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Feasibility of high-flow nasal cannula implementation for children with acute lower respiratory tract disease in rural Kenya

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ABSTRACT

Background: High-flow nasal cannula (HFNC) is a well-established respiratory support device in high-income countries, but to our knowledge, its use in sub-Saharan Africa has not been reported. This feasability study describes the implementation process of HFNC in rural Kenya. **Methods**: HFNC was implemented in intensive care and high dependency units at Kijabe Hospital, Kenya for children with acute lower respiratory disease. Rate of intubation was compared with historical controls and challenges of implementation described.

Results: Fifteen patients received HFNC between January and November 2016, and compared to 25 historical control patients. Both groups had many comorbidities, and control patients were significantly younger. There were no significant differences in clinical outcome between the groups: 5 (33%) HFNC vs 12 (48%) controls required intubation; 10 (67%) HFNC vs 22 (88%) controls survived to discharge; and the HFNC required 3 vs the controls' 4 days on respiratory support. The greatest technical issues encountered were large pressure differences between air from a wall outlet (wall air) and oxygen and an inability to automatically refill humidifier water chambers.

Conclusion: HFNC in limited-resource settings is feasible but there were technical challenges and concern about the increased workload. The small sample size, heterogeneous population, availability of oxygen and blending of wall air at the study site limit inferences for other sites in low- and middle-income countries.

Abbreviations: ALRI, acute lower respiratory infection; CPAP, continuous positive airway pressure; ETAT, emergency triage, assessment and treatment; HDU, high dependency unit; HFNC, high-flow nasal cannula; HIC, high-income country; HR, heart rate; ICU, intensive care unit; LMIC, low- and middle-income countries; PSI, pounds per square inch; RR, respiratory rate; mRISC, modified Respiratory Index of Severity in Children.

Introduction

Acute lower respiratory infection (ALRI) is the largest single cause of mortality in children under 5 years in low- and middle-income countries (LMIC), responsible for 880,000 annual deaths [1]. There are many reasons for the poor outcome of ALRI in LMIC including limited and delayed access to healthcare, malnutrition and delay in or lack of basic interventions with antibiotics or oxygen [2]. While it is important to focus on preventative strategies and increased availability of antibiotics and oxygen, simple and effective respiratory support systems in resource-limited settings are needed for children with severe disease.

Non-invasive respiratory support such as bubble-CPAP (bCPAP) has been successful and cost-efficient in supporting neonates and infants with respiratory compromise in limited-resource settings [3–5]. However, CPAP can present challenges including

CONTACT Amélie O. von Saint André-von Arnim 🔯 ameliev@uw.edu © 2018 Informa UK Limited, trading as Taylor & Francis Group cumbersome implementation, difficulty in obtaining adequate facial interface seal, and poor tolerance of tight-fitting interfaces [6]. Heated, humidified highflow nasal cannula (HFNC) is a simple, effective method of providing respiratory support which allows delivery of inspired gas flows ranging from 2 to 70 L/ blend. The World min air/oxygen Health Organization's (WHO) Paediatric Emergency Triage, Assessment and Treatment (ETAT) Guidelines for Emergency Treatment of Hypoxaemia in Limited Resource Settings recommend the addition of effective heated humidification when flows of >4 L/min through nasal cannulae are required for more than 1-2 h [7]. HFNC therapy has been introduced for preterm infants to adults in high-income countries (HIC), but data on its use in children in LMIC are limited [8], and, as far as we know, its use in sub-Saharan Africa has not been reported.

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KEYWORDS

Low- and middle-income countries; respiratory disease; high-flow nasal cannula; respiratory support; global health; pneumonia; children



HFNC was introduced as a feasibility intervention for infants and children presenting with severe acute lower respiratory tract disease to the African Inland Church (AIC), Kijabe Hospital in rural Kenya, 65 km north-west of Nairobi in Kiambu County. Prior to this, non-invasive respiratory support via bCPAP was limited to neonates and small infants. Rescue therapy with intubation and mechanical ventilation is available at Kijabe Hospital. The objective was to safely and effectively introduce HFNC to these settings with the hope of preventing progression to respiratory failure requiring mechanical ventilation, and to relieve severe dyspnoea. A secondary objective was to gather information and observe and discuss the challenges of introducing HFNC to healthcare facilities in resource-limited settings similar to Kijabe Hospital.

Methods

Study site

AIC Kijabe Hospital has 74 paediatric beds. HFNC was implemented in the high dependency (HDU) and intensive care units (ICU), the only areas providing continuous monitoring of vital signs and adequately trained staff to closely monitor patients, allowing for early detection and intervention of treatment failure. During the study period, first three then five HDU beds were available in addition to three paediatric beds in a fivebed mixed adult/paediatric ICU. Kijabe Hospital has its own oxygen plant and the oxygen supply is not limited.

Clinical team and training

Ten of 13 ICU nurses, all ICU clinical officers, 5 of 8 HDU nurses and all 5 full-time paediatricians were trained in the use of HFNC through lecture-based and hands-on training, followed by written and practical assessments. One dedicated HFNC nurse received additional HFNC training and was available for ongoing HFNC training and support on week days.

Inclusion and exclusion criteria

HFNC was offered to patients aged 2 months to 14 years who presented with ALRI or asthma, who met the WHO criteria for severe pneumonia [9] and who required admission to the HDU or ICU. Patients with pre-existing abnormal central respiratory drive, congenital airway abnormality, pre-existing pneumothorax/respiratory air-leak syndrome or nasal/facial abnormality interfering with the HFNC application were excluded.

Equipment

Despite higher prices than in the USA, some equipment and supplies were purchased from the Kenyan Fisher-Paykel (F&P) distributors (Asterisk Ltd, Nairobi, Kenya) in order to allow for long-term local equipment service contracts. The equipment used for the study included MR850 heated humidifiers (F&P), RT330 Optiflow circuits (F&P) for infants and children with RT316 infant and RT318 paediatric optiflow nasal cannulae (F&P) and RT2019 circuits (F&P) for older children and adolescents with small (OPT 542), medium (OPT 544) or large (OPT 546) cannulae. The oxygen blenders (Bird) with a flow range of 2–120 L/min were used for blending oxygen with air from a wall outlet (wall air).

Intervention

From late January to early November 2016, HFNC was introduced using a weight-based titration protocol derived from the published literature and in discussion with global HFNC experts [6,10,11] (see Appendix 1, Kijabe HFNC Flow Chart; and Appendix 2, HFNC Kijabe Flow and Cannula Table). The protocol was based on HFNC initiation at the highest flow rate deemed safe per patients' weight, with structured intervals for assessment and weaning and, if necessary, a re-escalation arm as described in the HFNC Protocol for Clinial Staff (Appendix 3). No other changes were made to the clinical management of HFNC patients. Bundle implementation according to the protocol was checked by the HFNC nurse. The main safety checks during HFNC initiation included use of the correct HFNC flow rates and patient re-evaluation by the treating physicians and nurses 1 h after commencement to rule out the need to escalate respiratory support.

Patients on HFNC were assessed and basic vital signs including oxygen saturation were observed every 2 h as per the local ICU/HDU standard, and more frequently if there was clinical deterioration. When respiratory status worsened, necessitating intubation, HFNC was discontinued.

Severity of illness scoring

The modified Respiratory Index of Severity in Children (mRISC), a severity of illness score validated in Kenya for respiratory patients <5 years of age, was measured on admission [12]. The score ranges between 0 and 6 (0 best, 6 worst), with a predicted mortality of nearly 40% for mRISC \geq 3. Parameters for other severity of illness scores are not routinely available in Kijabe Hospital.

Feedback

At the end of the intervention, an anonymous written survey of HFNC users assessed their experience of its use.

Data analysis

The primary outcome was the rate of intubation during the entire hospital admission compared with historical controls. Secondary outcomes included survival to discharge and number of days on respiratory support. Data were also collected for a control group of patients admitted to ICU/HDU for acute lower respiratory tract disease prior to the introduction of HFNC (July to December 2015). Respiratory and heart rates in HFNC patients before and 2 h after initiation of HFNC were compared. Adherence to the HFNC protocol and adverse events related to HFNC were recorded.

Data were summarised using counts (%) for categorical variables and means (SD) for continuous, normally distributed variables; skewed continuous variables were summarised by medians and interquartile ranges. Baseline characteristics for HFNC patients were compared with controls using Fisher's Exact test for categorical variables, the *t*-test for continuous, normally distributed variables and the Wilcoxon rank sum test for skewed continuous variables. Outcomes were compared between cases and controls using multivariate regression for continuous variables and logistic regression for binary variables, and the models were adjusted for age. Skewed continuous variables were log-transformed before analysis.

Regulatory compliance

An exempt status was determined by the Seattle Children's institutional review board (IRB) for HFNC implementation. The Kijabe providers did not require IRB approval for HFNC implementation since it was considered to be a new standard of care. IRB approval was obtained from Seattle Children's and AIC Kijabe Hospital for mRISC implementation and to collect pre-HFNC data on control patients.

Results

During the intervention period, 15 patients received HFNC support. Pneumonia was the most common admitting diagnosis (Table 1). The majority of patients had multiple comorbidities. mRISC scores in children <5 years old were 2.8 (1.7) for intervention and 2.3 (2.1) for controls (p = 0.18). The intervention group patients were significantly older than the controls (p < 0.001).

Five HFNC patients (33%) required intubation and mechanical ventilation (Table 2) compared with 12 (48%) controls (p = 0.54). Ten HFNC patients (67%) survived to discharge compared with 22 (88%) controls (p = 0.24). Mean (SD) duration of HFNC therapy was 2.4 (1.5) days. Patients in the HFNC group received 3.0 (2.0–6.5) days of respiratory support total (oxygen via nasal cannula/face mask, HFNC or intubation with mechanical ventilation) compared with 4.0 (2.8–6.5) days pre-HFNC (p = 0.27). Heart rate (HR) and respiratory rate (RR) did not change

Table 1. Demographic	and	baseline	characteristics	of	HFNC
and historical controls.					

	Controls	HFNC patients	р-
Characteristics	n = 25	n = 15	value
Age, yrs, median (IQR)	0.75 (0.58–1.38)	3.0 (1.46-6.00)	<0.001
Male, n (%)	13 (52)	13 (87)	0.040
Admission diagnosis (not	20 (80)	11(73)	
mutually exclusive):	3 (12)	3 (20)	
Pneumonia	2 (8)	1(7)	
Asthma			
Bronchiolitis			
Comorbidities, n (%)	21 (84)	10 (67)	0.72
Severe acute malnutrition	10 (40)	3 (20)	
Tuberculosis	10 (40)	2 (13)	
Rickets	7 (28)	2 (13)	
Development delay, cerebral palsy,	4 (16)	7 (43.8)	
hydrocephalus			
Urinary tract infection	3(12)	2 (13)	
Cardiac disease (congenital and	2(8)	3(20)	
acquired)	a (a)	a (1a)	
Pulmonary hypertension	2 (8)	2 (13)	
Seizures or status epilepticus	2(8)	2 (13)	
Hypocalcaemia	2(8)	2 (13)	
Sepsis	2(8)	1(7)	
Diarrhoea	1(4)	1(7)	
HIV	1 (4)	0 (0)	
mRISC on admission ^a , median (IOR)	1.0 (1.0–3.0)	2.5 (2.0–3.8)	0.18

Results are expressed as n (%) unless otherwise stated. ^aChildren <5 years of age.

^amRISC is determined by history of presenting illness (unconscious child, inability to drink/breastfeed = 1 point each, night sweats = -1 point), physical examination (chest wall indrawing = 1 point, not alert/ active = 2 points) and presence of comorbidities (diagnosis of malaria = -1 point, malaria and chest-wall indrawing = 1 point, dehydration = 1 point, malnutrition with Z-score $\leq 2 = 1$ point)

 Table 2. Outcome in patients with acute respiratory tract

 disease before and after implementation of HFNC.

Variable	Controls, n = 25	HFNC patients, n = 15	<i>p</i> - value
Days on respiratory	4.0 (2.8–6.5)	3.0 (2.0–6.5)	0.27 ^a
support			
Days on HFNC	-	2.0 (1.0-3.0)	-
Intubation required, n (%)	12 (48)	5 (33)	0.54 ^a
Days on ventilator	4.0 (2.8–6.5)	2.0 (2.0-4.0)	0.38 ^a
Days in ICU	2.5 (2.0-3.8)	2.5 (1.0-4.0)	0.40 ^a
Survival to discharge, n (%)	22 (88)	10 (67)	0.24

Results are expressed in median (IQR) unless otherwise stated. ^aAdjusted for age.

significantly between admission and 2 h after initiation of HFNC: mean (SD) HR was 145 (26) beats/min on admission and 136 (26) at 2 h (p = 0.25), and RR was 45 (14) breaths/min on admission and 41 (11) at 2 h (p = 0.09).

No clear adverse effects secondary to HFNC were reported. One patient with previous chest radiography excluding air leak developed a pneumothorax and pneumo-mediastinum after cardiac arrest secondary to hypocalcaemia followed by aggressive bagmask ventilation and chest compression. Detailed case review by the Kijabe team suggested that the air leak developed secondary to chest compression and bag-mask ventilation at high pressure during resuscitation. The Kenyan clinical team thoroughly reviewed all clinical data on HFNC patients who required advanced airway support or who died: all of these patients underwent a period of clinical improvement on HFNC and were deemed to have deteriorated because of other comorbidities such as septic shock, severe electrolyte imbalance or status epilepticus.

HFNC technical issues

Sterile or distilled water bags required for auto-refilling the humidification chambers were not available in Kenya. Hence, additional nursing training in monitoring/manually refilling these chambers every 2 h with vital sign checks was required. Checking that water levels were within pre-set demarcations in the humidification chamber was straightforward but refilling the water chamber manually with distilled water from canisters increased the nurses' workload.

The oxygen blenders had been successfully tested at Seattle Children's Hospital but on connection to wall air and oxygen in Kenya they constantly alarmed. According to the operator manual, a large pressure difference between wall air and oxygen was assumed with this type of alarm and confirmed by connecting a ventilator to air and oxygen wall outlets and measuring their respective pressures with a resulting pressure difference of >20 PSI. A local engineer helped find and install an oxygen pressure regulator (Gentec) at the oxygen wall outlet to adjust the high oxygen pressure from the hospital's oxygen plant.

Flowmeters for flows greater than 15 L/min could not be connected to wall outputs in the HDU and this was overcome temporarily by connecting larger flowmeters to oxygen tanks, requiring frequent refilling of oxygen tanks, especially for patients requiring higher air flows.

No equipment maintenance issues were encountered and the equipment remains functional now.

Since the enrolment rate was slow in the first month, the HFNC nurse conducted 4 formal training sessions throughout the study period to retrain 16 nurses and keep technical skills up-to-date.

HFNC bundle compliance

For the implementation phase, maximal flow rates could not be achieved for four HDU patients for whom large flowmeters could not be connected to wall outlets, limiting maximum flow rates to 15 L/min. Three of these patients improved on lower HFNC flow settings; one required transfer to the ICU for up-titration of HFNC flow and, eventually, intubation and mechanical ventilation. For the weaning phase, one patient improved quickly and needed to be moved out of the ICU/HDU which had limited beds, leading to faster weaning than recommended but without any sequelae. HFNC re-escalation was initiated in two patients, eventually leading to intubation and mechanical ventilation.

Staff survey

Eight months after implementation of HFNC, 20 medical staff including doctors, clinical officers and ICU/ HDU nurses were surveyed regarding their opinion on the use of HFNC: 100% rated it easy-to-use and 14 (75%) thought their patients were comfortable on this support. Nineteen (95%) responses were generally positive about HFNC which was considered to be a useful tool that might help avoid mechanical ventilation and decrease the number of ICU beds required. All five paediatricians were concerned about HFNC use outside monitored sites (ICU/HDU) and about enhanced nurse training, especially given the frequent nursing turnover, a common problem in Kenya. Seven (50%) of the ICU/HDU nurses surveyed pointed out the increased workload related to frequent refilling of the of humidification chambers, but the physicians did not think that their workload had changed.

Discussion

This report describes the feasibility and challenges of implementing HFNC in a resource-limited setting in sub-Saharan Africa and the several technical and safety issues which need to be considered. They include close clinical monitoring capabilities, possibly with increased nursing staff to account for a potentially greater workload; ideally, the skills and resources for invasive respiratory support in case of HFNC failure; the availability of oxygen and the ability to blend it; HFNC experts on site for ongoing education, technical support and quality assurance; and reliable local suppliers of HFNC equipment and its maintenance.

While this study was conducted in a small, heterogeneous sample, it provides a framework for training in the use of and implementing HFNC. Patient outcomes were not worse than with standard care and no clear adverse events were observed. Since this feasibility intervention was commenced, HFNC has become the standard of care for non-invasive respiratory support beyond low-flow oxygen for paediatric HDU/ICU patients at Kijabe Hospital, albeit intermittently limited by a lack of HFNC supplies.

Several reports suggest that LMIC healthcare providers can be trained in a single day to use noninvasive, positive-pressure ventilation [5,13,14]. Our results suggest that ongoing training would be beneficial, especially where staff turnover is high. A dedicated provider responsible for training and for HFNC equipment was helpful in this study.

As with any non-invasive ventilation strategy, HFNC may delay more invasive management (where available)

in cases of respiratory decompensation. In children, the risk of HFNC failure ranges from 8% to 19% [6,15]. Hence, appropriate levels of monitoring and staffing are key. HFNC failure needs to be considered early, especially in LMIC settings where intubation and mechanical ventilation may not be available. Further data are needed, particularly for HFNC re-escalation, to define treatment safety margins in LMIC.

Only Christi et al. have reported on HFNC in LMIC [8]. In their single-centre trial in Bangladesh, hypoxaemic children with pneumonia were randomised to receive bCPAP, HFNC or low-flow nasal cannula. Rates of subsequent mechanical ventilation and mortality were lower for bCPAP than for HFNC and low-flow nasal cannula, but the trial was stopped before reaching the required sample size to determine the superiority of CPAP over HFNC. Unlike the Kijabe experience, the administration of HFNC was found to be more difficult than that of CPAP.

This study has a number of limitations which include the small sample size and a historical and significantly younger control group from different seasons, but both included a rainy period with a surge in viral illnesses, a lack of validated severity of illness scores for patients >5 years, a heterogeneous patient population with multiple co-morbidities and the quality improvement approach. These factors limit the inferences that can be drawn from this feasibility study. The need for oxygen, blended air and reliable electricity may limit the use of HFNC in settings more poorly resourced than Kijabe Hospital. Cost-effectiveness analyses, essential in this context, were not performed. Nonetheless, the study provides a strong rationale for conducting larger RCTs to further evaluate the feasibility, safety, clinical efficacy and cost-effectiveness of HFNC in LMIC.

In this pilot implementation of HFNC involving 15 children, HFNC was feasible and acceptable, but was resource-intense and posed technical challenges.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Appendix 1. Kijabe HFNC Flow Chart



Appendix 2. HFNC Kijabe Flow and Cannula Table

	Patient weight (kg)									
-	3–4	5–6	7–8	9–10	11–14	15–20	21-40	41–50	51–60	≥61
Max HFNC flow (L/min)	5	10	14	18	20	25	30	35	40	45
HFNC cannula sizea (with maximal deliverable flows)	Infant (0.5–20 L)	Infant (0.5–20 L)	Infant (0.5–20 L) or paediatric (0.5–25 L)	Infant (0.5–20 L) or paediatric (0.5–25 L)	Paediatric (0.5–25 L)	Paediatric (0.5–25 L	Small adult) (3–45 L)	Small/ medium adult (3–45 L)	Small/ mediun adult (3–45 L	Small/medium/ n large adult (3–45 L) _)
Patient circuit		RT	330 Optiflow tubing kit		14 250/		RT219	9 tubing kit		
Patient circuit		RT	330 Optiflow tubing kit		24 250%		RT219	9 tubing kit		

aFive sizes of nasal cannula are available: the RT316 infant (3–15 kg) and RT318 paediatric (12–22 kg) optiflow and small (OPT 542), medium (OPT 544) and large (OPT 546) adult Optiflow cannulae with max flow rates specified above. Do not use flows outside the specified range for the specific nasal cannula type. The choice of best nasal cannula size will depend on patient size as well as facial anatomy with the aim to occlude 50% of the nares with the cannula.

Appendix 3. Kijabe HFNC Protocol for Clinical Staff

HFNC general guidelines for HFNC clinical staff:

- 1. HFNC can only be used as part of this HFNC intervention.
- 2. Perform daily equipment checks.
- 3. HFNC patient circuits and nasal cannulas are for single patient use only.

HFNC Initiation

Initiate HFNC on patients who meet inclusion criteria, and are admitted to HDU or ICU with failure of respiratory support by maximal face mask or low-flow cannula oxygen only (see Kijabe HFNC Flow Chart—Appendix 2).

HFNC initiation algorithm

• Check if CXR was done and air-leak syndrome excluded.

- Prior to HFNC initiation, document patient's RR, HR, oxygen saturations, mental status (AVPU), degree of chest in-drawing/ accessory muscle use (mild, moderate, severe).
- Make patient NPO. Nasogastric or nasoduodenal feeds are required for all patients on HFNC.
- Start HFNC at maximal flows and with correct cannula size per weight per HFNC Kijabe Flow and Cannula Table (Appendix 2).
- Monitor and document before HFNC initiation:
- o RR, oxygen saturation, HR, mental status (AVPU), accessory muscle use (mild/moderate/severe).
- Perform a patient re-evaluation by all key-players in the patient's care (doctor, nurse) after 60 min of HFNC to make decisions on next steps:
 - (a) Start maintenance protocol if the patient appears clinically stable or improved as per clinician assessment.
 - (b) If the patient appears **clinically worse or unstable** after up to 1 h on HFNC, the treating doctor should escalate management at their discretion.
 - (c) If the decision is made to continue HFNC in **an unstable/worsening patient**, continue with every 30– 60 min monitoring, and do not start maintenance protocol. Further management decisions are up to the treating physician.

HFNC Maintenance algorithm

(1). Monitor and document the following signs and symptoms **every 2 h** for the remainder of HFNC treatment duration, unless HFNC support is being weaned or escalated (see weaning and escalation protocol):

- RR, oxygen saturation, HR, mental status (AVPU), accessory muscle use (mild/moderate/severe).
- 2. Keep patient on maintenance protocol for at least 4 h before starting the weaning protocol.

HFNC Weaning

Consider weaning HFNC flow and FiO2 once patient is clinically improving and has been on maintenance protocol for at least 4 h.

HFNC weaning algorithm for clinical staff

- 1. Wean oxygen as tolerated for O2 saturations \geq 90%,
- 2. Wean HFNC flows by 1-2 L/min every 2-4 h as tolerated to the lowest flow of 2 L/min if:
- i. O2 saturations >90% on less than 50% FiO2 AND
- ii. mild or moderate respiratory distress (not severe distress) AND only one of the two other severe pneumonia criteria are present
- iii. lethargy or reduced level of consciousness OR
- iv. RR in 2–11 months of \leq 50 breaths/min;
 - RR in 1–5 years, \leq 40 breaths/min;
- RR in 6–14 years, <30 breaths/min),
- 3. Monitor and document every 2 h:
 - RR, oxygen saturation, HR, mental status (AVPU), accessory muscle use (mild/moderate/severe).
- 4. If patient is clinically worsening, and meeting more than 1 out of 4 severe pneumonia criteria (see above), stop weaning and start escalation protocol if no other causes can explain the clinical change.
- 5. Check nasal cannula patency and need for suctioning if patient unexpectedly decompensates.
- 6. Once at HFNC of 2 L/min on pediatric cannula or 5 L/min adult cannula, transition to 1–2 L/min regular nasal cannula oxygen or face mask.

Escalation

Start escalation of HFNC flow when patient is worse after weaning and more than one out of four severe pneumonia criteria are met.

a. If >1 out of the following 4 severe pneumonia criteria met, start escalation protocol:

- i. O2 saturations <90% on \geq 50% FiO2,
- ii. severe respiratory distress,
- iii. presence of lethargy or reduced level of consciousness,
- iv. RR in 2–11 months of \geq 50 breaths/min;
- RR in 1–5 years, ≥40 breaths/min;
- RR in 6-14 years >30 breaths/min).

HFNC escalation protocol for clinical staff

- 1. Check nasal cannula patency and suction airways as necessary. If no improvement, escalate HFNC flows.
- 2. Do NOT escalate above maximal flows per weight (per HFNC Kijabe Flow Chart).
- 3. Escalate to most recent HFNC setting prior to last wean.
- 4. Monitor patient at least hourly for 1 h after escalation of HFNC flow.
- RR, oxygen saturation, HR, mental status (AVPU), accessory muscle use (mild/moderate/severe)
- 5. If patient is stable or improved after 1 h of escalated HFNC, start maintenance protocol.
- 6. If patient is not improved, escalate to **maximal HFNC flows per weight**, followed by at least hourly monitoring, **call the treating doctor and follow the doctor's instruction**.
 - If patient improves, may start maintenance protocol in discussion with treating doctor.
 - If the patient remains on HFNC despite clinical worsening, continue at least every 1 h monitoring until patient improves or requires intubation per the treating physician's discretion.