and t3).

Outcome measures

Categorical primary outcomes of this study were divided in the occurrence of a PICU-transfer (i.e. yes/no) and corresponded PEWS-score (i.e. ≤9 or ≥10). Furthermore, infants were categorized as PICU-transfers based on alarming PEWS of ≥10 (i.e. true-positive PEWS) and based on a PEWS of ≤9 (i.e. false-negative PEWS), and as infants remaining on the general ward during HFNC with PEWS ≤9 (i.e. true-negative) and PEWS ≥10 (i.e. false-positive). All expressed as numbers and percentages.

Secondary, protocol adherence of nursing staff and oxygen-concentrations were measured as continues variables and expressed as means, standard deviations and in ranges. Protocol adherence was defined as the adherence to predetermined time intervals according to protocol (i.e. before HFNC started, after 1,5 and 3 hours) for both cut-off points (i.e. ≤9 and ≥10). Oxygen-concentrations as additional parameter was defined as correlated with corresponding PEWS in case of a correlation between .30 and .50.

Analysis

Statistical tests and descriptive statistics were performed using quantitative software package, IBM SPSS statistics, version 24.0. Both primary-, and secondary outcomes were two-sided and considered statistically significant in case $p < 0.05$. No correction of missing values was executed due to the descriptive design of the study. Therefore, these cases were excluded from analyses.

A Chi-Square sample size calculation was performed for the dichotomous primary outcomes. Assuming small frequencies of PICU-transfers, Fishers exact estimation was used. Based on a power of 80% and a 2-sided test with a type 1 error of 0.05, the required sample size contained 134 measurements.[17]

Sensitivity and specificity were analysed using a contingency table.

Pearson's correlation coefficient was calculated between oxygen-concentrations and all pews and between alarming PEWS of ≥10.

Results

Sample characteristics

Between January 2014 and January 2017, a total of 117 infants received HFNC on the general ward. During the analyses (Fig 3), 13 cases were excluded because important information was lacking, such as: all PEWS and oxygen-concentrations. Therefore, no missing values occurred and 104 infants were found eligible to include for further analyses.

The sample characteristics are presented in Table 1. Frequency of included infants decreased during the study period, due to infants that were transferred and died at these measuring moments. According to the age-range references of PEWS, the lowest represented category were infants aged 12 years and older (n=11, 11.5%) and the highest category were infants aged between 4 and 12 years old (n=31, 29.8%). Diagnoses of the included children were primarily respiratory insufficiency (n=84, 80.7%). Of this group bronchiolitis and pneumonia occurred mostly (n=34, 32.7%). Other diagnoses such as: cystic fibrosis, drowning or stem cell transplantations, occurred in 19.4% of the infants (n=20). Co-morbidity did not occur in 44% of the infants. Infants with co-morbidity, mostly had a genetic or chromosomal abnormality (n=36, 34.6%). Length of hospitalization varied between 1-32 days (SD 5.24). Most infants had one period of HFNC admission (n=74, 71.2%).

Means, standard deviations and absolute range of PEWS are presented in Table 2. A total of 337 retrospective PEWS were abstracted from medical charts, of which 298 during HFNC (t1, t2, t3) and 39 before HFNC started (t0). A PEWS of ≥10 occurred in 76 cases (22.6%).

Six infants (5.8%) died during their first HFNC-episode. One infant was transferred home included HFNC, palliative treatment was provided in 2 cases. All infants had a treatment limitation consisting of: non-reanimation-, non-breathing and no PICU-transfer policy. Five were male infants and three were aged between 12 and 18 years (50%). One was diagnosed with bronchiolitis, 3 with pneumonia and 2 with other diagnoses. Five infants had a genetic or chromosomal abnormalities in their histories. One had a haematological or oncological comorbidity. The absolute range of PEWS observed within this subgroup varied between 5-13 (SD=1.82).

Primary outcome

A significant association was found alarming PEWS of ≥10 infants that had a PICU-transfer (x^2=10.131, *df*=1, *p*= .001). Results of the primary outcome are presented in Table 2. Furthermore, PICU-transfers occurred in 9 of the 104 included infants (8.7%). Six PICU-transfers (5.8%) were based on an alarming PEWS of ≥10 (i.e. true-positive) and 3 (2.9%)

were based on a PEWS ≤9 (i.e. false-negative). Range of PEWS before PICU-transfer varied between 7-16 (n=9, Mean=10.6, SD=2.3). PICU-transfers were based on a PEWS of 7 (n=1, at t1), PEWS of 9 (n=2, at t1), PEWS of 10 (n=1, at t3), PEWS of 11 (n=4, at t1, t2, t2, t3) and a PEWS of 16 (n=1, t3). Alarming PEWS of ≥10 without PICU-transfer (i.e. false-positive) occurred in 68 of the 298 registered PEWS (22.8%). Therefore, a cut-off PEWS of ≥10 had a sensitivity and specificity of 0.66 and 0.77, respectively. Based on this sample, we would expect the ability of an alarming PEWS of ≥10 to identify the risk of PICU-transfer in 66% of the infants that deteriorated (i.e. true-positive). Moreover, the identification of true-negative cases in 77% of the infants that remained on the general ward without a PICU-transfer.

Secondary outcomes

Thirteen cases were excluded from analyses because nursing staff registered no PEWS or oxygen-concentrations, and therefore they were nonadherent to the protocol. Moreover, 39 of the 104 PEWS were registered at t0 (37.5%), at t1 all infants were scored (100%) and at t2 and t3 this decreased to 100 and 94 infants (100%) due to transfers and infants that died. Frequency of-, and time interval between PEWS are presented in Table 3.

Nursing staff was adhering to the predetermined time interval of 1,5 hours between t1 and t2 in 33 of the 104 cases (31.7%). Of these 33 infants, subsequent time interval of 3 hours between t2 and t3 was registered in 23 of the 100 infants (23%). Alarming PEWS of ≥10 occurred in 16 of the 33 correctly registered infants between t1 and t2 (48.5%, range 10-20). Other infants had a PEWS of ≤9 (n=17, 51.5%, range 6-9). Between t2 and t3, 12 infants of the 23 correctly registered infants had an alarming PEWS of ≥10 (52.2%, range 10-14). Eleven infants had a PEWS of ≤9 (47.8%, range 5-9).

Oxygen-concentrations and alarming PEWS of ≥10 (n=70) were not found significantly correlated r = .128, p .292. A significant correlation was found between all PEWS and oxygen-concentrations r = .221, p .000. Means oxygen-concentrations are presented in Table 4. In case of an alarming PEWS of ≥10 mean oxygen-concentration was 75.56% (n=68, SD=20.29). For a PEWS of ≤9 this was 68.11% (n=230, SD=20.07). PICU-transfers based on an alarming PEWS of ≥10 had mean oxygen-concentrations of 84.83% (n=6, SD=6.64). And PICU-transfers based on a PEWS ≤9 had mean oxygen-concentrations of 87% (n=3, SD=5.10).

Discussion

A significant association was found between PICU-transfers and alarming PEWS of ≥10. Sensitivity and specificity of the cut-off PEWS of ≥10 were 0.66 and 0.77, respectively was found. PICU-transfers occurred in 8.7% of the infants (n=9). Three false-negative PICU-transfers were identified. False-positive PEWS occurred in 22.8% of all PEWS-scores. Nursing staff was nonadherent to the HFNC-protocol in 62.5% of the infants to score PEWS before HFNC started and in 68.3% of the infants within 1.5 hours after HFNC started. Almost 50% of the correctly scored infants had a PEWS of ≥10. Finally, no significant correlation occurred between alarming PEWS of ≥10 and oxygen-concentrations, however all PEWS-scores in total were significantly correlated with oxygen-concentrations.

Before interpretation of these results there are some limitations worth noting. First, the results of this singe-centre study cannot be generalised to other hospitals without an embedded PICU. Second, thirteen cases were excluded from statistical analyses because all required measurements were lacking, therefore no missing data occurred. In order to restrain selection bias, these 13 cases were described as results, since protocol adherence of nursing staff was a secondary outcome. Third, the retrospective design complicated to assess the process of data registration of the nurses by the investigators. Forth, 337 PEWS of 104 infants were abstracted and therefore sensitivity and specificity should be interpreted cautiously. In order to fully interpreted the results, prospectively comparison with other early warning instruments is recommended. Fifth, time to PICU-transfer could have occurred outside the measured time intervals, due to a maximum abstracted PEWS of four in this study. Moreover, variation of time intervals could have occurred because calculated time intervals were rounded of hours and half hours.

The validity of an alarming PEWS of ≥10 during HFNC is questionable. Firstly, significant group differences between PEWS and PICU-transfers suggested a discriminative ability of PEWS between infants at risk of PICU-transfer and those who can remain on the ward during HFNC. However, 3 false-negative PICU-transfers occurred. By decreasing the cut-off PEWS of ≥10 to a cut-off PEWS of ≥9, this might influence protocol adherence of nursing staff by the increased number of false-positive PEWS. Although this percentage in our sample was 22.8%, it was slightly less than the validation study of Fuijkschot et al showed (27%).[14] Therefore, we recommend that an alarming PEWS of ≥10 during HFNC should be taken seriously by clinicians and nursing staff but a low PEWS is poor in ruling out the risk of a PICU-transfer.

Although no previous studies investigated the use of PEWS during HFNC on a general ward, in order to interpret the found sensitivity and specificity of 0.66 and 0.77, a comparison to other studies including PEWS should be made. Parshuram et al validated

PEWS in an internationally multicentre case-control design, using cardiopulmonary resuscitation as endpoint, showing a sensitivity and specificity of 0.57 and 0.94 at a cut-off point of 8.[13] The study of Fuijkschot et al validated a modified PEWS, including temperature, in a general population. Sensitivity and specificity of 0.67 and 0.88, in case of a PEWS of 8.[14] Although the interpretability of alarming PEWS of ≥10 during HFNC is limited due to the design and population as compared to the previously appointed studies, a cut-off PEWS of ≥10 shows the same sensitivity as a PEWS of 8, but is less specific. Therefore, the identification of true-negative infants can be improved by a prospective validation study.

As previously stated, adjusting the cut-off value might increase false-positive PEWS, which can lead to a nonadherence of the nursing staff. Although PEWS-scores of most infants were frequently registered, 13 cases were excluded because all measurements were lacking and reference PEWS before HFNC started, lacked in 62.5% of the infants. In order to increase protocol adherence, an alarming PEWS of ≥10 during HFNC should be maintained and nursing staff should be re-educated on the HFNC-protocol and increase awareness of a reliable reference PEWS for clinical decision-making.

Not only PEWS-scores were lacking, nursing staff was also not adhered to the predefined time intervals. Only 31.7% was scored during HFNC within 1,5 hours and of these infants only 23% were scored within subsequent time interval of 3 hours. Almost 50% of these correctly scored infants had alarming PEWS of ≥10. This might indicate discrepancies between the visible appearance and actual PEWS. Bressan et al expressed the same concerns about the possibility that during HFNC, high oxygen-concentrations could provide falsely reassuring oxygenation of sick infants.[7] Although we investigated if these high oxygen-concentrations were correlated to high PEWS-scores, no significant correlation occurred, possibly due to a small sample size (n=68). However, all PEWS-scores were significantly correlated with oxygen-concentrations. This might indicate that a correlation occurred in case a larger sample size was available. However, the results of the pilot-study of Bressan et al, revealed no escalations of other respiratory supports and a decrease in ETCO2 and respiratory rate, which may identify responders to HFNC.[7] Therefore, these contradicting results provide opportunities for follow-up research.

These findings are generalizable and applicable to secondary care settings due to a diverse mix of infants and large numbers of PEWS-scores, but limited to those without an embedded PICU. Prospective validation including a control group, is recommended to translate the found results to general hospitals. Moreover, patient outcomes could be improved by future investigation for all infants receiving HFNC in different settings, as part of a National guideline to implement HFNC on general wards.

Conclusion

Although 3 false-negative cases were identified, an alarming PEWS of 10 is able to identify the risk of PICU-transfers during HFNC. However, this cut-off PEWS cannot be adjusted in order to maintain protocol adherence of the nursing staff. Therefore, we recommend that an alarming PEWS of ≥10 during HFNC should be taken seriously by clinicians and nursing staff but a low PEWS is poor in ruling out the risk of a PICU-transfer. Follow-up research is recommended to review the consequences for nurses and the applicability of oxygen-concentration as additional parameter.

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Tables and figures

Variable	Results
All participants *n*	104
Age *n (%)*	
0-3 months	13 (12.5%)
3 months - 1 year	23 (22.1%)
1 year - 4 years	25 (24.0%)
4 years - 12 years	31 (29.8%)
12 years- 19 years	12 (11.5%)
Sex *n (%)*	
Male	58 (55.8%)
Female	46 (44.2%)
Length in cm *mean (SD*)	92.31 (33.40)
Weight in kg *mean (SD*)	16.64 (13.36)
Diagnosis *n (%)*	
Bronchiolitis	34 (32.7%)
Asthma/ Viral Wheeze	16 (15.4%)
Pneumonia	34 (32.7%)
Others	20 (19.2%)
Morbidity *n (%)*	
Genetic/chromosomal	36 (34.6%)
Premature	19 (18.3%)
Haematological/Oncological	6 (5.8%)
No abnormalities	42 (40.4%)
PEWS remained on general ward *n (%)*	290 PEWS (95 infants, 91.3%)
Admission PICU *n (%)*	9 (8.7%)
Deceased during HFNC *n (%)*	8 (7.7%)
Resuscitation policy *n (%)*	8 (7.7%)
Tracheostomy *n (%)*	5 (4.8%)
Primary start points *n (%)*	
PICU	32 (30.8%)
General ward	72 (96.2%)
Cut-off PEWS during HFNC n (%)	
≤9	230 (77.2)
≥10	68 (22.8)
Duration HFNC in days *mean (SD)*	5.72 (5.2)
Length of hospitalization in days *mean (SD)*	18.07 (24.1)
Amount of HFNC admissions *mean (SD), n (%)*	1.52 (1.07)
1	74 (71.2%)
2	18 (17.3%)
3	7 (6.7%)
5	4 (3.8%)
7	1 (1.0%)

HFNC= high-flow nasal cannula

Table 1 Demographic and clinical characteristics

	General	**T=0**	**T=1**	**T=2**	**T=3**
PEWS *n*	298	39	104	100	94
2	3			3	
3	8		3	2	3
4	17	1	3	5	9
5	42	4	10	14	18
6	55	3	18	19	18
7	39	6	14	12	13
8	34	11	12	14	8
9	33	4	19	8	5
10	25	2	9	10	7
11	19	1	6	6	7
12	7	3	3	2	2
13	6		2	2	2
14	3	1	1	2	
15	1	1	1		
16	3	1	2	1	2
17		1			
20	1		1		
Pews *mean (range, SD)*	7.58 (2-20, 2.813)	8.64 (4-17, 3.048)	8.11 (3-20, 2.893)	7.44 (2-16,2.735)	7.15 (3-16, 2.751)
Pews remaining on ward *mean*		8.64	7.92	7.29	7.03
Pews admission PICU *mean*		10.0	10.38	10.20	10.67
Pews infants died *mean*		9.50	8.75	8.67	9.5

Table 2 Primary outcome 'PEWS-scores and PICU-transfers'.

Outcomes	**Results**
All measurements lacking *n*	13
Eligible infants for analyses *n*	104
Measuring frequency PEWS *n (%)*	
T0	39/104
T1	104/104
T2	100/100
T3	94/94
Measuring time intervals *n (%)*	
Between t1 – t2	33/104 (31.7%)
Between t2 – t3	23/33 (68.7%)
Correctly registered PEWS *n (%)*	
≤9	17/33 between t1 and t2 (51.5%) 11/23 between t2 and t3 (47.8%)
≥10	16/33 between t1 and t2 (48.5%) 12/23 between t2 and t3 (52.2%)
Time between time intervals in hours *median* (*range)*	
Before HFNC started	2.5 (0.30min – 120)
T0 – t1	1.5 (0.30 min – 10)
T1 – t2	2.5 (0.30 min – 32)
T2 – t3	3.0 (0.30 min – 27.5)

Table 3 Secondary outcome 'protocol adherence'.

Outcomes	**Results**
% oxygen-concentrations *mean (n, SD)*	
T0	9.19 (75, 14.82)
T1	70.88 (104, 20.80)
T2	69.01 (100, 19.43)
T3	68.88 (94, 20.04)
% oxygen-concentrations *mean (n, SD)*	
≤9	68.11 (230, 20.07)
≥10	75.56 (68, 20.29)
% oxygen-concentrations PICU-transfers *mean (n, SD)*	
≤9	87 (3, 5.10)
≥10	84.83 (6, 6.64)

Table 4 Secondary outcome 'oxygen-concentrations'.

Figure 1 Protocol HFNC on general ward

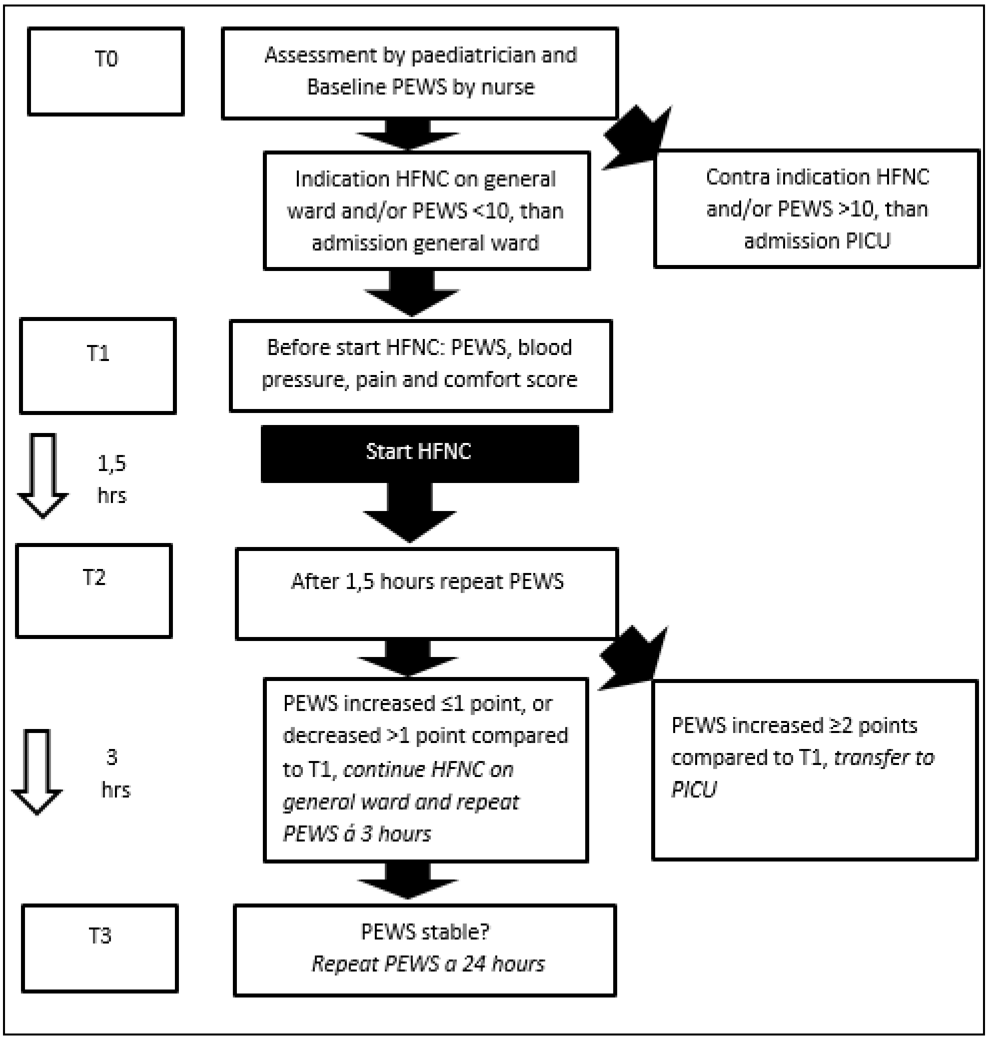

Figure 2 Measuring moments