IM[PLEMENTATION OF HIGH FLOW NASAL CANULA VENTILATION IN KENYATTA NATIONAL HOSPITAL PAEDIATRIC INTENSIVE CARE UNIT

PRINCIPAL INVESTIGATOR:
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DEPARTMENT OF PAEDIATRICS AND CHILD HEALTH,

A research Project submitted in partial fulfillment of the requirements for the award of the degree of Fellowship in Paediatrics Intesive Care Unit, Department of Pediatrics and Child, Faculty of Health Sciences, University of Nairobi.

2023

DECLARATION

I confirm that this project is original work and has not been submitted elsewhere for approval

Signature:  **Date:** 23rd October 2023

Dr. Brenda Mukami Kunga

Supervisor Approval

Signature:  **Date:** 23rd October 2023

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LIST OF ABBREVIATIONS

ALRI acute lower respiratory infection

CME continuous medical education

CPAP continuous positive airway pressure

HFNC high flow nasal canula

HVNI high velocity nasal insufflation

IMCI intergrated management of childhood illnesses

KNH Kenyatta National Hospital

LMIC lower and middle income country

MRISC modified respiratory illness severity score

OJT on job training

PICU paediatric intensive care unit

REDCAP research electronic data capture

RCT randomized control trial

SOT standard oxygen therapy

WHO World Health Organisation

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INTRODUCTION

Acute lower respiratory infections (ALRI) such as pneumonia account for 880,000 annual deaths in children under 5 in in LMIC.[1] Kenya is among the top 15 countries in Sub Saharan Africa, with the highest number of deaths from pneumonia, with the mortality rate currently 50.3 per 10000 under-fives per year.[2]

While some of these patients can be managed with antibiotics and supplemental oxygen, children with severe disease often require a higher level of respiratory support and equipment. Low flow supplemental oxygen in severe disease is inferior to devices that deliver oxygen with pressure such as continuous positive airway pressure (CPAP) which are effective at treating otherwise refractory hypoxemia. However, CPAP has challenges including difficulty with implementation, inability to obtain an adequate nasal/facial interface seal and poor tolerance by children. These challenges usually imply an escalation to invasive ventilation when low flow oxygen supplementation has failed to improve hypoxia.

A newer therapy currently in use termed High flow Nasal Cannula (HFNC) and the analog, High Velocity Nasal Insufflation (HVNI) [3,4] are a safe and effective method of providing not only improved oxygenation but also enhanced ventilation by delivering of warm, humidified, inspired gas at higher flow rates than a traditional nasal cannula. Enhanced ventilation results from flushing out exhaled carbon dioxide from the upper airways between breaths.[3] This combination of improved oxygenation and ventilation has the potential to save children at risk with acute lower respiratory infections. It is well-tolerated because of its greater comfort and ease of use. [3]

HFNC has been shown to be feasible in lower, and middle-income countries (LMICs).[4] It has been used extensively in high-income countries for respiratory support during periods of acute distress. HFNC could have a significant impact on child mortality In LMICs where the burden of morbidity and mortality from respiratory disease is greater. [5] The challenge is to provide the resources needed to implement the technology. This includes compressed oxygen and distilled water in rural locations. New solar-powered technology has made this feasible.

BACKGROUND

Pneumonia is a leading cause of death in children under 5 in Kenya. Appropriate and timely treatment is imperative to reduce child mortality. Children with severe ALRI often require further respiratory support by non-invasive or invasive ventilation. HFNC represents a standard of care which has been used successfully in higher income countries. It may lessen the need for mechanical ventilation which remains a significantly limited resource in our setting.

The implementation of HFNC in pneumonia may provide escalation of respiratory support from low flow oxygen supplementation and possibly avoid the use of mechanical ventilation or the requirement of intensive care.

HFNC MECHANISMS OF ACTION

There are many beneficial mechanisms of action that have been attributed to the effectiveness of high-flow nasal cannula in adult and pediatric patients with respiratory failure. It is not clear which of the benefits are most important, and it may depend on the individual patient's etiology of respiratory failure.

Heated and Humidified

Heated and humidified oxygen has several benefits compared to standard oxygen therapy. Standard oxygen therapy delivered through a nasal cannula or another device, such as a non-rebreather mask, delivers cold, dry gas. This cold, dry gas can lead to airway inflammation, increase airway resistance, and impair mucociliary function, possibly impairing secretion clearance. Also, a significant amount of energy is expended by individuals to both warm and humidify gas during normal breathing [2]. Thus, heated and humidified oxygen may improve secretion clearance, decrease airway inflammation, and also decrease energy expenditure, particularly in the setting of acute respiratory failure [2]

Inspiratory Demands

HFNC can deliver very high flow rates of gas to match a patient's inspiratory flow demands. This is important as patients in acute respiratory failure can become extremely tachypneic, and their peak inspiratory flows (PIF), which may normally be 30 L/min - 60 L/min at rest, can reach upwards of 120 L/min in acute respiratory failure. [3] If these patients with respiratory failure (with PIF rates of up to 60 - 120 L/min and high minute volumes (> 20 L/min in some adults)) are placed on a 15 L/min NRB mask, then this may not provide adequate support. One of the main mechanisms to improve a patient's work of breathing is to attempt to match their peak inspiratory flow demands with the use of a high-flow device.

Functional Residual Capacity

There is some debate over the level of positive end-expiratory pressure (PEEP) provided by high-flow devices. Best estimates are 1 cm H_20 of PEEP for every 10 L/min of flow delivered with closed mouth breathing [4]

There has been a lot of variation in studies measuring how much PEEP that high-flow cannulas can generate. This may vary from patient to patient as there are many factors that can affect how much PEEP can be delivered to a patient. Factors, such as the patient’s size (obese, adult, child), the liter flow rate being delivered (L/min), and mouth open versus mouth closed breathing (pressure may escape when a patient's mouth is open), can all affect the amount of PEEP being delivered [4]

The debate can continue, but it appears that HFNC can increase a patient’s functional residual capacity (FRC) or the lung volume at the end of expiration, which is something that PEEP usually improves. A study by Riera et al. showed the use of HFNC increased end-expiratory lung impedance (EELI), implying there was an improvement in FRC [5] They used electrical impedance tomography (EIT), a noninvasive, real-time imaging method that provides a cross-sectional ventilation image of the lung, to demonstrate an increased EELI.

It also appears that the use of HFNC can decrease preload by increasing intrathoracic pressure, again another feature commonly attributed to the addition of PEEP. Roca et al. demonstrated in a sequential interval study on 10 patients (New York Heart Association

(NYHA) Classification III - heart failure but not in an acute congestive heart failure (CHF) exacerbation) that the use of HIFLOW caused an inspiratory collapse of the inferior vena cava (IVC) from the patient's baseline which was measured by echocardiogram [6].

High-flow nasal cannula use seems to cause alveolar recruitment and increased FRC, as well as increased intrathoracic pressure, likely because of the added PEEP; however, it is not certain if perhaps another mechanism may be responsible for these findings.

Lighter

Patients often prefer the use of HFNC to that of non-invasive continuous or bilevel positive pressure ventilation (CPAP or BPAP) because the tight-fitting mask can be uncomfortable for some patients. They may even prefer it to the standard nasal cannula (NC) because of the warmed, humidified gases that won't dry their mucosa like standard oxygen therapy [7]. This may lead to higher compliance with HFNC and perhaps an improvement in the patient's oxygenation and work of breathing.

Washout of Dead-space

We can normally rebreathe a third of our previously expired tidal volume, and instead of breathing 21% (room air) and negligible amounts of carbon dioxide, we may rebreathe more like 15 - 16% oxygen and 5 - 6% carbon dioxide. This is because the previously exhaled breath (low in oxygen and containing carbon dioxide) is not fully exhaled and remains in the upper airway. When the patient takes their next breath from atmospheric gas, not all that gas will actually enter the alveoli. In fact, it's a mixture of the new atmospheric gas (21% FiO_2, negligible CO_2) and their previously exhaled gas (< 21% oxygen with a larger amount of CO_2) that enters the alveoli for gas exchange. In patients with acute respiratory failure, the percentage of gas we rebreathe gets larger, and as a result, we can rebreathe larger amounts of carbon dioxide as we inspire from a mixed reservoir from our upper airway.

One of the major benefits of HFNC (some argue it's actually the main benefit) is that it gives you a continuous flow of fresh gas at high-flow rates replacing or washing out the patient's pharyngeal dead-space (the old gas low in oxygen and high in CO_2). Each breath that the

patient now re-breathes with high-flow nasal cannula will have had its carbon dioxide washed out and replaced with oxygen-rich gas and thus improving breathing efficiency

Fig 1: Benefits of HFNC reproduced from REBELEM FOAM

LITERATURE REVIEW

Due to the complications associated with invasive mechanical ventilation, there has been an increase in the utilization of non-invasive modes.[5] High flow nasal cannula is a non-invasive modality that allows comfortable delivery at flow rates higher than the patient's inspiratory flow rate.[6]

Unlike room air, oxygen is a dry gas and prolonged administration can cause dryness and irritation of the mucus membranes. The bubble humidifier used with nasal cannulae cannot provide adequate humidification for gas flows above 5Litres/min. In addition, at very high flow rates, the airway mucosa cannot heat or humidify air/oxygen blends at flow rates higher than normal physiologic rates.[7]

Postulated mechanisms of action for improving ventilation and oxygenation by HFNC include reducing the work of breathing; by reducing inspiratory resistance in the nasopharynx; improved alveolar ventilation by washing out the dead space in the nasopharynx; providing positive airway pressure; minimizing the effect of cold air, thereby improving the conduction of the airway and lung compliance.[8]

Some indications for HFNC use in paediatrics include bronchiolitis, pneumonia, asthma, post-extubation respiratory support and transport of critically ill patients. The findings from some of the more recent studies are summarized below.

Bronchiolitis

In a multicenter randomized control trial, carried out by Franklin et al in 2018, 1472 infants met inclusion criteria: Children under 12 months, diagnosed with bronchiolitis, required oxygen supplementation. They were randomized to receive either HFNC or standard oxygen therapy (SOT).

Lower rate of treatment failure in the

The primary outcome was escalation of care due to treatment failure. Secondary outcomes were length of hospital stay, duration of treatment with oxygen, and rates of referral to a tertiary hospital, rates of admission to ICU, rates of intubation, and adverse events.

They found a lower rate of treatment failure in HFNC. Duration of oxygen therapy, hospital stay, and ICU transfer were the same.[12]

These findings are similar to a smaller study conducted in Australia, by Kepreotes et al. This was an RCT that aimed to establish whether HFNC provided superior respiratory support, and resulted in a shorter time to weaning off oxygen.

202 infants under 24 months with moderate acute viral bronchiolitis were randomized to two treatment arms: standard oxygen therapy or HFNC. Fewer children experienced treatment failure in the HFNC group. While there was no reduction in time on oxygen or ICU transfer, but they summarized that HFNC may be used as rescue therapy and reduce the number of children requiring intensive care.[13]

Asthma

In 2017, Baudin et al conducted a retrospective observational study comparing the use of HFNC and SOT in 73 patients aged 1-18 years with asthma. These patients were admitted to the PICU with 39 treated with HFNC and 34 receiving SOT. Only one child failed HFNC and was switched to invasive ventilation. One patient developed a pneumothorax and HFNC was discontinued. All patients randomized to the HFNC arm showed an improvement in pH, heart rate, respiratory rate partial pressure of carbon dioxide, and oxygenation, during the first 24 hours of admission compared to the SOT arm.[14]

Ballestro et al in 2018 carried out a prospective randomized trial of children (aged 1-14 years) who presented to a pediatric casualty with moderate-to-severe asthma exacerbations from 2012 to 2015. Patients with a pulmonary score (PS) ≥6 or oxygen saturation <94% with a face mask despite initial treatment (salbutamol/ipratropium bromide and corticosteroids) were randomized to HFNC or to conventional oxygen therapy. A total of 62 patients were enrolled. They found an improvement in pulmonary score as early as 2 hours after the start of therapy in children randomized to the HFNC arm.[15]

Pneumonia

An open RCT carried out in Bangladesh in 2015, by Christi et al randomized 225 under 5 children, with severe pneumonia and hypoxemia to three treatment arms: to receive oxygen therapy by CPAP, standard low flow nasal canula or high flow nasal canula. The primary outcome was treatment failure, defined as: clinical failure, progression to intubation and

mechanical ventilation, death, or termination of hospital stay against medical advice, after more than an hour of treatment.

Treatment failed for 31 children. Fewer children in the bubble CPAP group had treatment failure than in the standard oxygen therapy group. No significant difference in treatment failure was noted in children randomized to the CPAP group and those in the high-flow oxygen therapy group.[16]

Feasibility in Lower- and Middle-Income Countries

While HFNC is well described in high income countries, its use in Sub Saharan Africa is not extensively documented. Andre-Von Armin et al carried out a feasibility study in between January and November 2016 in Kijabe, Kenya. Fifteen patients, with ALRI were enrolled into the study and their data was compared to historical controls. While there was little significant difference in clinical outcome, fewer patients who received HFNC therapy (33%) required intubation compared to 48% of the controls. There was also a difference in the length of respiratory support required, with the HFNC group needing 3 days of support, compared to 4 days of support for the control group. Only 67% of the HFNC group survived to discharge, while 88% controls survived to discharge.

The challenges they faced in implementation were large pressure differences between air from a wall outlet and oxygen and inability to automatically refill humidifier water chambers. They concluded that HFNC in resource constrained settings is feasible, despite technical challenges. This study was limited by a small sample size, heterogenous population and availability of oxygen as well as blending capabilities (with medical air) [17]

The mechanism of action of HFNC and literature supporting its use in the management of children with ALRI suggest that a wide number of conditions can be managed with HFNC.

Following extensive deliberations with my supervisor, the head of the PICU at KNH and several paediatric intensivists and pulmonologists, the following list was generated, of "respiratory conditions" that commonly present to KNH and may benefit from the use of HFNC.

The KNH statistics and records department generates lists based on ICD10 codes and these are the codes associated with the conditions described

J00-J99 ICD10 CODES: DISEASES OF THE RESPIRATORY SYSTEM

J12 viral pneumonia

J15 bacterial pneumonia

J18 pneumonia

J18.0 bronchopneumonia

J18.1 lobar pmneumonia unspecified organism

J18.2 hypostatic pneumonia

J18.8 other pneumonia otherwise unspecified

J21 bronchiolitis

J21.9 acute bronchiolitis unspecified organism

J45 asthma

J45.9 acute asthma

J46 status asthmaticus

J69 aspiration pneumonia

J98 disorders of bronchus otherwise unspecified

The next step was to determine how many of these cases present to KNH annually. The files of children aged 2 months to 12 years were selected. Neonates (under 2 months) were excluded from the subclassification because this is a PICU driven initiative and neonates are admitted to the NICU; and this sub group presents with a wide range of diseases that present as respiratory illness, from meconium aspiration, transient tachypnea of the newborn, respiratory distress syndrome, persistent pulmonary hypertension, neonatal pneumonia etc. the upper limit of 12 represents the age limit of paediatrics in KNH -children aged 13 and above are admitted to the adult Critical Care Unit

A quick glance at the data provided by the records department demonstrated a large number of patients who fit the profile as represented in the table below

ICD10 CODE	**ALIVE**	**DECEASED**	**TOTAL**
J18	2	0	2
J18.0	17	2	19
J18.1	7	0	7
J18.2	0	1	1
J18.8	2	1	3
J18.9	1131	225	1356
J21.9	30	4	34
J45	1	0	1
J45.9	23	0	23
J46	7	0	7
J69	31	22	53
TOTAL	**1251**	**225**	**1506**

Table 1: Children aged 2 months to 12 years admitted to KNH in 2019 with diseases of the respiratory system

KENYATTA NATIONAL HOSPITAL PAEDIATRIC INTENSIVE CARE UNIT

The KNH PICU established in 2014 is a 5 bed ICU with 4 ventilators. Average annual admissions to the PICU are 360 to 400. Children are admitted for a variety of reasons not limited to Acute Respiratory distress syndrome, status asthmaticus, Diabetic ketoacidosis, bronchiolitis, respiratory failure, status epilepticus, septic shock. Because of our severely limited bed capacity, patients admitted to PICU are those who require mechanical ventilation. This unfortunately creates a large pool of underserved children in the wards, who while awaiting admission for intubation and ventilation, only have standard oxygen therapy as an option for ventilatory support. High flow nasal canula may bridge this gap , may reduce the admissions to PICU for ventilatory support and all the attendant complications of mechanical ventilation

This project was designed as a pre implementation intervention to prepare the nursing and clinical staff at KNH PICU for the introduction of HFNC. The aim was to introduce new technology in a structured way with “for us, by us” energy; to increase ownership of the project, enhance collaboration between the nursing and clinical cadres and ultimately have PICU own the project.

Sensitisation of the clinical team of a new noninvasive ventilation strategy, the potential patients who may benefit from it, the contraindications to its use would ideally promote uptake of the new technology. Preparing the nursing team on the clinical and technical aspects-would ensure they were confident to suggest its application, to initiate HFNC on suitable candidates, to monitor and recognize signs of HFNC failure, to identify patients on HFNC who require escalation of care and to keep a new machine in good working order.

HFNC TRAINING

HFNC machines are manufactured by only two companies worldwide- Vapotherm, who manufacture the Precision Flow system and Fischer-Paykell who manufacture the Airvo system.

Vapotherm, who were donating 3 Precision Flow machines to KNH PICU invited myself, my supervisor Dr Bhupi Reel and the PICU biomedical engineer Mr Thomas Njogu to their factory in New Hampshire for an intensive two weeks of training on the technical and

biomedical aspects of the machine. Due to delays in processing visas, with interview dates for visas set in 2024, this trip was not possible. They waived cost of access to their online training application - The Vapotherm Academy and created a training curriculum that was divided into three critical areas

1. **Bio-Medical:** To understand the basic mechanical and technical operation of the Precision Flow units, including power requirements, service, preventative maintenance, and repairs.
2. **Technical:** Basic in-servicing which includes how to set the Precision Flow Unit up for patient use, basic operation, disposables, and troubleshooting.
3. **Clinical:** Patient selection and application, including recommendations on settings, and expected outcomes.

They required some pre-work to be done from The Vapotherm Academy prior to the live virtual training. This will serve as introduction and post training follow-up as a resource for them.

Bio Medical:

o Pre-work: Quick Use Check List

o Virtual Session

Technical:

o Pre-work: Respiratory Precision Flow In-service; Nursing Precision Flow In-service; Quick Tips

o Virtual Session:

Clinical:

o Pre-work: PICU Focused Presentation; High Velocity Grand Rounds; High Velocity Grand Rounds II

o Virtual Session:

The pre-work was 120 hours of online self-guided work and to ensure that the module was

completed, a certificate was issued after completing a timed posttest. The test had a 100% pass mark This certificate had to be uploaded prior to attending the virtual session

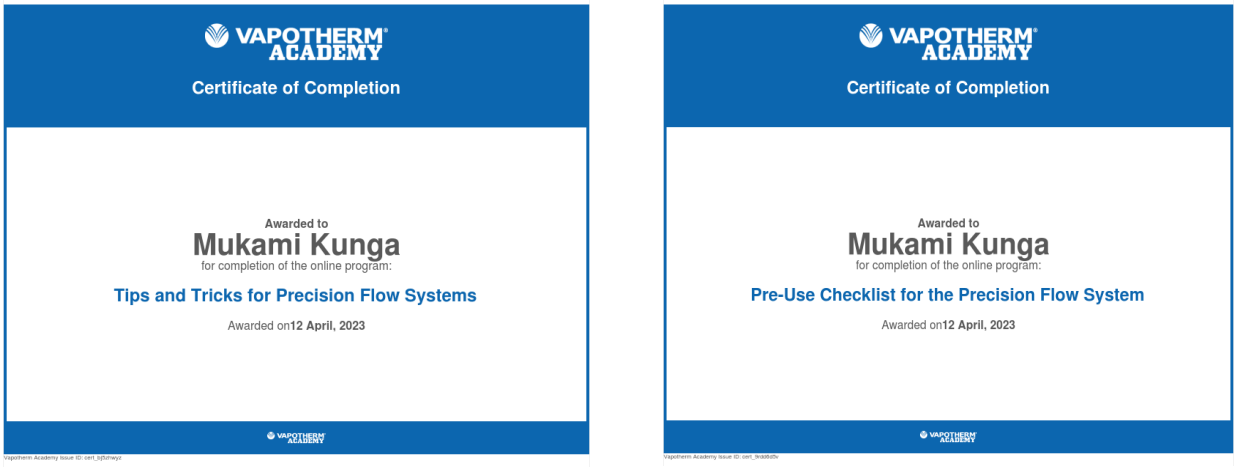


Fig 2: Certificates of completion of online vapotherm academy modules

The virtual sessions were led by Vapotherm Trainers and Technicians and were mandatory to attend. It was also an opportunity to touch base with our handlers-who would be an invaluable resource for trouble shooting if we encountered challenges with the use of the Precision Flow Unit

PICU STAFFING

The PICU is staffed by (in rotation)

- 30 critical care nurses
- 3 paediatric intensivists
- 0-4 emergency and critical care fellows
- 4 medical officers
- 0-2 paediatric and child health residents

From the nursing staff a nurse champion was identified to help train the staff, to manage the equipment. The champion is currently completing the Vapotherm Academy training

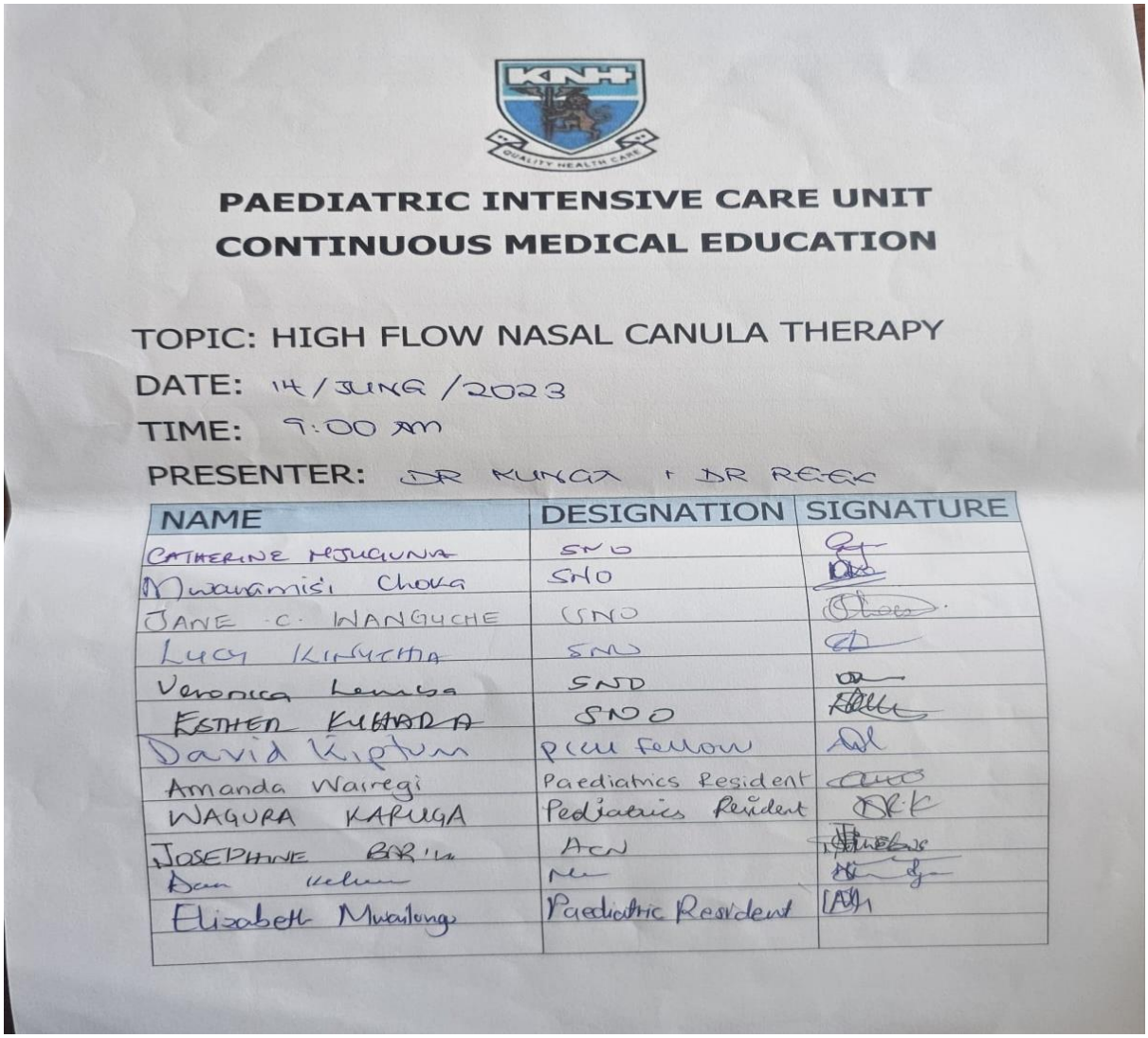
The PICU shifts are divided into three blocks

- Morning 8am-2pm
- Afternoon 2pm-8pm
- Night 8pm-8am

COACHING SCHEDULE

The coaching schedule for HFNC in PICU is as follows. Training will be carried out once a quarter and will be comprised of:

A CME. This is a powerpoint lecture delivered by the fellow or the nursing champion. It will be preceded and followed by a pre test and post test both on the clinical and technical aspects of HFNC.



PAEDIATRIC INTENSIVE CARE UNIT
CONTINUOUS MEDICAL EDUCATION

TOPIC: HIGH FLOW NASAL CANULA THERAPY

DATE: 14/JUNE/2023

TIME: 9:00 AM

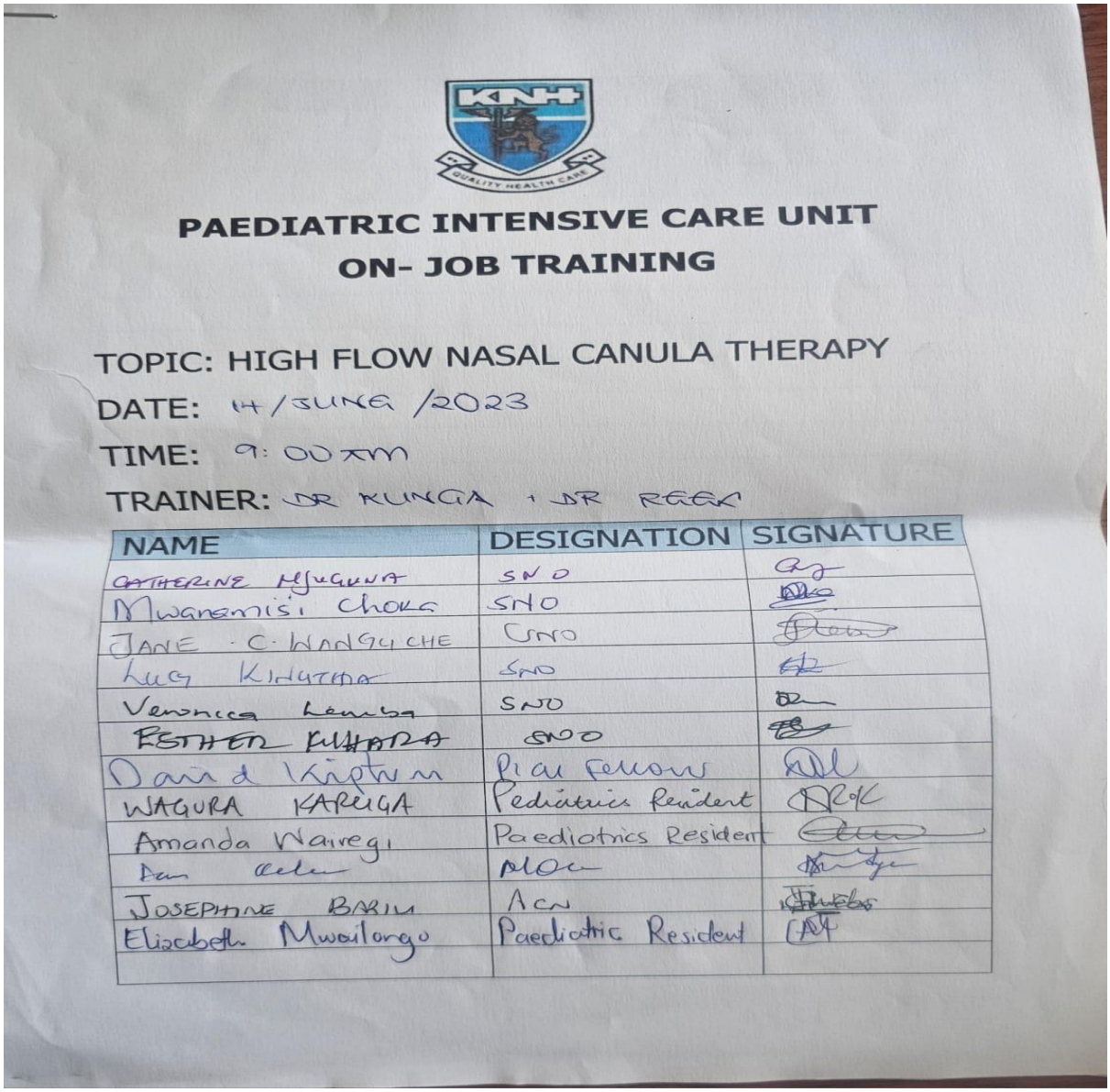
PRESENTER: DR KUNGA & DR REEK

NAME	DESIGNATION	SIGNATURE
CATHERINE MJUGUNA	SNO	
Mwanamisi Choka	SNO	
JANE C. WANGUCHE	SNO	
LUCY KINYUCHIA	SNO	
Veronica Lemisa	SNO	
ESTHER KUBASA	SNO	
David Kiptum	PICU fellow	
Amanda Wairegi	Paediatrics Resident	
WAGURA KARUGA	Pediatrics Resident	
JOSEPHINE BR'la	ACN	
Dan Kelum		
Elizabeth Mwalongo	Paediatric Resident	

Fig 3: Attendance Register for HFNC CME carried out on 14th June 2023

On job training. This will be in three parts

1. Observing assembly of the machine by the fellow or nursing champion
2. Participant setting up the machine with coaching and supervision
3. Participant setting up the machine without coaching or assistance



PAEDIATRIC INTENSIVE CARE UNIT
ON- JOB TRAINING

TOPIC: HIGH FLOW NASAL CANULA THERAPY
DATE: 14/JUNE/2023
TIME: 9:00 AM
TRAINER: DR KUNGA + DR REEK

NAME	DESIGNATION	SIGNATURE
CATHERINE MUGUNA	SNO	
Mwanamisi Choka	SNO	
JANE C. WANGUCHE	SNO	
LUCY KINUTHIA	SNO	
Veronica Lemuya	SNO	
ESTHER [illegible]	SNO	
David Kiptum	Pic Fellow	
WAGURA KARUGA	Pediatrics Resident	
Amanda Wairegi	Paediatrics Resident	
[illegible]	MO	
JOSEPHINE BARIU	ACN	
Elizabeth Mwailongo	Paediatric Resident	

Fig 4: Attendance Register for HFNC OJT carried out on 14th June 2023

Fig 5: FPECC Fellow Dr Kunga and the HFNC Nursing Champion Critical Care Nurse Dan Kelvin demonstrating the set up of the machine

Fig 6: Paediatric Intensivist Dr Reel, ACN Sr Josephine Bariu and HFNC Champion Dan Kelvin assembling the Precision Flow machine

PRE TEST AND POST TEST RESULTS

The pre training and post test training tests were divided into two to assess the following areas:

- Technical knowledge pass mark 100%
- Clinical knowledge pass mark 100%

The distribution of the first group trained on HFNC was as follows

- 8 nurses
- 3 residents
- 1 PFECC fellow

The performance of the first group trained on HFNC was as follows

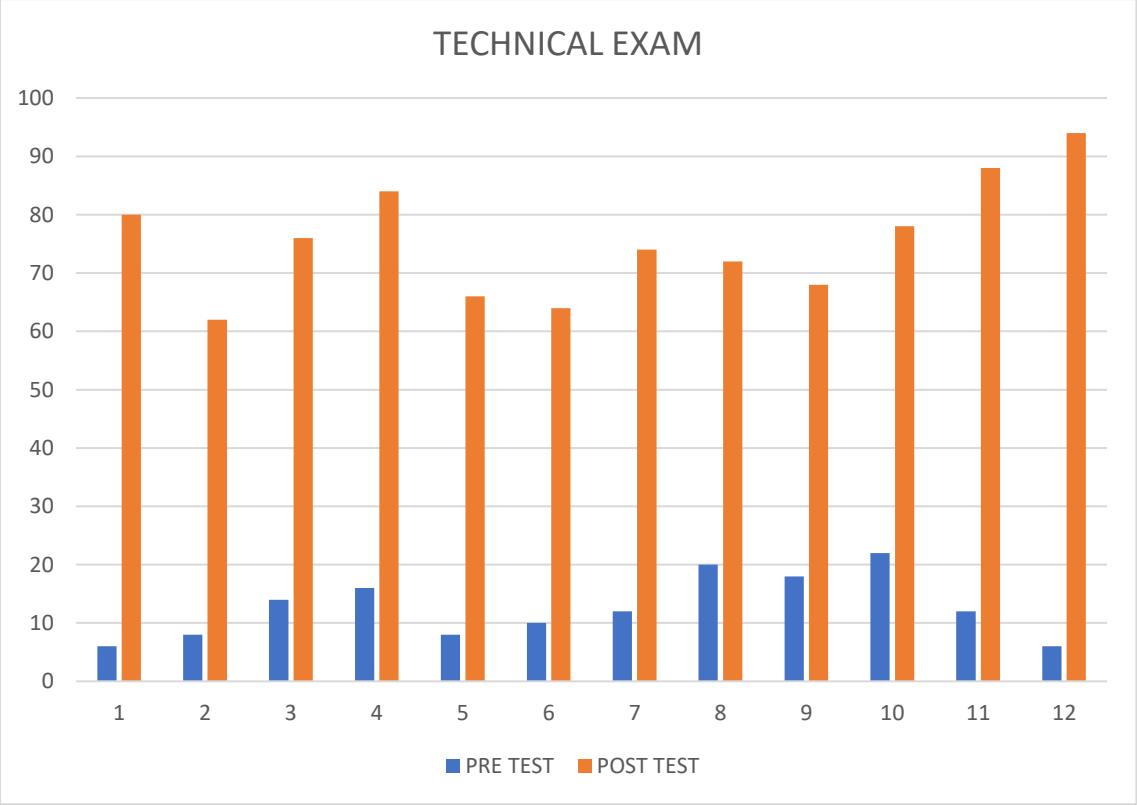


Table 2 : Technical exam pre and post test

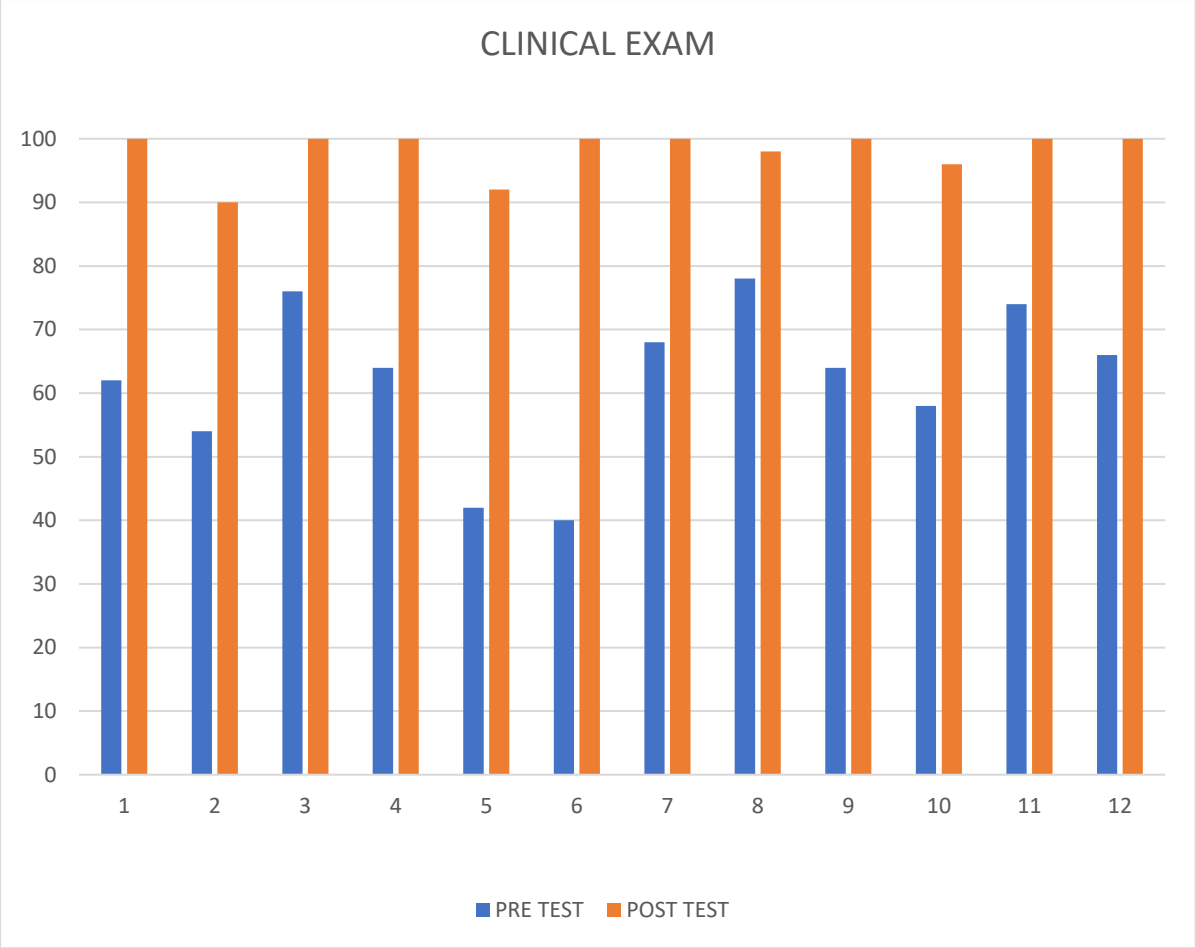


Table 3: Clinical exam pre and post test

TOOLS, JOB AIDS AND PROTOCOL DEVELOPMENT

Tools and job aids were developed to ensure uniform management of patients on HFNC, appropriate weaning if successful and timely escalation to mechanical ventilation

The protocols were developed after extensive review of the available literature, and after consultation with intensivists who use HFNC in their daily practice in Kenya- from The Kijabe Hospital and The MPShah Hospital.

The tools we developed included:

- Definition of terms reference sheet
- HFNC indications and contraindications
- HFNC initiation protocol

- HFNC failure protocol
- HFNC weaning and discontinuation protocol
- HFNC nursing care guide
- HFNC monitoring chart
- HFNC alarm status table
- HFNC registers-on job training, CME
- Pre and Post tests

A poster on the Clinical Respiratory Score was printed and placed in the PICU.

Currently the codex with the above resources (see in the appendix) has been approved by the intensivist in charge of PICU and will be presented to the HOD Paediatrics and Child Health KNH. This will then be forwarded to the therapeutics unit of KNH. Following this there will be defense of protocol and subsequent adoption.

A google drive containing the documents as a reference has been created and will be availed to PICU staff when the protocols have been approved.

We are awaiting written approval from Vapotherm to begin the process of filming short videos starring the nurse champion demonstrating some of the technical aspects of the Precision Flow machine which will be uploaded to the drive to serve as pre-course material for the training.

CHALLENGES AND OPPORTUNITIES

Finding time to train the staff posed a great challenge-the night shift staff would like to hand over and go home, the morning shift staff would like to settle their patients as fast as possible, morning rounds and procedures are pending. We hope to streamline the CME days, send out the coaching calendar early so participants can choose the most convenient time to attend coaching sessions

One of the biggest concerns raised by the nursing team was the additional workload. To mitigate this, the monitoring chart was modeled after the existing respiratory monitoring chart- a patient on HFNC has fewer parameters to monitor than a patient on mechanical ventilation

The failure protocol for patients on high flow requires escalation to mechanical ventilation and as PICU still only has 4 ventilators we forsee a scenario where patients who fail HFNC when it is introduced on the wards cannot progress to invasive ventilation. This is an opportunity to continue to advocate for allocation of resources for more ventilators for PICU

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APPENDIX 1: CLINICAL RESPIRATORY SCORE

PAEDIATRIC INTENSIVE CARE UNIT

HIGH FLOW NASAL CANULA

CLINICAL RESPIRATORY SCORE

ASSESS	SCORE 0	SCORE 1	SCORE 2
RESPIRATORY RATE	AGE 1-5 <30 AGE>5 <20	AGE 1-5 30-40 AGE >5 20-30	AGE 1-5 >40 AGE>5 >30
AUSCULTATION	Good air movement, Expiratory scattered wheezing or crackles	Depressed air movement, inspiratory and expiratory wheezes or crackles	Diminished or absent breath sounds, severe wheezing or crackles or marked prolonged expiration
ACCESSORY MUSCLES	Mild to no use of accessory muscles. Mild to no retractions or nasal flaring on inspiration	Moderate intercostal retractions, mild to moderate use of accessory muscles, nasal flaring.	Severe intercostal and substernal retractions, nasal flaring
MENTAL STATUS	Normal to Mildly irritable	Irritable, agitated, restless	Lethargic
ROOM AIR SP02	>95%	90-95%	<90%
COLOR	Normal	Pale	Cyanotic/dusky

CLINICAL RESPIRATORY SCORE

MILD<3 MODERATE 4-7 SEVERE >8

APPENDIX 2:

DEFINITION OF TERMS

- **FiO_2**: Fraction of inspired oxygen (%).
- **$PaCO_2$**: The partial pressure of CO_2 in arterial blood. It is used to assess the adequacy of ventilation.
- **PaO_2**: The partial pressure of oxygen in arterial blood. It is used to assess the adequacy of oxygenation.
- **SaO_2**: Arterial oxygen saturation measured from blood specimen.
- **SpO_2**: Arterial oxygen saturation measured via pulse oximetry.
- **High flow nasal canula**: High flow systems are specific devices that deliver the patient's entire ventilatory demand, meeting, or exceeding the patients Peak Inspiratory Flow Rate (PIFR), thereby providing an accurate FiO_2. Where the total flow delivered to the patient meets or exceeds their Peak Inspiratory Flow Rate the FiO_2 delivered to the patient will be accurate.
- **Humidification** is the addition of heat and moisture to a gas. The amount of water vapour that a gas can carry increases with temperature.
- **Hypercapnea**: Increased amounts of carbon dioxide in the blood.
- **Hypoxaemia**: Low arterial oxygen tension (in the blood.)
- **Hypoxia**: Low oxygen level at the tissues.
- **Low flow**: Low flow systems are specific devices that do not provide the patient's entire ventilatory requirements, room air is entrained with the oxygen, diluting the FiO_2.
- **Peak Inspiratory Flow Rate (PIFR)**: The fastest flow rate of air during inspiration, measured in litres per second.
- **Tidal Volume**: The amount of gas that moves in, and out, of the lungs with each breath, measured in millilitres (6-10 ml/kg).
- **Ventilation - Perfusion (VQ) mismatch**: An imbalance between alveolar ventilation and pulmonary capillary blood flow.

APPENDIX 3: HFNC INITIATION

HIGH FLOW NASAL CANULA

Initial Settings

Flow rate: 2L/kg/min for the first 10kg then 1L/kg/min for each kg thereafter (max flow 50L/min)

Fi02: 0.4-0.6 to maintain sp02 92%-95%

Gas temperature: 34-37^{0}C

No improvement, worsening WOB (CRS SCORE) or SP02

Flow rate: Increase to 2L/kg/min (max flow 50L/min)

Fi02: Titrate Fi02 up and monitor response.

If no improvement **after 1 hour**, **HFNC Failure**

OR any signs of impending respiratory failure: **PaC02>60 Fi02>0.6**

Escalate respiratory support to invasive ventilation

Respiratory distress improved: respiratory parameters stable for 24-48 hours

HFNC successful

Wean HFNC

Flow rate: flow by 0.5L/kg/min every 4-6 hours.

Fi02: Wean Fi02 first to 0.3-0.4

APPENDIX 4: HFNC FAILURE PROTOCOL

HFNC FAILURE: ESCALATION PROTOCOL

Patients on HFNC will be assessed hourly as per PICU KNH standards of care

A full re-evaluation one hour after initiation will determine the need for escalation to mechanical ventilation

The following parameters will be assessed:

Vital Signs: HR BP MAP Temp Sp02

GCS

ABG: pH PaC02 Pa02 Sa02 BE HC03 Lactate

HFNC: Gas Temp Fi02 Flow Rate

RESP EXAM: RR Auscultation Accessory Muscles Mental status Color

Clinical Respiratory Score

APPENDIX 5: HFNC WEANING AND DISCONTINUATION PROTOCOL

Weaning HFNC Therapy

When the child's clinical condition is improving as indicated by:

- Decreased work of breathing
- Normal or improved respiratory rate
- Return to normal cardiovascular parameters

Flow Rate: Wean flow by 0.5L/kg/min every 4-6 hours.

Fi02: Wean Fi02 to 0.3-0.4

Discontinuing HFNC Therapy

Patient respiratory parameters-CRS Score, Spo2 RR, HR stable

Flow Rate: </= 0.5L/kg/min

Fi02: </= 0.4 and Sp02 >/=92% with

Start 02 therapy via nasal canula. May be weaned to room air if no 02 requirement

Continue monitoring

APPENDIX 6: HFNC INDICATIONS AND CONTRAINDICATIONS

INDICATIONS

- Patients with acute lower respiratory tract illness who require respiratory support e.g. asthma, pneumonia, bronchiolitis
- Ages 2 months to 12 years
- Hypoxaemia spo2 <92%
- Post- extubation respiratory support

CONTRAINDICATIONS

- Any patient who requires emergent intubation
- Patients with decreased level of consciousness
- Pre-existing abnormal central respiratory drive or central apnea that precludes the use of HFNC
- Congenital airway abnormalities that preclude the use of HFNC e.g upper airway obstruction, choanal atresia
- Nasal or facial abnormalities that interfere with the HFNC application
- Trauma or surgery to the nasopharynx
- Haemodynamic instability
- Air leaks-pneumothorax, pneumomediastinum

APPENDIX 7: HFNC OJT REGISTER

TOPIC: HIGH FLOW NASAL CANULA THERAPY

DATE:

TIME:

TRAINER:

NAME	DESIGNATION	SIGNATURE

APPENDIX 8: HFNC CME REGISTER

TOPIC: HIGH FLOW NASAL CANULA THERAPY

DATE:

TIME:

TRAINER:

NAME	DESIGNATION	SIGNATURE

APPENDIX 9: HFNC COACHING SCHEDULE

PAEDIATRIC INTENSIVE CARE UNIT

HIGH FLOW NASAL CANULA

TRAINING SCHEDULE 2023

QUARTER 1 **DATE:** **TRAINER:**

NUMBER OF NURSES	
NUMBER OF FELLOWS	
NUMBER OF MEDICAL OFFICERS	
NUMBER OF RESIDENTS	
NUMBER OF INTENSIVISTS	

QUARTER 2 **DATE:** **TRAINER:**

NUMBER OF NURSES	
NUMBER OF FELLOWS	
NUMBER OF MEDICAL OFFICERS	
NUMBER OF RESIDENTS	
NUMBER OF INTENSIVISTS	

QUARTER 3 **DATE:** **TRAINER:**

NUMBER OF NURSES	
NUMBER OF FELLOWS	
NUMBER OF MEDICAL OFFICERS	
NUMBER OF RESIDENTS	
NUMBER OF INTENSIVISTS	

QUARTER 4 **DATE:** **TRAINER:**

NUMBER OF NURSES	
NUMBER OF FELLOWS	
NUMBER OF MEDICAL OFFICERS	
NUMBER OF RESIDENTS	
NUMBER OF INTENSIVISTS	

APPENDIX 10: HFNC NURSING CARE

PAEDIATRIC INTENSIVE CARE UNIT

HIGH FLOW NASAL CANULA

NURSING CARE

- Patients on HFNC therapy should have a strict fluid balance
- Patients on HFNC should have a NGT for air decompression (unless contraindicated)
- Method of nutrition/ hydration should be based on severity of respiratory distress
- Do not feed during the initial 2 hours following commencement of HFNC therapy.
- Once stable the child should be assessed as to whether they can tolerate oral feeds.
- Oral feed should be ceased if child clinically deteriorates during feeding.
- If oral feeding is not tolerated, commence 2 hourly NG bolus feeds with EBM or formula as appropriate, reduce total volume to 2/3 maintenance.
- Consider continuous NG feeds if not tolerating bolus feeds.
- Infants who do not clinically stabilize within 2 hours or who do not tolerate NGT feeds should have an I.V. inserted to receive hydration.
- Aspirate the NGT for air 2-4 hourly.
- Oral and nasal care must be performed 4 hourly.
- Check for pressure areas, nasal prongs are in correct position and saturation probe moved regularly
- Gentle suction as required to keep nares clear.
- Monitor for abdominal distention and aspirate NGT as clinically indicated
- Cluster cares and minimal handling

KNH/R&P/FORM/01

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Study Registration Certificate

1. Name of the Principal Investigator/Researcher
   BRENDA MUKAMI KUNGA
2. Email address: mukami.kunga@gmail.com Tel No. 0721226092
3. Contact person (if different from PI) CONTACT PERSON - PI
4. Email address: ..... Tel No. .....
5. Study Title
   COMPARISON OF STANDARD OXYGEN THERAPY AND HIGH FLOW NASAL CANULA FOR THE MANAGEMENT OF CHILDREN WITH ACUTE LOWER RESPIRATORY TRACT DISEASE IN KENYATTA NATIONAL HOSPITAL
6. Department where the study will be conducted DEPARTMENT OF PAEDIATRICS
   (Please attach copy of Abstract)
7. Endorsed by KNH Head of Department where study will be conducted.
   Name: DR. J. MUIVA Signature ..... Date 2/9/2022
8. KNH UoN Ethics Research Committee approved study number P899/11/2021
   (Please attach copy of ERC approval)
9. I BRENDA MUKAMI KUNGA commit to submit a report of my study findings to the Department where the study will be conducted and to the Department of Medical Research.
   Signature ..... Date 01/SEP/2022
10. Study Registration number (Dept/Number/Year) Paediatrics/339/2022
    (To be completed by Medical Research Department)
11. Research and Program Stamp KENYATTA NATIONAL HOSPITAL 05 SEP 2022

All studies conducted at Kenyatta National Hospital must be registered with the Department of Medical Research and Investigators must commit to share results with the hospital.

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Ref: KNH/PAEDS-HOD/48 Vol.II

Date: 5th September 2022

Dr. Brenda Kunga
Reg. No.H116/40864/2021
Fellow in Paediatric Emergency &Critical Care
Department of Paediatrics and Child Health
Faculty of Health Sciences
University of Nairobi

Dear Dr Kunga,

RE: AUTHORITY TO COLLECT DATA IN PAEDIATRICS DEPARTMENT

Following approval of your Research proposal by the KNH/UON-Ethics & Research Committee and subsequent filing of the Study Registration Certificate, this is to inform you that authority has been granted to collect data in ***Paediatrics Department***, on your study titled ***"Comparison of standard oxygen therapy and high flow nasal canula for the management of children with acute lower respiratory tract disease in Kenyatta National Hospital)".***

Kindly liaise with the Senior Assistant Chief Nurse (SACN) Paediatric General Wards for facilitation.

You will also be required to submit a report of your study findings to the office of the HOD, Paediatrics - KNH after completion of your study.

Dr. Juliana Muiva-Gitobu
Head of Department, Paediatrics

Cc. SACN, Paediatric Specialized Ward/Clinics
SACN, Paediatric General Ward
HOD, Health Information
ACN Incharge, PICU